

Regulation of crop load and quality in sweet cherry cv. 'Sweet Heart' using blossom thinning

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ABSTRACT

Self-fertile cultivars of sweet cherry (*Prunus avium*) produce heavy crop load that is often associated with small and poor-quality fruits. Therefore, a crop load-management strategy is required to improve the quality of the fruit. In this study, the effect of blossom thinners on fruit set, yield and quality of the fruits was evaluated. Three types of blossom thinners were used at three different concentrations viz., ammonium thiosulphate (ATS) (1, 1.5 and 2%), naphthaleneacetic acid (NAA) (20, 40 and 60 ppm) and corn oil emulsion (1, 2 and 3%). These were sprayed at 80% of the bloom stage. The vegetative, flowering, fruit set and yield parameters were observed and recorded. Fruit quality was evaluated by measuring the physical and chemical characteristics of the fruits at the harvest stage. Negative correlation was found between fruit set and quality of fruit. The reduction in the crop load was associated with enhanced vegetative growth, including higher leaf:fruit ratio, higher supply and availability of photosynthates to the remaining fruitlets and reduced fruit firmness and titratable acidity. Fruit size, weight, volume, hue value, chroma value, soluble solid content (SSC), total sugars, SSC/acid ratio, anthocyanin and ascorbic acid content were enhanced as a result of thinning. The foliar spray of ATS at 2% and NAA at 60 ppm, at 80% bloom proved to be the most effective in reducing crop load and enhancing the fruit quality.

Keywords: corn oil emulsion, fruit set, self-fertile, sweet cherry, thinning, quality, vegetative growth, yield

INTRODUCTION

Cherry is a fleshy drupe (stone fruit) that belongs to the genus *Prunus*. It is a member of the Rosaceae family and is well known among temperate fruits all over the world (Mahmoodi et al., 2006). It is a non-climacteric

fruit that produces low ethylene during ripening (Gong et al., 2002). The exocarp and mesocarp are the edible parts of the cherry (outer layer of the mature ovary wall). Sweet cherry is a valuable horticultural

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trading commodity all over the world (Webster and Looney, 1996). The trees are found throughout temperate Asia, Europe, North Africa, Australia and the majority of North America. In India, the major cherry producers are Jammu and Kashmir, parts of Himachal Pradesh and Uttarakhand. The union territory of Jammu and Kashmir alone produces >95% of the country's commercial cherry varieties. Sweet cherry is a high-value crop due to the commercial and nutritional value of its fruits (Perez-Sanchez et al., 2010). They are rich source of minerals and they have anti-infective, detoxifying and refreshing properties.

'Sweet Heart' is a cultivar of cherry and is a hybrid of the 'Van' and 'Newstar' cultivars. It was developed at the Pacific Agri-Food Research Centre in Summerland, British Columbia (Lane and MacDonald, 1996). The cultivar was awarded the 'Outstanding Fruit Cultivar' by the American Society for Horticultural Science in 2012. 'Sweet Heart' is a self-fertile cultivar that can be used as a universal polliniser for other cherry varieties that bloom around the same time. It is a late season cherry with red flesh and dark bright red skin. Its commercial importance lies in its self-fertility, as it does not need any polliniser while it can also be used as a polliniser for other cultivars. This self-fertility leads to profuse bearing in the cultivar (Whiting et al., 2006), often with small size and low sugar content of the fruits (Lane and Schmid, 1984). Hence, to overcome the quality- and quantity-related issues, the crop load needs to be managed.

Chemical, manual or mechanical thinning is performed depending on the fruit species for crop load management. Mechanical thinning is used as an alternative to manual thinning because manual thinning is a laborious process (Martin-Gorriz et al., 2012) and due to the decreasing workforce availability, it becomes further hard to implement such type of thinning every year (Lordan et al., 2018). However, mechanical thinning is commonly used on apples, pears and peaches, but fruit thinning with hand-held devices requires much more effort than chemical thinning and its efficiency is disputable; so, the best solution is to develop an effective chemical thinning method. As such, the use of chemical blossom and post blossom thinners can prove to be the best strategy for crop load management (Westwood and Westwood, 1993). In sweet and sour cherries, hand thinning is considered as an unprofitable practice due to the high labour requirement (Davarynejad et al., 2008). In comparison to pome, stone species require more flowers to be left on the trees in order to obtain a profitable commercial yield of high quality. The number of flowers on the tree should be around 25% for peaches (Costa et al., 2012), while for sweet and sour cherries, it should be 75% (Roubik, 2018).

The quality of sweet cherries in the market is usually determined by fruit size, skin colour, flavour, sweetness, sourness, firmness and stem colour; however, these attributes have been found to be closely related to

consumer's acceptability and market prices (Dever et al., 1996).

Different concentrations of these blossom thinners have been evaluated in various studies conducted earlier. Kurlus et al. (2020) conducted a study with the objective to evaluate the effect of ammonium thiosulphate (ATS), at the rate of 20, 30 and 40 g · L⁻¹ and by hand on the quality and regularity of yield of 'Regina' cherries. Taghipour et al. (2011) conducted a study on the effects of chemical and hand thinning on fruit quality of 'Gerdi' apricot. In the study, chemical thinning was performed (3 weeks after full bloom) with naphthaleneacetic acid (NAA) at 10, 20 and 40 mg · L⁻¹, naphthalene acetamide (NAD) at 20, 40 and 80 mg · L⁻¹, ethephon at 50, 100 and 200 mg · L⁻¹ and urea at 0.2, 0.4 and 0.6%. The effect of corn oil emulsions at 1, 3 and 5% sprayed to 'Delicious' apple, 'Feng Huang' peach and 'Bing' cherry trees at pre bloom and at 20, 50, and 80% full bloom, respectively, was studied by Ju et al. (2001). Although various concentrations of these blossom thinners have been studied separately in various researches conducted earlier, no one study has compared the effects of all of these thinners.

Considering the issues in size and quality of self-fertile sweet cherry cv. 'Sweet Heart', the present work investigated the effect of blossom thinners such as ATS, NAA and corn oil emulsion in the reduction of heavy crop load, to obtain better fruit set, quality and yield of the fruit.

MATERIALS AND METHODS

Planting material and treatments

The experiment was carried out at the field of Sher-e-Kashmir University of Agricultural Science & Technology of Kashmir located at Jammu & Kashmir, India during the year 2021–2022. The experimental site is located at an elevation of 1,685 m above the mean sea level having the latitude of 34°5' N and longitude of 74°47' E. Eight-year-old trees of sweet cherry cv. 'Sweet Heart' on colt rootstock having uniform vigour and health were selected. The trees were spaced at a distance of 4 × 2 m and received uniform cultural operations. ATS, NAA and corn oil emulsion were used as blossom thinners. The experiment was laid in randomised complete block design (RCBD) with four replications. The blossom thinners were sprayed at full bloom (80%) stage as shown in Figure 1, illustrating the phenological stages of sweet cherry.

The experiment consisted of 10 treatments as evident from Table 1. The treatments were compared with control, which was water sprayed. ATS was prepared by dissolving requisite quantities directly in water, whereas the spray solution of NAA was prepared by dissolving the required amount in 100 mL of 80% ethanol solution before making the final volume with water. Corn oil emulsion was prepared by mixing the required concentration of corn oil in lukewarm water;

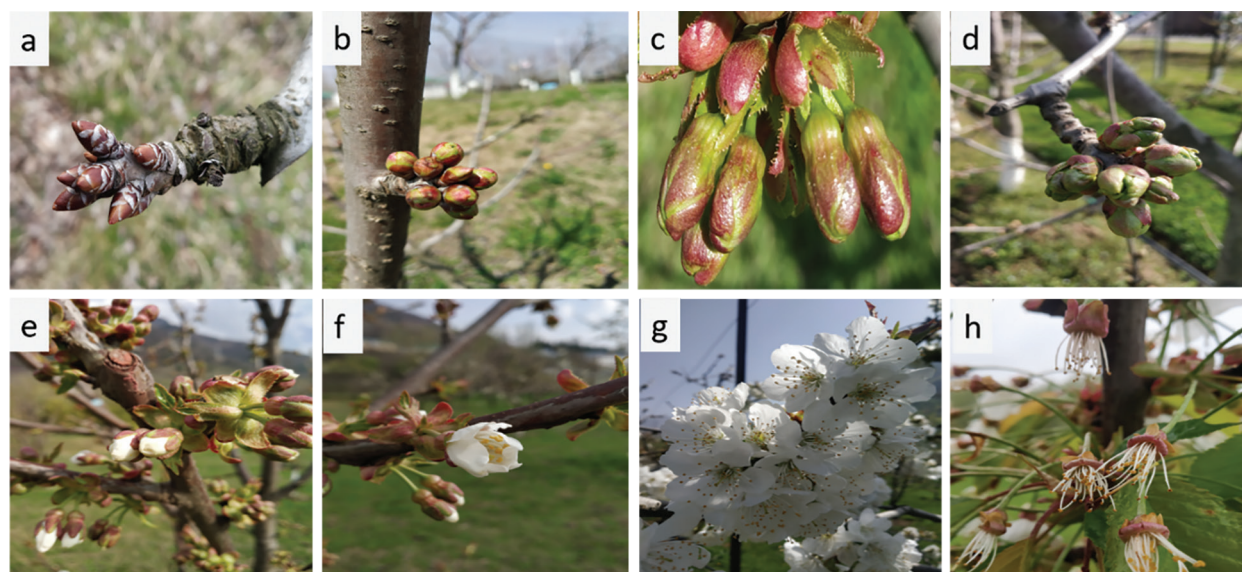


Figure 1. Phenological stages of sweet cherry; (A) dormant bud, (B) swollen bud, (C) green tip, (D) tight cluster, (E) white bud, (F) initial bloom, (G) final bloom, (H) petal fall.

Table 1. Chemicals and their concentrations used in different treatments.

Treatment	Chemical	Concentration
T ₁	Water spray (Control)	—
T ₂	ATS	1%
T ₃	ATS	1.5%
T ₄	ATS	2%
T ₅	NAA	20 ppm
T ₆	NAA	40 ppm
T ₇	NAA	60 ppm
T ₈	Corn oil emulsion	1%
T ₉	Corn oil emulsion	2%
T ₁₀	Corn oil emulsion	3%

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

Tween 60 was added to it with active stirring until the oil dissolved in water to form an emulsion.

Vegetative growth

Annual shoot extension growth (ASEG) was recorded with the help of a measuring scale by taking the mean of four different branches from each experimental tree. Twenty fully developed and matured leaves were randomly selected from each experimental tree and the area of selected leaves was measured with the help of a Systronic Leaf Area Meter-211 and expressed in cm². Leaf chlorophyll content was determined by taking 1 g of crushed leaf sample and incubating it in 10 mL of dimethyl sulfoxide (DMSO) at 70°C for 20 min. The supernatant was discarded and absorbance of the extract was measured at 645 nm and 663 nm in a UV-VIS spectrophotometer with DMSO as the blank (Shoaf and Lium, 1976). Chlorophyll content was calculated using the Arnon formula and expressed in terms of mg · 100 g⁻¹ fresh weight.

Flowering, fruit set and yield

Initial fruit set (%) was calculated by dividing the number of fruitlets at the pea stage of the selected four branches with the number of flowers counted on each branch. The number of fruits on the four selected branches on each replication was also counted after fruit set and 1 week before harvesting to determine the fruit retention (%). Return bloom was determined in the following year by counting the number of flowers and comparing it with previous seasons flowering, expressed in per cent. The total yield per tree was calculated by weighing the total harvested fruits from each tree and it was expressed in kilograms (kg).

Fruit quality evaluation

For physico-chemical evaluation of fruits, 20 fruits were randomly selected from each treatment. Fruit length (mm), diameter (mm), thickness (mm) and stone length (mm) were recorded with the help of a digital vernier calliper, while the L/D ratio was calculated by dividing the length of the fruit with the diameter of the corresponding fruit. Fruit weight (g) and stone weight (g) were measured using a digital weighing balance; however, the increase in the fruit weight (%) was determined during each treatment by comparing the fruits with the control. The fruit/stone ratio was calculated on the basis of their weight by subtracting stone weight from fruit weight and dividing it with the stone weight. Fruit firmness was determined with the Texture Profile Analyzer TA HD PLUS and expressed in Newton (N). For measuring the fruit volume (cm³), the water displacement method was used. Flesh weight of the fruit was calculated by subtracting the stone weight from fruit weight, averaged and expressed in gram (g). Fruit skin colour was measured in terms of Hunter Lab L*, a*, b* values using the Hunter lab Miniscan XE plus

colorimeter (Model No. 45/0-L. Hunter Lab, USA) on a sample of 20 cherries in each treatment. Hue value (h°) was calculated using Eq. (1).

$$h^\circ = \tan^{-1} \times (b^*/a^*) \quad (1)$$

whereas chroma value (C), was calculated using a^* and b^* scales by using Eq. (2).

$$C = \sqrt{a^2 + b^2} \quad (2)$$

The soluble solid content (SSC) was determined using the Erma hand refractometer made in Japan and expressed in °Brix. Titratable acidity (%) was calculated as malic acid by titrating 10 mL of the juice sample with 0.1 N NaOH to pH 8.2 and using phenolphthalein as indicator. The SSC/acid ratio was calculated by dividing the SSC with titratable acidity of the fruit. Total sugar, anthocyanins and ascorbic acid content of the fruit were determined as per the procedures described by Ranganna (1986).

The observations recorded during the course of investigation were subjected to statistical analysis as per the method of analysis of variance (Fisher, 1950). The significance and non-significance of the treatment effects were judged with the help of R software. The significant difference on the means was tested against the critical difference at the 5% level.

RESULTS AND DISCUSSION

Effect of thinning on vegetative growth

The effect of the different thinning treatments on the vegetative growth is presented in Figure 2. The application of ATS 2% and NAA 60 ppm resulted in a significant increase in the vegetative growth viz., ASEG and leaf area. While as the minimum value of ASEG was recorded under control, that was found statistically at par with corn oil 1%. In addition, the minimum value

of leaf area was recorded under corn oil 2% that was statistically at par with control, corn oil 1% and 3%. It indicates that there was no effect of corn oil on the vegetative characteristics of cherry. The application of ATS 2% and NAA 60 ppm led to the significant decrease in leaf chlorophyll content of the sweet cherry cv. 'Sweet Heart' in comparison to the other treatments as shown in Figure 3. The maximum value of the leaf chlorophyll content ($2.52 \text{ mg} \cdot \text{g}^{-1}$ fresh weight) was found in the control that was statistically at par with corn oil 1% and NAA 20 ppm. Similar findings were obtained by Lenahan and Whiting (2006) in cherry cv. 'Bing'. The highest vegetative growth in such treatments may be attributed to the effect of chemical blossom thinners on nutrient composition of foliage, which has direct and indirect effects on shoot growth. Their direct effects are achieved by lowering the basipetal movement of auxin, which lowers the acropetal movement of Ca and other mineral elements, resulting in a decrease in the Ca mineral content. In contrast, the indirect effects are associated with the elimination of the shoot–fruit competition for nutrients, change in fruit size and eventually increased vegetative growth (Faust and Miller, 1989). Similar results have been obtained by El-Boray et al. (2013) for leaf area and by Kurlus et al. (2020) for ASEG. Previous studies found non-fruiting cherry trees to have a stronger increase in the number of shoots and a larger leaf area; these attributes also confirm that trees with a lower yield as a result of thinning have greater vegetative growth (Kappel, 1991).

Effect of thinning on flowering, fruit set and yield

Various studies have been conducted on chemical thinning such as blossom burning formulations, growth regulators and photosynthetic inhibitors (Gonzalez-Rossia et al., 2007; Stern et al., 2009). These studies

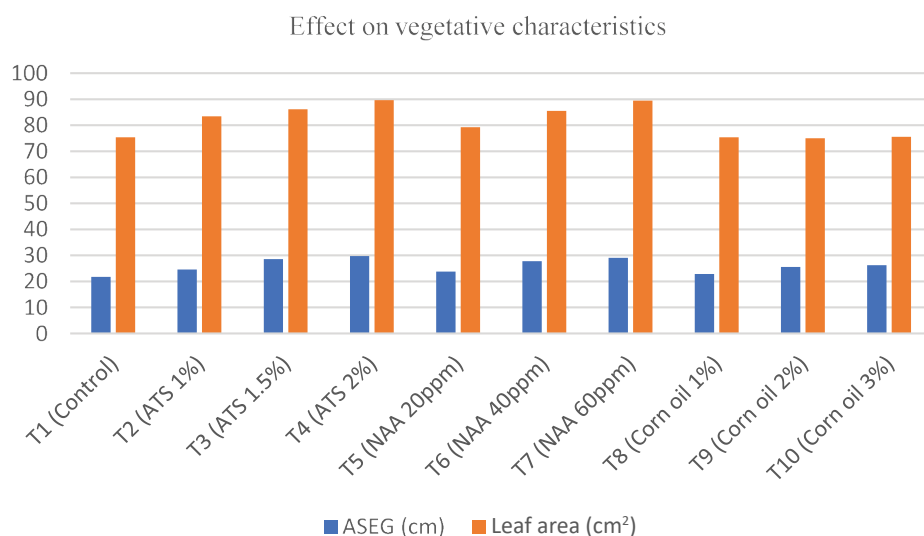


Figure 2. Effect of blossom thinners on the vegetative characteristics of sweet cherry cv. 'Sweet Heart'. ASEG, annual shoot extension growth; ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

have shown that the chemical thinning can be done during flowering or shortly after to reduce the load on trees during the growing season (Wertheim, 2000). Removing flowers and fruitlets during the early growth period preserves more assimilates and reduces the competition between the vegetative and generative parts of the tress. It not only promotes stronger vegetative growth, but it also promotes flower bud differentiation and improves fruit yield and quality (Costa and Vizzotto, 2010). The response of sweet cherry cv. 'Sweet Heart', with respect to flowering, initial fruit set and yield as influenced by different thinning treatments in the present study is shown in Figures 4 and 5. The initial fruit set was found to be significantly affected by different thinning treatments. The maximum initial fruit set (65.07%) was recorded under control and it

decreased with increasing the concentration of blossom thinners. The thinning activity of ATS is a consequence of damage to the stigma, style, anther and pollen, which prevents pollination of flowers (Janoudi and Flore, 2005). Similar results have been reported by Whiting et al. (2006) and Milic et al. (2015) in cherry and Osborne and Robinson (2008) and Rasouli et al. (2020) in peach. In addition, NAA also performed well as a blossom thinner and significantly thinned the crop load. The efficacy of NAA in thinning flowers and fruit set is due to the fact that it prevents ovule fertilisation and fruit set and results in ovule/embryo abortion, depending on the phenological growth stage at treatment. NAA has been found to have a gametocidal effect on mature but unfertilised as well as newly fertilised ovules (Reig et al., 2014). Moreover, corn oil emulsion's efficacy as

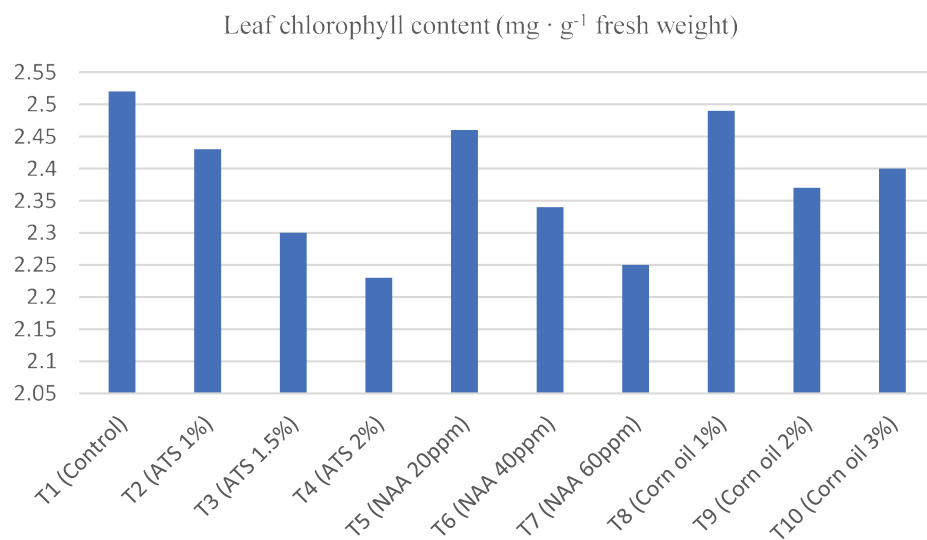


Figure 3. Effect of blossom thinners on the leaf chlorophyll content of sweet cherry cv. 'Sweet Heart'. ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

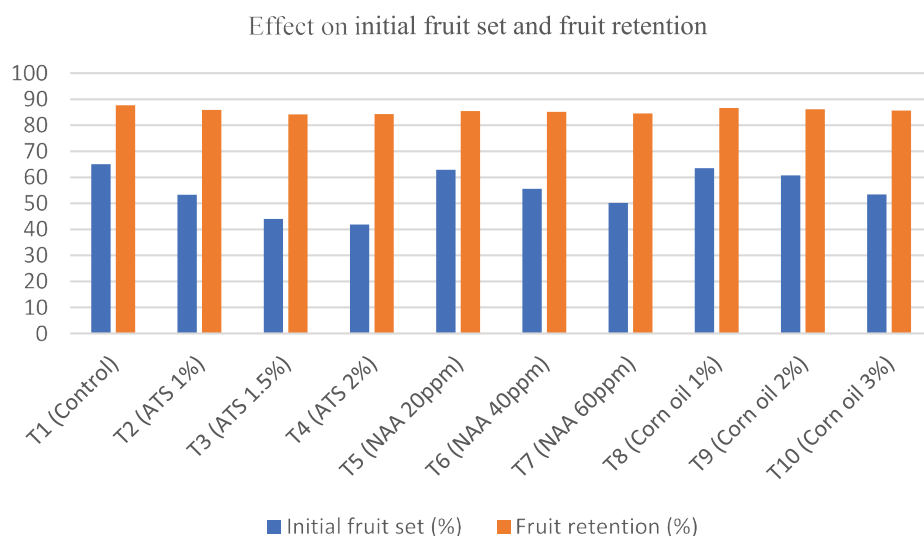


Figure 4. Effect of blossom thinners on fruit set and fruit retention of sweet cherry cv. 'Sweet Heart'. ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

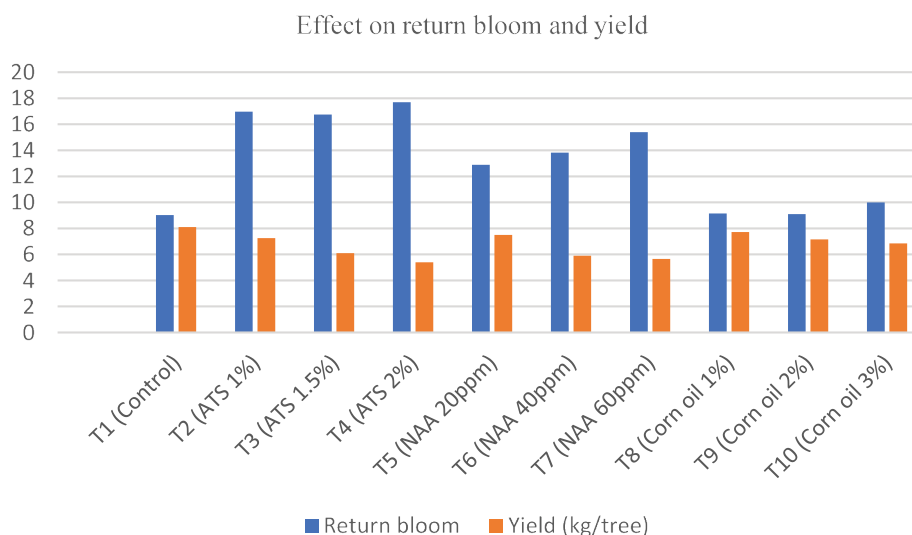


Figure 5. Effect of blossom thinners on return bloom and yield of sweet cherry cv. 'Sweet Heart'. ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

a thinning agent was found to be dependent on the oil concentration and application time. Blossom thinners such as plant oils damage flower petals, prevent some flowers from opening and cause fruit abscission from unopened flowers. The treatment with ATS, NAA and corn oil emulsion (3%) further led to the increase in fruit drop and reduction of the final retention of fruits as evident from Figure 4. Fruit drop had negative interactions with final fruit retention. Similar results have been obtained by Bhatt et al. (2017) in plum cv. 'Kala Amritsari'.

Different thinning treatments also considerably affected the return bloom, with the maximum return bloom (17.70%) observed under ATS 2% as evident from Figure 5. It may be due to the reason that the heavy crop load acts as a drain for all available nutrients, inhibiting flower bud formation in the following year. Apparently, crop loads in the previous year were not heavy enough to prevent flowering in the following year. Apart from carbohydrates and activation or inactivation of genes involved in the flower initiation, the levels of crop load also cause significant fluctuations in metabolites such as hydroxycinnamates, salicylates and salicylic acid intermediates in the biosynthesis process and flavanols as well as phytohormones such as cytokinin. Consequently, a significant factor in the suppression of flower initiation in the next year is the heavy crop load (Reddy et al., 2022). The results of the study are in congruence with that of Bound and Jones (2004) and Meland (2007).

The maximum yield was recorded under control, while the minimum (5.40 kg/tree) was obtained under treatment of ATS 2% followed by NAA 60 ppm as shown in Figure 5. As yield is determined by factors such as fruit number, fruit weight and fruit size, therefore reducing the crop load typically reduces the

total fruit yield per tree (Meland, 2009). ATS thinned the blossoms while increasing the fruit size and weight by increasing photoassimilate of source and sink. As a result, there is an inverse relationship between fruit quality and yield per tree (Roper and Loescher, 1987; Whiting and Lang, 2004). Thus, the treatments ATS 2%, NAA 60 ppm and corn oil 3% significantly affected the initial fruit set, return bloom and yield while the effect of different treatments on fruit retention was nearly insignificant.

Effect of thinning on fruit quality

The main qualitative factor determining cherry prices in the market is the size of the fruit. This characteristic was influenced by the thinning treatments. Various thinning treatments significantly enhanced fruit length, diameter, thickness, length:diameter ratio, fruit/stone ratio and volume as compared to control as evident from Tables 2–4, respectively. This increase could be attributed to enhanced vegetative growth, including higher leaf:fruit ratio that led to higher supply and availability of photosynthates to the remaining fruitlets (Williams and Edgerton, 1981). These results are in agreement with the findings of Whiting et al. (2006) in sweet cherry cv. 'Bing' and Kurlus et al. (2020). Fruit weight, percent increase in fruit weight and flesh weight were also significantly influenced by the different thinning treatments (Table 3). Maximum fruit weight (7.30 ± 0.11 g) and increase in fruit weight ($23.70 \pm 0.05\%$) and flesh weight (6.85 ± 0.09 g) were obtained with treatment T₄ (ATS 2%). This increase may be attributed to reduced crop load and increased photosynthate deposition thereby increasing weight of the remaining fruits. Generally, chemical thinners reduce reproductive growth and enhance vegetative growth, thereby reducing competition for

Table 2. Effect of blossom thinners on fruit length, diameter, thickness and L/D ratio of sweet cherry cv. 'Sweet Heart'.

Treatment	Fruit length (mm)	Fruit diameter (mm)	Fruit thickness (mm)	Fruit length/diameter ratio
T ₁ (Control)	17.70 ± 0.21	19.87 ± 0.12	17.25 ± 0.57	0.89 ± 0.01
T ₂ (ATS 1%)	18.80 ± 0.14	20.97 ± 0.33	17.85 ± 1.20	0.89 ± 0.01
T ₃ (ATS 1.5%)	19.77 ± 0.33	21.80 ± 0.47	18.60 ± 0.86	0.90 ± 0.01
T ₄ (ATS 2%)	22.05 ± 0.31	22.85 ± 0.23	19.90 ± 0.92	0.96 ± 0.02
T ₅ (NAA 20 ppm)	18.65 ± 0.17	20.75 ± 0.55	17.75 ± 0.35	0.89 ± 0.02
T ₆ (NAA 40 ppm)	19.42 ± 0.26	21.75 ± 0.61	18.10 ± 0.29	0.89 ± 0.01
T ₇ (NAA 60 ppm)	20.85 ± 0.26	22.42 ± 0.49	19.80 ± 0.6	0.92 ± 0.02
T ₈ (Corn oil 1%)	18.62 ± 0.18	20.62 ± 0.72	17.65 ± 1.40	0.90 ± 0.02
T ₉ (Corn oil 2%)	19.00 ± 0.21	21.40 ± 0.40	17.92 ± 0.60	0.88 ± 0.01
T ₁₀ (Corn oil 3%)	19.35 ± 0.17	21.57 ± 0.45	18.08 ± 0.70	0.89 ± 0.01
C.D ($p \leq 0.05$)	0.238	0.444	0.441	0.019

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

Table 3. Effect of blossom thinners on fruit weight, increase in fruit weight, stone weight, flesh weight and fruit/stone ratio of sweet cherry cv. 'Sweet Heart'.

Treatment	Fruit weight (g)	Increase in fruit weight (%)	Stone weight (g)	Flesh weight (g)	Fruit/stone ratio
T ₁ (Control)	5.90 ± 0.77	0.00	0.43 ± 0.02	5.47 ± 0.79	12.72 ± 0.27
T ₂ (ATS 1%)	6.72 ± 0.12	13.89 ± 0.24	0.45 ± 0.02	6.27 ± 0.12	13.93 ± 0.81
T ₃ (ATS 1.5%)	6.97 ± 0.17	18.13 ± 0.04	0.44 ± 0.02	6.53 ± 0.19	14.84 ± 1.20
T ₄ (ATS 2%)	7.30 ± 0.11	23.70 ± 0.05	0.45 ± 0.02	6.85 ± 0.09	15.59 ± 0.70
T ₅ (NAA 20 ppm)	6.70 ± 0.18	13.50 ± 0.29	0.43 ± 0.02	6.26 ± 0.15	14.22 ± 0.50
T ₆ (NAA 40 ppm)	6.90 ± 0.14	16.90 ± 0.25	0.43 ± 0.02	6.47 ± 0.16	15.04 ± 1.30
T ₇ (NAA 60 ppm)	7.07 ± 0.09	18.60 ± 0.28	0.45 ± 0.02	6.55 ± 0.07	14.71 ± 0.60
T ₈ (Corn oil 1%)	6.50 ± 0.08	10.10 ± 0.15	0.45 ± 0.02	6.05 ± 0.08	13.44 ± 0.70
T ₉ (Corn oil 2%)	6.80 ± 0.21	15.20 ± 0.05	0.44 ± 0.03	6.36 ± 0.20	14.45 ± 0.90
T ₁₀ (Corn oil 3%)	6.87 ± 0.09	16.40 ± 0.09	0.43 ± 0.03	6.44 ± 0.10	14.97 ± 1.20
C.D ($p \leq 0.05$)	0.282	0.264	NS	0.280	0.690

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid; NS, non significant.

Table 4. Effect of blossom thinners on fruit volume, firmness, pedicel length and stone length of sweet cherry cv. 'Sweet Heart'.

Treatment	Fruit volume (cm ³)	Fruit firmness (N)	Pedicel length (mm)	Stone length (mm)
T ₁ (Control)	5.25 ± 0.50	3.81 ± 0.14	38.19 ± 0.01	11.45 ± 0.02
T ₂ (ATS 1%)	5.90 ± 0.14	3.06 ± 0.19	38.18 ± 0.01	11.46 ± 0.02
T ₃ (ATS 1.5%)	6.25 ± 0.50	2.57 ± 0.05	38.20 ± 0.02	11.45 ± 0.01
T ₄ (ATS 2%)	6.55 ± 0.10	2.24 ± 0.18	38.20 ± 0.01	11.46 ± 0.01
T ₅ (NAA 20 ppm)	5.75 ± 0.95	2.76 ± 0.27	38.19 ± 0.02	11.46 ± 0.01
T ₆ (NAA 40 ppm)	6.22 ± 0.20	2.62 ± 0.35	38.18 ± 0.01	11.46 ± 0.02
T ₇ (NAA 60 ppm)	6.42 ± 0.09	2.40 ± 0.16	38.18 ± 0.01	11.45 ± 0.02
T ₈ (Corn oil 1%)	5.50 ± 0.57	3.25 ± 0.20	38.19 ± 0.02	11.46 ± 0.02
T ₉ (Corn oil 2%)	5.92 ± 0.95	3.07 ± 0.27	38.20 ± 0.03	11.46 ± 0.01
T ₁₀ (Corn oil 3%)	6.00 ± 0.01	2.71 ± 0.20	38.19 ± 0.02	11.46 ± 0.01
C.D ($p \leq 0.05$)	0.406	0.198	NS	NS

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid; NS, non significant.

photosynthates and minerals. In the present study, results revealed that flower thinning with ATS improved the average fruit weight more than the rest of the treatments. This increase might be due to its ability to reduce crop load, which indirectly affects fruit weight by reducing interfruit competition (Coneva and Cline, 2006). The results are in harmony with the findings of Rajput and Bhatia (2017) in Japanese plum and Rasouli et al. (2020) in peach. Fruit firmness was reduced by thinning treatments as shown in Table 4. The reduction may be due to the larger fruit size, which decreases the strength of the cell wall and creates lesser cohesion between the cells (Deshmukh et al., 2012). This agrees well with previous reports given by Johnson (1994) that flesh firmness is negatively correlated with mean fruit weight. Generally, the decrease in fruit firmness under different chemical thinning treatments may be due to the larger fruit size and higher accumulation of nitrogen in the fruit, resulting in fruit softening via the activation of the cell wall softening enzymes.

The different thinning treatments were found to have a non-significant effect on pedicel length (mm),

stone length (mm) and stone weight (g) of sweet cherry cv. 'Sweet Heart' as evident from Tables 3 and 4. The results are in conformity with the study of Miletic et al. (2014) who found that thinning of sour cherry with LG-GER-ATS did not show any significant difference in the pedicel length, stone length and stone weight of treated trees.

All the treatments of blossom thinners showed a significant effect on fruit colour parameters (L^* , a^* , b^* , hue° and chroma) as compared to control as shown in Table 5. This may be due to the increased leaf:fruit ratio as a result of decreased crop load, which ultimately leads to faster accumulation of colouring pigments. These findings are consistent with those of Link (2000), who found that only fruits that are sufficiently supplied with carbohydrates develop good flavour and colour.

Furthermore, the maximum SSC, total sugars and SSC:acid ratio were attained in the fruits harvested from trees of ATS 2% as shown in Table 6. The increase in the content of SSC, total sugars and SSC:acid ratio can be attributed to higher leaf: fruit ratio and reduced

Table 5. Effect of blossom thinners on colour intensity of sweet cherry cv. 'Sweet Heart'.

Treatment	L^*	a^*	b^*	Hue°	Chroma
T ₁ (Control)	24.46 ± 0.11	29.49 ± 0.59	10.71 ± 0.18	19.95 ± 0.55	31.28 ± 0.05
T ₂ (ATS 1%)	23.94 ± 0.21	30.93 ± 0.15	12.04 ± 0.17	21.25 ± 0.39	33.17 ± 0.06
T ₃ (ATS 1.5%)	23.03 ± 0.06	31.84 ± 0.13	12.46 ± 0.18	21.35 ± 0.29	34.18 ± 0.05
T ₄ (ATS 2%)	22.98 ± 0.10	32.21 ± 0.06	13.25 ± 0.12	22.34 ± 0.20	34.81 ± 0.06
T ₅ (NAA 20 ppm)	23.99 ± 0.15	30.86 ± 0.12	12.00 ± 0.32	21.20 ± 0.58	33.11 ± 0.09
T ₆ (NAA 40 ppm)	23.74 ± 0.05	31.75 ± 0.20	12.36 ± 0.10	21.25 ± 0.07	34.06 ± 0.09
T ₇ (NAA 60 ppm)	23.01 ± 0.24	31.94 ± 0.10	12.44 ± 0.07	21.25 ± 0.13	34.27 ± 0.03
T ₈ (Corn oil 1%)	24.01 ± 0.38	30.10 ± 0.16	10.97 ± 0.17	20.00 ± 0.34	32.03 ± 0.14
T ₉ (Corn oil 2%)	23.90 ± 0.21	31.66 ± 0.23	12.12 ± 0.12	20.90 ± 0.30	33.89 ± 0.03
T ₁₀ (Corn oil 3%)	23.89 ± 0.14	31.72 ± 0.13	12.29 ± 0.11	20.90 ± 0.51	34.01 ± 0.20
C.D ($p \leq 0.05$)	0.231	0.223	0.154	0.382	0.081

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

Table 6. Effect of blossom thinners on the chemical characteristics of sweet cherry cv. 'Sweet Heart'.

Treatment	SSC (°Brix)	Total sugars (%)	Titrateable acidity (%)	SSC/acid ratio
T ₁ (Control)	17.37 ± 0.77	12.82 ± 0.09	0.89 ± 0.01	19.51 ± 1.45
T ₂ (ATS 1%)	18.07 ± 0.36	13.55 ± 0.26	0.87 ± 0.01	20.77 ± 0.92
T ₃ (ATS 1.5%)	18.77 ± 1.38	14.57 ± 0.35	0.77 ± 0.02	24.38 ± 2.19
T ₄ (ATS 2%)	19.35 ± 0.62	15.32 ± 0.09	0.74 ± 0.02	26.14 ± 1.65
T ₅ (NAA 20 ppm)	17.95 ± 0.23	13.50 ± 0.08	0.87 ± 0.02	20.63 ± 0.65
T ₆ (NAA 40 ppm)	18.65 ± 0.65	14.35 ± 0.31	0.80 ± 0.02	23.31 ± 1.45
T ₇ (NAA 60 ppm)	19.00 ± 0.90	14.87 ± 0.25	0.76 ± 0.02	25.00 ± 1.53
T ₈ (Corn oil 1%)	17.45 ± 0.53	13.10 ± 0.11	0.86 ± 0.01	20.29 ± 0.80
T ₉ (Corn oil 2%)	18.35 ± 0.23	13.80 ± 0.08	0.88 ± 0.01	20.85 ± 0.68
T ₁₀ (Corn oil 3%)	18.50 ± 0.81	14.10 ± 0.18	0.82 ± 0.02	22.56 ± 1.20
C.D ($p \leq 0.05$)	0.102	0.061	0.026	0.483

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid; SSC, soluble solid content.

Table 7. Effect of blossom thinners on anthocyanin and ascorbic acid content of sweet cherry cv. 'Sweet Heart'.

Treatment	Anthocyanin (mg · 100 g ⁻¹)	Ascorbic acid (mg · 100 g ⁻¹)
T ₁ (Control)	18.42 ± 0.29	12.22 ± 0.09
T ₂ (ATS 1%)	19.37 ± 0.48	12.72 ± 0.17
T ₃ (ATS 1.5%)	19.77 ± 0.38	13.40 ± 0.14
T ₄ (ATS 2%)	20.87 ± 0.29	13.64 ± 0.12
T ₅ (NAA 20 ppm)	18.77 ± 0.40	12.72 ± 0.17
T ₆ (NAA 40 ppm)	19.57 ± 0.35	13.30 ± 0.24
T ₇ (NAA 60 ppm)	19.85 ± 0.28	13.77 ± 0.12
T ₈ (Corn oil 1%)	18.85 ± 0.12	12.40 ± 0.14
T ₉ (Corn oil 2%)	19.42 ± 0.29	13.07 ± 0.09
T ₁₀ (Corn oil 3%)	19.45 ± 0.33	13.15 ± 0.12
C.D (<i>p</i> ≤ 0.05)	0.327	0.145

ATS, ammonium thiosulphate; NAA, naphthaleneacetic acid.

competition for assimilates among the remaining fruits as observed by Whiting and Lang (2004), Usenik et al. (2010) in cherry and Milic et al. (2015) in peach cultivars.

All the treatments showed significant reduction in the titratable acidity of fruits. This may be due to the conversion of organic acids into sugar and due to the dilution effect as a result of increased fruit size, which results in a change in the quality attributes. These results were in agreement with the research conducted by Roussos et al. (2011) on apricot. The increased leaf: fruit ratio appeared to boost anthocyanin accumulation as shown in Table 7. This could be because of more photosynthates available per fruit, resulting in less inter-fruit competition for minerals, metabolites and precursors. As a result, more sugar is delivered for anthocyanin production, which in turn leads to faster buildup of colouring pigments. These results are in congruence with the findings of Khalil and Stino (1987), Whiting et al. (2006) and Szot et al. (2016), who found an increase in the total anthocyanin content on thinning of nectarine, cherry and apple, respectively. In addition, there was also an increase in the ascorbic acid content of the fruit as a result of different thinning treatments as evident from Table 7. The increase in ascorbic acid content is correlated with an adequate supply of sugars through photosynthetic activity as a result of higher leaf: fruit ratio.

CONCLUSIONS

The usage of blossom thinners proved to be helpful in reducing the crop load of self-fertile cultivars of sweet cherry. The foliar spray of ATS at the concentration of 2% and 60 ppm of NAA, at full bloom (80%) stage, was found to reduce the fruit set to 41.85% and 50.17%, respectively, thereby increasing the size, weight and quality of cherry fruit. Moreover, for organic fruit production, oil emulsions like corn oil emulsion have great potential in flower thinning for reducing the fruit set and improving the quality of fruits. Furthermore,

it is found to be safer, environmental friendly and of low cost.

ACKNOWLEDGEMENTS

The authors extend their appreciation to the Division of Fruit Science, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India. The authors would like to acknowledge Researchers Supporting Project number RSPD2024R686, King Saud University, Riyadh, Saudi Arabia.

AUTHOR CONTRIBUTIONS

M.U.P. and M.M.M. – conceptualisation. M.U.P. – methodology. I.K., A.R.Z.G.– software. M.M.M., M.R. and U.I. – validation. I.K., A.R.Z.G., and P.K.– formal analysis. M.U.P. – investigation. F.A.K. – resources. I.K. – data curation. M.U.P. – writing – original draft preparation. S.Q.K., I.M and H.K.S. – writing – review & editing. M.R. and U.I. – visualisation. S.Q. – supervision.

FUNDING

This research received no grant from any funding agency.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Received: October 18, 2023; accepted: June 25, 2024