Flower thinning of apple cultivar Braeburn using ammonium and potassium thiosulfate – Short communication

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Abstract

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Ammonium and potassium thiosulfate are used commercially or experimentally as flower thinners because they are considered user, environment and consumer safe. The thinning trials were conducted in 2009 and 2010, on three- and four-year-old Braeburn Mariri Red* trees. The chemicals were applied at 1%, 2% and 3% rates of ammonium and 0.5%, 1% and 1.5% of potassium thiosulfate. Both thinning agents reduced fruit set, but were more efficient in 2009, when applied at 20% full bloom, than in 2010, when they were applied at 80% full bloom. Flower thinning with ammonium and potassium thiosulfate increased the average fruit weight, but the highest chemical rates retarded fruit growth. Ammonium and potassium thiosulfate did not affect fruit shape and firmness, but they increased starch degradation, total soluble solids content and titratable acidity. The treatments increased the percentage of flower buds, except at the highest chemical rates, where leaf damage reduced flower bud formation. Ammonium or potassium thiosulfate application may be recommended as the first step in a chemical thinning program.

Keywords: fruit set; fruit quality; bearing potential; phytotoxicity

Flower and fruit thinning of apple is an important practice used to regulate crop load and improve fruit quality at harvest. A heavy crop load reduces flower bud initiation, resulting in low yields in the following year (Keserović et al. 2005). The mean fruit weight is negatively correlated with crop load, which means that if there are too many fruits per tree, they are small and grouped in clusters (Link 2000). The thinning of flowers and young fruits has many positive effects on regular bearing and fruit quality. An advantage of early thinning, when carried out during the flowering period, is the possibility to additionally thin fruits later by using plant growth regulators, and adjust crop load to the optimum level. Ammonium (ATS) is used as a flower thinner because it is considered user, environment and consumer safe. Being a caustic chemical, ATS damages petals, pistils and anthers and prevents fertilization (Janoudi, Flore 2005). ATS treatment increases the average fruit weight, soluble solids content, fruit firmness and decreases seed number (Basak 2006; Bound, Wilson 2007). Flower thinning with potassium thiosulfate (KTS) lead to a decrease in fruit set and an increase in average fruit weight of Red Delicious and Gala apples (Bound, Wilson 2004). KTS increased soluble solids content, but decreased fruit firmness in Red Delicious.

Braeburn is a highly productive apple cultivar, but tends to alternate bearing (Hampson, Kemp 2003). It flowers abundantly and has a high fruit set so thinning is needed to obtain regular bearing. This is especially pronounced in young trees, where high crop load leads to growth stunting. The objective of these trials was to investigate the effects of ATS and KTS on fruit set, fruit quality and flower bud formation in apple cultivar Braeburn.

MATERIALS AND METHODS

The trials were conducted in 2009 and 2010 in a commercial apple orchard, on three- and four-year-old Braeburn Mariri Red* trees. The trees were on M9 T337 rootstock, planted at a 3.2 × 0.8 m distance.

Each treatment was tested on six uniform trees, randomly chosen from along the rows, with one tree per replicate. Fruit set was presented with two parameters: the number of fruits harvested per cm^2 of trunk cross-sectional area (TCSA) and per 100 flower clusters. The average trunk girth and the number of flower clusters per tree were used to calculate target values of fruit set parameters needed to obtain a planned commercial yield of 40 to 45 fruits per a three-year-old tree and 50 to 60 fruits per a four-year-old tree.

Flower thinning chemicals used were ammonium thiosulfate (98% a.i.) and potassium thiosulfate (≥ 95% a.i.), in crystalline form (Sigma-Aldrich, Steinheim, Germany). Chemicals were applied as single applications at the rates of 1%, 2% and 3% ATS and 0.5%, 1% and 1.5% KTS, at 20% full bloom in 2009, and 80% full bloom in 2010. The trees were sprayed with a mistblower (STIHL SR-420) until run-off, at spray volume of 1,000 l/ha. An unsprayed control was included in the trial.

A mean sample of 30 fruits per replicate was used to assess fruit quality. Fruit flesh firmness was measured using a FT 327 penetrometer (Winopal Forshchungsbedarf GmbH, Ahnsbeck, Germany), with an 11 mm probe. The starch index was evaluated using the starch iodine test (Code Amidon, Ctifl, 2002). Total soluble solids (TSS) were determined using a hand refractometer (0–32%). Titratable acidity (TA) was measured by titration with 0.1N NaOH to pH 8.1. The results were expressed as a percentage of malic acid in the fruits.

A mean sample of 100 flower buds per treatment was collected to assess the bearing potential of thinned trees during the winter period. The buds were cut longitudinally, and flower primordia were detected under a binocular microscope (12.5×). The bearing potential was presented as the percentage of buds with flower primordia in the total number of buds in the sample.

The data were analyzed using variance analysis (ANOVA). Duncan's multiple range test was used to compare the means ($P < 0.05$) with STATISTICA 9 (StatSoft Inc., Tulsa, USA). The differences in the bearing potential among treatments were tested using χ^2 test ($P < 0.05$).

RESULTS AND DISCUSSION

The research showed that ATS and KTS could be used for bearing control in young Braeburn orchards, as they efficiently reduce fruit set with an acceptable influence on fruit quality. Bound and Jones (2004) reported severe leaf burning and bud damage after 4% ATS application. In the present study, 3% ATS and 1.5% KTS caused severe leaf and inflorescence burning.

Table 1. The effects of flower thinning with ATS and KTS on fruit set and average fruit weight of cv. Braeburn in 2009

Treatment	No. of fruits/cm^2 TCSA	No. of fruits/100 flower clusters	Average fruit weight (g)
Control	28.8^{b*}	137^{c}	195.2^{b}
1% ATS	6.0^{a}	41^{ab}	237.8^{a}
2% ATS	4.2^{a}	33^{ab}	241.7^{a}
3% ATS	4.8^{a}	27^{a}	233.6^{ba}
0.5% KTS	8.2^{a}	54^{b}	227.0^{a}
1% KTS	6.1^{a}	48^{ab}	229.1^{a}
1.5% KTS	9.8^{a}	48^{ab}	225.4^{a}
Target values[1]	4–5	40–60	180

ATS – ammonium, KTS – potassium thiosulfate, TCSA – trunk cross-sectional area; [1]target values needed to obtain a planned commercial yield of 40–45 fruits/a three-year-old tree and 50–60 fruits/a four-year-old tree; *means followed by the same letter do not differ significantly according to the Duncan's Multiple Range Test at $P = 0.05$

Table 2. The effects of flower thinning with ATS and KTS on fruit set and average fruit weight of cv. Braeburn in 2010

Treatment	No. of fruits/cm² TCSA	No. of fruits/100 flower clusters	Average fruit weight (g)
Control	11.4[c]	83[c]	162.1[bc]
1% ATS	8.8[ac]	71[bc]	177.7[ab]
2% ATS	6.2[ab]	56[ab]	195.8[d]
3% ATS	6.5[ab]	50[ab]	176.5[ab]
0.5% KTS	6.3[ab]	55[ab]	179.0[a]
1% KTS	5.0[b]	41[a]	187.0[ad]
1.5% KTS	8.9[ac]	59[ab]	153.0[c]
Target values[1]	4–5	40–60	180

For abbreviations see Table 1; [1]target values needed to obtain a planned commercial yield of 50–60 fruits/a four-year-old tree

Fruit set and weight

In 2009, all ATS and KTS treatments significantly decreased the number of fruits per cm² of TCSA compared to the untreated control (Table 1). The target values of the number of fruits per cm² of TCSA were reached with 2% and 3% ATS. The number of fruits per 100 flower clusters in treated trees was significantly smaller when compared to the control in 2009. 1% ATS and all KTS treatments reached target levels, while 2% and 3% ATS reduced the number of fruits per 100 clusters too intensively. In 2010, the number of fruits per cm² of TCSA was in the optimum range only trees treated with 1% KTS (Table 2). The number of fruits per 100 flower clusters was significantly lower in all treatments compared to the control, except 1% ATS, which showed no thinning effect. At the 80% full bloom stage, a high percentage of flowers set fruit, and as desiccants are not effective on fertilized flowers, an undesirably high crop load was achieved when ATS was applied at that stage (Bound, Wilson 2007). In the present study, both thinning agents were more efficient in reducing fruit set in 2009, when applied at 20% full bloom, than in 2010, when applied at 80% full bloom.

Flower thinning with ATS and KTS resulted in an increased average fruit weight in 2009 in all treatments, but only control fruits had an average weight similar to the target value of 180 g (Table 1). Early thinning of large-fruited cultivars such as Braeburn, may result in oversized fruit at harvest (McArtney et al. 1996). In 2010, all flower thinning treatments significantly increased the average fruit weight up to the target value of 180 g (Table 2). The smallest average fruit weight among treatments, in both years, was detected following the highest rates of thinning chemicals, 3% ATS and 1.5% KTS, which may be due to leaf burning (Fallahi et al. 2006).

Fruit quality

The present research confirmed that ATS treatments did not affect fruit shape represented by the length/diameter (L/D) ratio (Bound, Wilson 2007) (Tables 2 and 3). On the contrary, Basak (2006) states that full bloom ATS application increased fruit L/D ratio in cv. Gala. KTS did not flatten the fruits as stated by Bound and Wilson (2004).

Table 3. The effects of flower thinning with ATS and KTS on fruit quality of cv. Braeburn in 2009

Treatment	L/D ratio	Fruit firmness (kg/cm²)	Starch index (1–10)	TSS (%)	TA (%)
Control	0.86[a]	9.2[ab]	6.4[a]	13.4[ab]	2.92[d]
1% ATS	0.90[ab]	9.0[ab]	7.0[a]	13.8[b]	3.59[bc]
2% ATS	0.92[b]	9.3[ab]	6.7[a]	13.1[ab]	3.41[ab]
3% ATS	0.87[a]	10.2[c]	6.5[a]	13.4[ab]	3.68[c]
0.5% KTS	0.87[a]	8.9[ab]	7.2[a]	13.4[ab]	3.37[ab]
1% KTS	0.87[a]	8.8[a]	6.6[a]	12.6[a]	3.22[a]
1.5% KTS	0.87[a]	9.4[b]	6.6[a]	13.3[ab]	4.82[e]

L/D – length/diameter ratio, TSS – total soluble solids content, TA – titratable acidity

Table 4. The effects of flower thinning with ATS and KTS on fruit quality of cv. Braeburn in 2010

Treatment	L/D ratio	Fruit firmness (kg/cm^2)	Starch index (1–10)	TSS (%)	TA (%)
Control	0.90^a	9.1^{ab}	5.4^a	11.0^b	6.79^a
1% ATS	0.91^a	8.9^a	5.9^{ab}	11.7^{ab}	7.74^{ab}
2% ATS	0.93^a	9.1^{ab}	6.2^b	11.7^{ab}	7.68^{ab}
3% ATS	0.90^a	9.0^a	6.2^b	11.9^{ab}	7.52^{ab}
0.5% KTS	0.90^a	9.4^b	5.7^{ab}	12.2^a	7.82^b
1% KTS	0.93^a	8.9^a	6.3^b	11.5^{ab}	7.17^{ab}
1.5% KTS	0.92^a	8.9^a	6.2^b	12.0^a	6.84^a

For abbreviations see Table 3

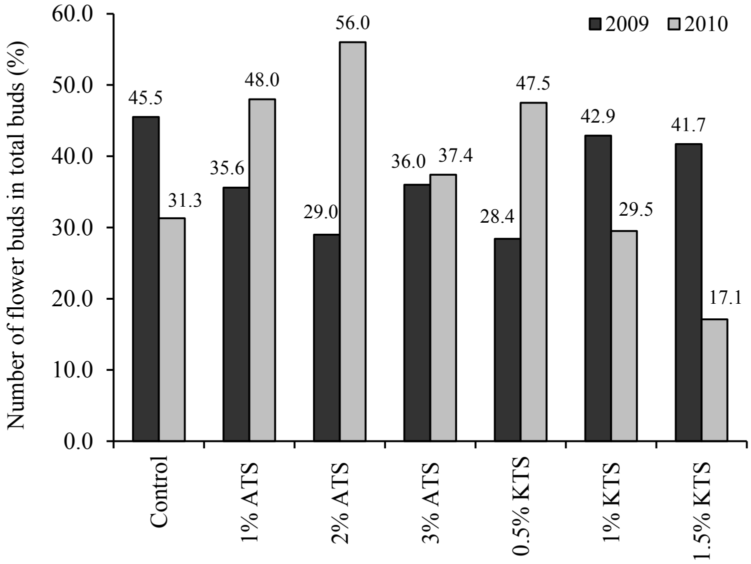

Fig. 1. The effects of flower thinning with ATS and KTS on bearing potential (%) of cv. Braeburn

$Hi^2_{0.05}$ = 12.5961, 2009 – χ^2 = 5.2670 NS, 2010 – χ^2 = 22.0416

NS – differences not significant at P = 0.05

The present research does not clearly confirm that ATS increases fruit firmness, as stated by Bound and Wilson (2007), as only 3% ATS in 2009 significantly increased fruit firmness. It was not confirmed that the largest fruits, produced as a result of over-thinning, at the highest rate of KTS (1.5%), were also the softest fruits (Bound, Wilson 2004). The starch index of the treated fruits indicates advanced maturity when compared to the control.

Thinning increases fruit TSS content by 2% to 3% and TA by 10% to 20% (Link 2000). TSS content was higher in all treatments compared to the control in 2010, which could be related to the thinning effect (Bound, Wilson 2004). Thinning increased titratable acidity in both years of study.

Bearing potential

A higher return bloom was achieved by a higher intensity of thinning with ATS (Bound, Wilson 2007). In 2009, the thinning treatments did not significantly affect the bearing potential, while in 2010 the bearing potential was higher compared to the control (Fig. 1). 3% ATS and 1.5% KTS induced severe leaf burning, which might have affected flower bud formation, as the percentage of flower buds was the lowest in these treatments.

1% and 2% ATS and 0.5% and 1% KTS can be successfully used to reduce fruit set in young trees of apple cv. Braeburn before they reach full bearing capacity. Rates up to 1% ATS are recommended for thinning trees younger than three years, as higher rates may result in oversized fruits at harvest and decrease their storage ability.

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