doi: 10.17221/288/2014-HORTSCI

Fruit set and quality of self-fertile sweet cherries as affected by chemical flower thinning

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Abstract

Milić B., Keserović Z., Dorić M., Ognjanov V., Magazin N. (2015): **Fruit set and quality of self-fertile sweet cherries as affected by chemical flower thinning**. Hort. Sci., 42: 119–124.

Self-fertile cherry cultivars can produce an excessive crop of small fruits with low sugar content. In order to prevent overcropping and provide high quality fruits, chemical thinning of flowers is required. Ammonium thiosulfate (ATS), surfactants and plant oils are used to thin flowers, mostly in apple and peach. The purpose of this research was to compare the effectiveness of the blossom thinners ATS, surfactant Silwet and rapeseed oil (Ogriol) in reducing fruit set of the self-fertile sweet cherry cultivars Alex and Sunburst and their potential to improve fruit quality. At lower rates (1 and 2%) ATS did not consistently reduce fruit set, while at higher rate (3%) it produced visible phytotoxicity on the leaves. ATS treatments did not increase the average weight and diameter of fruits. 10 and 30 ml/l Ogriol application did not reduce fruit set significantly or improve fruit quality of self-fertile sweet cherries. The surfactant Silwet applied at the rates of 1 or 3 ml/l was found to consistently thin self-fertile sweet cherry cultivars, leading to better fruit quality.

Keywords: *Prunus avium*; bearing potential; fruit size; ammonium thiosulfate; Silwet; Ogriol

Introducing highly productive cherry rootstocks, such as Gisela 5, without an adequate crop load regulating strategy may lead to reduced size and poor quality of fruits. A negative linear relationship was found between fruit to leaf area ratio on the one hand and fruit weight, diameter and soluble solids content in sweet cherry on the other (Whiting, Lang 2004). Growing self-fertile sweet cherry cultivars which provide high and regular yields (Whiting et al. 2006) may also result in overcropping, small fruit size and lower sugar contents (Lane, Schmid 1984). Regulating sweet cherry crop load only by dormant pruning is insufficient to provide high fruit quality, while manual removal of flowers and fruits is not practical due to high labour costs (Whiting, Ophardt 2005; Stern et al. 2009). By manually removing entire spurs, individual flower buds or flowers, a higher fruit weight and better fruit size distribution of self-fertile cv. Lapins cherry were achieved, without a reduction of total yield (Bennewitz et al. 2010).

Chemical flower and fruit thinning is widely used mainly in apple and pear fruit growing in order to control crop load and improve fruit quality. Although ammonium thiosulfate (ATS) successfully thins apple (Milić et al. 2011) and peach flowers (Coneva, Cline 2006), its application on cherries, although effective in reducing fruit set, did not improve fruit size, weight and soluble solids contents (Schoedl et al. 2009). Surfactant Armothin (Southwick et al. 1996) and Tergitol-TMN-6 (Ambrožič Turk et al. 2014) showed a promising

Supported by the Ministry of Education, Science and Technological Development of Serbia, Project No. TR 31038.

doi: 10.17221/288/2014-HORTSCI

flower thinning efficacy in peach while Silwet 408 significantly reduced fruit set in peach (Baugher et al. 2008) and apple (Bound, Klein 2010). The disadvantage of caustic flower thinning chemicals is that their thinning efficacy is not consistent due to drying time, flower development stage at the time of the treatment (Janoudi, Flore 2005), tree carbon supply, environmental factors and spray coverage (Whiting et al. 2006). Plant oil emulsions act by preventing flower opening and were used for flower thinning in apple, peach and sweet cherry (Ju et al. 2001; Stopar 2008).

The objective of this research was to compare the effectiveness of ATS, surfactant Silwet and rapeseed oil in reducing fruit set and their potential to improve the fruit quality of self-fertile sweet cherry cvs Alex and Sunburst.

MATERIAL AND METHODS

The experiments were conducted during 2011 and 2012 on the self-fertile sweet cherry cvs Alex and Sunburst grafted on cv. Mahaleb (*Prunus mahaleb* L.) rootstocks. The trees were planted in 2007 at a planting distance of 5.0 × 3.5 m. The orchard was located in Kać, northern Serbia (45°18'N and 19°55'E, 75 m a.s.l.). Dormant pruning and standard pest management were followed every year, while irrigation was not included.

The experiment was designed as a randomized complete block where a total of 32 trees of each cultivar were grouped into 4 blocks of 8 trees of similar growth vigour and bloom density. On each tree, three two-year-old branches were selected on the basis of flower abundance and sprayed or left untreated as a control. Each treatment was represented by three branches/replicates within a block. The total number of spurs, flower buds and flowers on each selected branch were counted before treatments. The chemicals used were ammonium thiosulfate (98% a.i.) in crystalline form (Sigma-Aldrich, Steinheim, Germany), a nonionic surfactant Silwet L-77 (Momentive Performance Materials Inc., Columbus, USA – 99.5% polyalkyleneoxide modified heptamethyltrisiloxane) and Ogriol (Pinus, Race, Slovenia – 92% rape oil + 8% emulsifiers). The concentrations of the commercial products used for treatments were as follows: (1) ATS 10.2 g/l, (2) ATS 20.4 g/l, (3) ATS 30.6 g/l, (4) Silwet 1 ml/l, (5) Silwet 3 ml/l, (6) Ogriol 10 ml/l, (7) Ogriol 30 ml/l, and (8) untreated control.

The treatments were applied at 40% full bloom in Alex and 60% full bloom in Sunburst in both years of the study, by using a hand-sprayer up to the drip point. Sprayings were carried out in morning with temperatures ranging from 16 to 18°C and relative humidity (RH) 40 to 22% in three-hour period following treatment in 2011 and 17 to 23°C, RH 49 to 37% in 2012. Fruits were picked once, at the commercial harvest time, according to the Centre technique interprofessionnel des fruits et légumes, Paris, France Cherry colour codes which ranged between 4 and 5 for cv. Sunburst (June 14th in 2011 and 11th in 2012) and 5 and 6 for cv. Alex (June 21st in 2011 and 13th in 2012). Fruit weight and diameter were measured on the total number of picked fruits. Fruit set was calculated as the number of fruits harvested per 100 flowers (%) and per cm^2 of branch cross-sectional area (BCSA). Juice was collected from each replicate in order to determine soluble solids content. Total soluble solids (TSS) were determined only in 2012 by using an automatic hand refractometer RHB-32/ATC (Huake Instrument Co., Shenzhen, China) with measuring range 0–32%.

The data were analysed using the analysis of variance (ANOVA). Duncan's multiple range test was used to compare the means ($P < 0.05$) with Statistica 12 (StatSoft Inc, Tulsa, USA).

RESULTS AND DISCUSSION

Bearing potential and fruit set

In the present research cv. Alex appeared to have a significantly larger number of spurs per two-year-old branch, number of flower buds per spur, number of flower buds per one-year-old branch, as well as the total number of flowers per branch compared to the Sunburst (Table 1). The differences in bearing potential between years can be explained by the occurrence of extremely low air temperatures in February 2012, up to –29°C. Such low temperatures caused a severe damage to the flower buds of sweet cherries at the experimental site, on about 50% of total flower buds.

Fruit sets of cvs Alex and Sunburst sweet cherries are presented in Figs 1 and 2 and were generally higher in 2011 than in 2012. In Alex, the differences in fruit set between the two years of the study are partially a consequence of the significant differences in the bearing potential between the years (Table 1).

doi: 10.17221/288/2014-HORTSCI

Table 1. Branch length, number of spurs per branch, number of flower buds per spur and per one-year-old branch, number of flowers per bud and per branch of sweet cherry cvs Alex and Sunburst

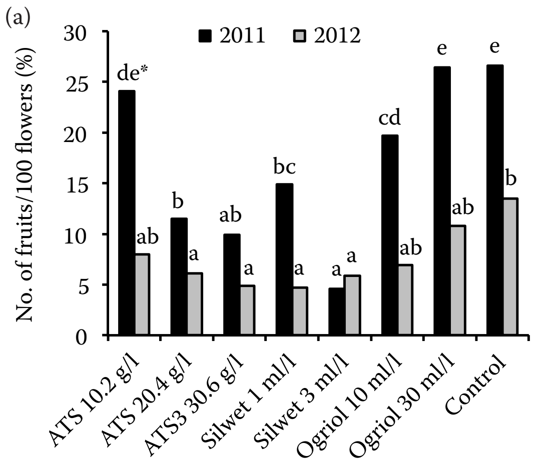
Cultivar	Year	Branch length (cm)	No. of spurs/ branch	No. of flower buds/spur	No. of flower buds/ one-year-old branch	No. of flowers/bud	No. of flowers/branch
Alex	2011	102.3[b]	15.6[c]	6.2[d]	9.9[c]	2.8[b]	303[c]
	2012	89.6[a]	12.0[b]	3.8[c]	7.5[b]	2.3[a]	119[b]
Sunburst	2011	99.9[ab]	8.4[a]	2.5[a]	5.7[a]	3.0[b]	86[a]
	2012	90.1[a]	9.3[a]	3.1[b]	5.3[a]	2.3[b]	82[a]
Statistical significance							
Year		*	n.s.	*	*	n.s.	*
Cultivar		n.s.	*	*	*	*	*
Year × cultivar		n.s.	*	*	*	n.s.	*

[a–d]mean separation within column by the Duncan's multiple range test at P = 0.05; n.s. – not significant; *significant differences between treatments at P = 0.05

Naturally occurring fruit set determined on the control group of branches was higher in cv. Alex than in cv. Sunburst. The number of fruits/100 flowers in cv. Alex was 26.6 in 2011 and 13.5 in 2012 (Fig. 1a), while in Sunburst it was 20.9 in 2011 and 10.1 in 2012 (Fig. 2a). Alex had 110.3 fruits/cm^2 of branch cross-sectional area (BCSA) on untreated branches in 2011 and 30.9 in 2012 (Fig. 1b), while Sunburst had 10.1 in 2011 and 12.2 in 2012 (Fig. 2b).

ATS appeared to be an effective flower thinner for sweet cherry cultivar Alex when applied at the rates of 20.4 or 30.6 g/l, in both years of the study (Fig 1). ATS at the rate of 10.2 g/l did not significantly reduce the fruit set except for the number of fruits/cm^2 BCSA in 2011 (Fig. 1b). Janoudi and Flore (2005) suggested that ATS damages petals, pistils and anthers in apple and therefore prevents fertilization. The same mode of action might be presumed in sweet cherries. The severity of flower damage depends on environmental conditions. Low relative humidity, such was in the present experiment, and high temperature favour rapid drying and limit chemical efficacy while the higher rates of ATS compensate for the rapid drying time.

Surfactant Silwet appeared to have a good effectiveness in reducing fruit set in cv. Alex, except for the number of fruits/cm^2 BCSA in 2012 where the decrease was not statistically significant (Fig. 1b). Surfactant Tergitol was used previously for thinning peach flowers and produced promising results



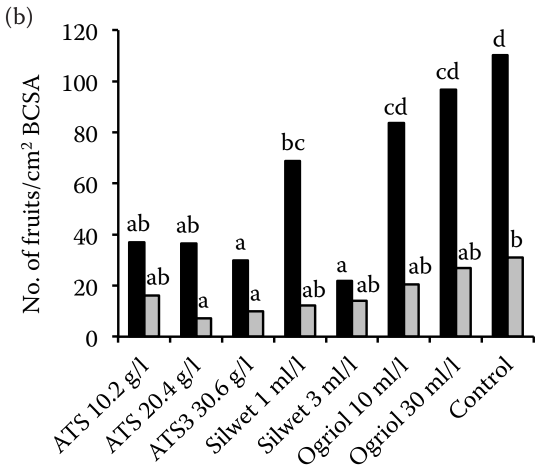


Fig. 1. The effect of thinning on (a) the number of fruits per 100 flowers (%) and (b) on the number of fruits per cm^2 of the branch cross-sectional area of sweet cherry cultivar Alex

*bars with different letters are significantly different within year (P < 0.05); BCSA – branch cross-sectional area

doi: 10.17221/288/2014-HORTSCI

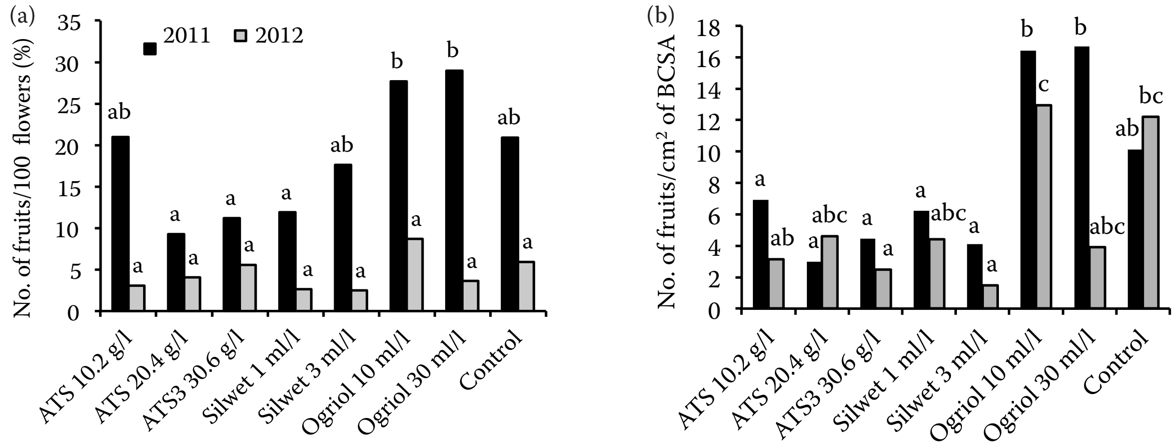


Fig. 2. The effect of thinning on (a) the number of fruits per 100 flowers (%) and (b) the number of fruits per cm² of the branch cross-sectional area of sweet cherry cultivar Sunburst

*bars with different letters are significantly different within year ($P < 0.05$); BCSA – branch cross-sectional area

in reducing fruit set and increasing fruit weight without causing visible phytotoxicity on the leaves or shoots (Ambrožić Turk et al. 2014). Baugher et al. (2008) reported that Silwet was more effective in reducing fruit set in peach than Tergitol, but did not specify the rates of the chemicals applied.

10 and 30 ml/l Ogriol treatments applied at 40 to 60% full bloom were not found to be effective in thinning sweet cherry flowers (Figs 1 and 2). Ju et al. (2001) reported that plant oils damaged petals and prevented flower opening and suggested that a decrease in fruit set occurred due to the prevention of pollination and fertilization. That would explain the effectiveness of plant oils thinning self-sterile sweet cherries. However, corn oil reduced fruit set in self-fertile peach which indicates a direct effect of plant oil on flower development and fertilization. A direct effect of oil on self-fertile sweet cherry flowers was not confirmed in the present research. According to the previously mentioned authors, the higher oil emulsion concentration (3 and 5%) applied earlier (between pre-bloom and 20% full bloom) provides a better thinning efficacy.

In cv. Sunburst the application of chemicals did not cause any significant thinning effects except with the highest rates of ATS and Silwet which caused a significant decrease of the fruit set and number of fruits/cm² BCSA in 2012 (Fig. 2).

Effects of thinning on fruit quality

According to the literature, both cvs Sunburst and Alex produce large fruits (Lane, Schmid 1984; Apostol 2005). Hrotkó et al. (2009) calculated the average fruit weight of 9.1 g in cv. Alex grown on seedling Mahaleb rootstock "CEMA" in the intensive orchard conditions. However, their being self-fertile makes them prone to small fruit size in case of overcropping. Vaszily (2009) reported the excellent fruit setting values on one- and two-year-old branches of cv. Alex which ranged between 60 and 70% of fruits set/100 flowers which resulted in small fruit weight of 5.9 g only. In the present research, the average fruit weight in cv. Alex ranged from 6.6 to 7.3 g in 2011 and 7.8 to 8.6 g in 2012 when the fruit set was reduced due to unfavourable weather conditions (Table 2). The average fruit diameter in cv. Alex ranged from 22.1 to 23.1 mm in 2011 and 23.8 to 24.8 mm in 2012 (Table 2), depending on the treatment applied. Sunburst appeared to have larger fruits than Alex, and they ranged from 10.7 to 11.7 g in weight in 2011 and 8.5 to 11.0 g in 2012 and 27.7 to 29.1 mm in diameter in 2011 and 26.4 to 28.7 mm in 2012 (Table 2).

ATS treatments were not effective in increasing the average weight and diameter (Table 2) of fruits in cv. Alex. The only effective treatment with ATS was that at the rate of 10.2 g/l in 2012 (the average fruit weight 8.5 g), although it did not significantly reduce fruit set, probably due to a lesser extent of phytotoxicity on the leaves at the lower rate of ATS. A negative linear relationship exists between fruit weight and diameter on the one hand and fruit to leaf area ratio on the other (Whiting, Lang 2004), which is why a healthy leaf area is a crucial factor that affects fruit size. It is previously reported by Milić et al. (2011) that phytotoxicity occurred on apple leaves after 3% ATS application and caused a decrease in

doi: 10.17221/288/2014-HORTSCI

Table 2. Effect of thinning on the average fruit weight and the average fruit diameter of sweet cherry cvs Alex and Sunburst

Treatment	Average fruit weight (g)				Average fruit diameter (mm)			
	Alex		Sunburst		Alex		Sunburst	
	2011	2012	2011	2012	2011		2012	
ATS 10.2 g/l	6.6^{a}	8.5^{cd}	10.9^{ab}	11.0^{b}	22.2^{a}	24.7^{b}	27.8^{a}	28.3^{ab}
ATS 20.4 g/l	7.0^{ab}	7.8^{a}	10.8^{a}	10.0^{ab}	22.2^{a}	24.1^{ab}	27.9^{ab}	27.5^{ab}
ATS 30.6 g/l	7.0^{ab}	7.9^{ab}	11.3^{ab}	8.5^{a}	22.1^{a}	24.1^{ab}	28.7^{bcd}	26.4^{a}
Silwet 1 ml/l	7.3^{b}	8.3^{bcd}	11.6^{b}	10.0^{ab}	23.1^{b}	24.5^{b}	29.1^{d}	27.4^{ab}
Silwet 3 ml/l	7.2^{b}	8.5^{d}	11.7^{b}	10.8^{b}	23.0^{b}	24.8^{b}	28.9^{cd}	28.7^{b}
Ogriol 10 ml/l	7.1^{ab}	8.6^{d}	11.2^{ab}	10.4^{b}	22.5^{ab}	24.5^{b}	28.0^{abc}	27.8^{ab}
Ogriol 30 ml/l	7.3^{b}	8.6^{d}	11.2^{ab}	9.8^{ab}	23.1^{b}	24.7^{b}	28.3^{abcd}	27.5^{ab}
Control	6.7^{a}	8.0^{abc}	10.7^{a}	9.6^{ab}	22.2^{a}	23.8^{a}	27.7^{a}	27.2^{ab}
Statistical significance	*	*	*	*	*	*	*	*

$^{a–d}$mean separation within column by the Duncan's multiple range test at $P = 0.05$; *significant differences between treatments at $P = 0.05$

fruit weight. It is assumed that more leaf damage occurred on apple than on sweet cherry because, at the time of flowering, an apple tree develops a larger leaf area susceptible to burning than sweet cherry. Ambrožić Turk et al. (2014) reported that 2% ATS application affected leaf development and caused some burned shoots in peach.

Flower thinning with Silwet significantly increased both fruit weight and diameter in cv. Alex. Surprisingly, Ogriol application caused a significant increase in fruit weight and diameter in cv. Alex in both years of the study although it was not consistently effective in the reduction of the fruit set.

In cv. Sunburst, only surfactant Silwet was effective in increasing the average fruit weight when applied at the rates of 1 and 3 ml/l in 2011 (Table 2). Silwet application, as well as the highest rate of ATS led to an increase in fruit diameter (Table 2). A significant increase in fruit weight and diameter in chemically thinned cherries of cv. Sunburst was not observed in 2012. The reason for that might be a very low fruit set (5.9 fruits/100 flowers and 12.2 fruits/cm^2 BCSA in the untreated control) and a lack of competition for the resources among the fruits (Choi, Andersen 2001).

The content of total soluble solids in fruits was not dependent on treatments in cv. Alex (Table 3). Significant increases in the content of TSS in cv. Sunburst were observed in treatments with ATS 10.2 and 30.6 g/l and Silwet 3 ml/l, which also decreased fruit set to the greatest extent. This is consistent with Whiting and Lang (2004) and Usenik et al. (2010), who reported that fruits from thinned trees had higher soluble solids due to the lower fruit to leaf area ratio and reduced competition for assimilates among the fruits.

In conclusion, surfactant Silwet applied at the rates of 1 or 3 ml/l was found to consistently thin self-fertile sweet cherries, leading to a better fruit quality.

Table 3. Total soluble solids content in fruits of sweet cherry cvs Alex and Sunburst in 2012

Treatment	Soluble solids (%)	
	Alex	Sunburst
ATS 10.2 g/l	17.0	18.1^{c}
ATS 20.4 g/l	17.6	17.4^{bc}
ATS 30.6 g/l	16.9	18.0^{c}
Silwet 1 ml/l	17.0	16.3^{ab}
Silwet 3 ml/l	17.6	18.6^{c}
Ogriol 10 ml/l	17.2	16.2^{ab}
Ogriol 30 ml/l	17.8	15.5^{a}
Control	16.4	16.3^{ab}
Statistical significance	ns	*

$^{a–c}$mean separation within column by the Duncan's multiple range test at $P = 0.05$; n.s. – not significant; *significant differences between treatments at $P = 0.05$

doi: 10.17221/288/2014-HORTSCI

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Received for publication October 21, 2014
Accepted after corrections January 27, 2015

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