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Vegetable Oil Emulsions, NaCl, CH_3COOH and CaS_x as Organically Acceptable Apple Blossom Thinning Compounds

M. Stopar
(Agricultural Institute of Slovenia, Ljubljana, Slovenia)

Summary

Full bloom application of possible thinning agents for organic apple growing was carried out in field experiments on mature 'Golden Delicious'/M.9, 'Summerred'/M.9 and 'Elstar'/M.9 apple trees. Sodium chloride (NaCl) 10 g l^{-1} or 15 g l^{-1} caused light thinning on the above cultivars and 20 g l^{-1} overthinned 'Elstar'. NaCl applications enhanced return bloom of 'Elstar' and 'Golden Delicious'. Acetic acid (CH_3COOH) 30 ml l^{-1} caused fruit shedding on 'Summerred' and 'Elstar'. When lime sulphur (CaS_x) 30 ml l^{-1} was sprayed in four trials, no thinning occurred on 'Summerred', moderate thinning on 'Golden Delicious' (year 2003) while a strong thinning response and increased return bloom was observed on 'Elstar' and 'Golden Delicious' (year 2002). No fruit russeting was observed when CH_3COOH or CaS_x was used. Thinning action of NaCl, CH_3COOH and CaS_x was dependent on concentration. The application of rape oil or soya oil 30 g l^{-1} emulsion thinned 'Golden Delicious' and 'Summerred' apples sufficiently, but with significant fruit russeting and without better return bloom. When the same amount of emulsifier (2.4 g l^{-1}) as used in rape oil emulsion 30 g l^{-1} was applied alone, thinning was induced and also fruit russeting and phytotoxicity appeared on 'Summerred'. Phytotoxicity observed after oil emulsion application appeared as leaf wrinkling and stunted growth of young shoots. When CH_3COOH or NaCl were sprayed phytotoxicity was expressed mostly as burning of leaf edges and partly as stunted growth of young leaves; in the case of CaS_x smaller leaves and suppressed growth of young shoots occurred. The phytotoxicity for all treatments appeared a few days after spraying, with the severity gradient from the highest CH_3COOH = NaCl > CaS_x > oil emulsions respectively, and then diminished two month later.

Key words. *Malus domestica* – bloom thinning – fruit quality – organic orchard management

Introduction

After abundant flowering most apple cultivars will retain a heavy set of fruit throughout the growing season resulting in small, poorly coloured, low quality fruit. At the same time a heavy set inhibits flower bud induction and biennial bearing takes place. Chemical fruit thinning efficiently enhances fruit size, quality and return bloom in commercial apple fruit production (Wertheim 1997). When bloom is heavy and conditions prior to bloom are favourable for fruit set, flower thinners or petal fall thinners are routinely applied (Williams and Fallahi 1999; Greene 2002). In intensive apple production where fruit set is usually high, flower thinners are often followed by the post bloom thinners when fruitlet size reaches 8–15 mm diameter (Wertheim 2000). Reducing fruit set is one of the greatest problems in organic apple production. Since no synthetic compounds or growth regulators are allowed in organically grown apples only hand thinning may be used to regulate the crop load. The problem of hand thinning is its high labour cost and the effect is limited to better fruit quality but there is little prevention of biennial bearing (Tromp 2000; Greene 2002). Recently, a few thinning studies were made with potentially acceptable organic compounds. All tested compounds were bloom thinners and possibly based on caustic action, meaning they burn stigmas and styles to prevent pollination and result in accelerated flower abscission (Williams 1994; Fallahi and Willemsen 2002). Lime sulphur (calcium polysulfide), a chemical product permitted in organic apple production under EU legislation, is effective as a bloom thinning agent on apples (Meland 1998; Bertschinger et al. 2000). Mineral oils or vegetable oil emulsions may be used as thinning agents in the organic production (Ju and Duan 1991; Kelderer et al. 1998; Kallsen 2001). Ju et al. (2001) report adequate thinning of 'Delicious' apple and 'Feng Huang' peach when 30 g l^{-1} or 50 g l^{-1} corn oil is applied between prebloom and 20 % full bloom (FB). Bloom application of sodium hydrogen bicarbonate (10 kg ha^{-1}), oxalic acid (20 kg ha^{-1}) and sodium salt (5–15 kg ha^{-1}) results in high 'Pinova' fruit shedding and severe leaf damage, while application of lime sulphur (30 l ha^{-1}) enhances fruit setting (Pfeiffer and Ruess 2002). Partial leaf necrosis, fruit russeting and fruit deformation on 'Delicious', 'Golden Delicious' or 'Elstar' apples occurs when rape oil or soap are applied as flower thinning agents (Strimmer et al. 1997).

Considering the thinning effect and fruit quality in previously published research, the effect of applied caustic agents gives variable results; unfortunately the return

bloom was not estimated precisely. A three year study was established to evaluate the most promising organic flower thinning agents relating on thinning, fruit quality, russeting, phytotoxicity and return bloom, for the russeting sensitive 'Golden Delicious'/M.9, 'Summerred'/M.9 and 'Elstar'/M.9 apple trees.

Materials and Methods

Sodium chloride (NaCl), acetic acid (CH_3COOH), calcium polysulfide (lime sulphur, CaS_x), oil emulsions and dextrin thinning studies

In the field trial, eight ('Golden Delicious'/M.9 in 2002) or ten ('Summerred'/M.9 in 2004) years old apple trees trained as slender spindle (about 2.5 m high and 1.2 m wide) with a density of 3000 trees ha^{-1} were selected according to uniform bloom and growth vigor in the spring. Two trials using a completely randomized block design were established with six ('Golden Delicious') and eight ('Summerred') replications per treatment with a single tree per plot. Spraying of both trials was done in morning during full bloom in sunny weather with temperatures about 18 °C, RH 65 % ('Golden Delicious') and 19 °C, RH 70 % ('Summerred').

The treatments of both trials were as follows:

- Control: no thinning, no spraying
- Hand thin (done just after the June drop time)
- NaCl 10 g l^{-1}, using kitchen salt (99 % pure) dissolved in water
- NaCl 15 g l^{-1}, using kitchen salt (99 % pure) dissolved in water
- CH_3COOH 10 ml l^{-1}, using acetic acid (99 % pure) dissolved in water
- CH_3COOH 30 ml l^{-1}, using acetic acid (99 % pure) dissolved in water
- CaS_x 30 ml l^{-1}, using lime sulphur 18.5 % (KZ Krka, Novo mesto, Slovenia), i.e. 1.0 l of CaS_x (18.5 %) + 5.2 l water
- Rape oil 10 g l^{-1}, using Ogriol (Pinus, Race, Slovenia – 92 % rape oil + 8 % emulsifiers) water suspension
- Rape oil 30 g l^{-1}, using Ogriol water suspension
- Sunflower oil 30 g l^{-1}, sunflower oil (96 % sunflower oil + 4 % emulsifiers) water suspension
- Soya oil 30 g l^{-1}, soya oil (96 % soya oil + 4 % emulsifiers) water suspension
- Dextrin 50 g l^{-1}, dextrin (as 100 % starch - partly hydrolysed) dissolved in water
- Emulsifiers 2.4 g l^{-1}, only on 'Summerred' trial, the same emulsifiers and in the same amount as is added to the rape oil treatment 30 g l^{-1} (i.e. 1.2 g l^{-1} Emulsifier 100 + 1.2 g l^{-1} Emulsifier OCA 30).

Emulsifiers in commercial rape oil agent (Ogriol) are the combination of 4 % (w/w) Emulsifier 100 (Teol, Ljubljana, Slovenia, mixture of non-ionic and anionic tensides) and 4 % (w/w) Emulsifier OCA 30 (Teol, Ljubljana, Slovenia, alkyl (C_{16}–C_{18}) polyethylene glycol ether). A mixture of sunflower oil, as well as soya oil, with emulsifiers was made and a test of suspension stability was done to establish the minimum quantity of emulsifiers needed. Based on the suspension subsistence test a 4 % (w/w) mixture of two emulsifiers (Emulsifier 100 (1 %) + Emulsifier OCA 30 (3 %)) with soya and/or sunflower oil was found to be adequate, i.e. the half amount of emulsifiers as prepared in the rape oil agent Ogriol. Rape oil Ogriol and CaS_x are certified in Slovene organic pest management program which based on European regulation on organic farming (Council regulation EEC No 2092/91). According to this regulation naturally occurring compounds as CH_3COOH or NaCl, similar as plant oil compounds, may be possible to use in organic management in the future.

Concentration response study of CH_3COOH, CaS_x and NaCl

Nine years old 'Golden Delicious'/M.9 apple trees, trained as slender spindle (about 2.5 m high and 1.2 m wide), were chosen according to uniform bloom and growth vigor at spring time 2003. The experimental design was a randomized block with eight replications and a single tree per plots. Trees were sprayed at full bloom, under partly cloudy weather in the morning with temperatures 16–20 °C and RH 50–75 %. The treatments were as follows: Control (no thinning, no spraying), hand thin (done just after the June drop time), CH_3COOH 10 ml l^{-1}, CH_3COOH 30 ml l^{-1}, CH_3COOH 50 ml l^{-1}, CaS_x 10 ml l^{-1}, CaS_x 30 ml l^{-1}, and CaS_x 50 ml l^{-1}. The same chemicals were used as described previously.

In 2004 'Elstar'/M.9 apple trees were used to study the concentration effects of CaS_x, CH_3COOH and NaCl on thinning properties of selected trees. Full flowering seven years old slender spindle trees with the uniform vigour (about 3 m high and 1.5 m wide) were selected. A randomized block design with eight replications and a single tree per plot was used in the field trial. Sprays were applied at full bloom on sunny afternoons with temperatures 15–18 °C and RH 45–60 %. The treatments were as follows: Control (no thinning, no spraying), hand thin (done just after the June drop time), CH_3COOH 10 ml l^{-1}, CH_3COOH 30 ml l^{-1}, CH_3COOH 50 ml l^{-1}, CaS_x 10 ml l^{-1}, CaS_x 30 ml l^{-1}, CaS_x 50 ml l^{-1}, NaCl 10 g l^{-1}, NaCl 15 g l^{-1}, and NaCl 20 g l^{-1}. The same chemicals were used as described previously.

Spraying technique, phytotoxicity, fruit quality, return bloom estimation and statistical analyses

The experiments were conducted on mature apple trees, at the experimental orchard Brdo operated by the Agricultural Institute of Slovenia in continental Slovenia. Sprays were applied with a hand (knapsack) sprayer to the point of drip. About half a litre of water per tree was used to satisfy the spray retention volume of experimental trees, except for 'Elstar' where about 1 l of water per tree was needed. During the experiment, the trees received standard pest and disease management program [integrated production (IP)].

Phytotoxic effect was estimated by observing the whole tree at weekly intervals after spraying. Estimation was focused on the leaves and shoots growth reduction and visual damage of leaves and flowers (stunted growth of young leaves, burning of leaves or petals, leaf surface blistering or wrinkling) using a 1–10 scale, where 1 = no visual damage on the tree, 2 = low phytotoxicity rating (damage difficult to notice), 3 = injuries are visible (farmers would estimate it as low importance), 5 = medium phytotoxicity (injuries severe enough to be unacceptable for farmers) and 10 = dead tree.

At maturity the fruits were harvested, graded into two size classes ('Golden Delicious' and 'Summerred':

<68 mm and >68 mm; for 'Elstar': <70 mm and >70 mm), counted and weighed. Ten fruits per each tree (plot) were randomly sampled from the larger size class to determine maturity and inner fruit quality parameters (starch-iodine score, firmness and percent of soluble solids, expressed as °Brix). Flesh firmness was measured by a digital table penetrometer with 11 mm probe (1 cm^{-2}), and the percentage of soluble solids by hand refractometer (using juice collected during measurement of flesh firmness). The starch-iodine score was measured by immersing apple halves into 0.1 M Iodine solution (1–10; 1= highest starch content, 10 = no starch present). Fruit russeting was assessed by a visual 0–10 scale (0 = no russeting present; 5 = 50 % of the fruit surface is covered by russet; 10 = 100 % of the fruit surface is covered by russet).

Return bloom was assessed visually the following spring at bloom time using the scale 1–10 (1 = no flower clusters present on the trees; 2 = a few flowers per tree; 3,4 = not enough flowering; 5,6,7 = medium flower set; 8,9 = heavy flowering; 10 = abundant flowering, "snowball").

Data was subjected to statistical analyses using the statistical program "Statgraphics 5.0" (STSC, Rockville, USA). Analyses of covariance were performed when the effects of NaCl, CH_3COOH, CaS_x, oil emulsions and dextrin were calculated. The number of flower clusters per tree at the initiation of the experiments was used as a covariate. Duncan's multiple range test P = 0.05 was used to separate the adjusted means between different thinning treatments. For the concentration response studies of CH_3COOH, CaS_x or NaCl, regression analysis was used to evaluate the significance of linear and quadratic trends of each spray.

Results

NaCl, CH_3COOH, CaS_x, oil emulsions and dextrin thinning studies

The full bloom application of NaCl 10 g l^{-1} and 15 g l^{-1} affected no significant thinning of 'Golden Delicious' apples

Table 1. Final fruit number, mean fruit fresh weight and size at harvest, russeting appearance and return bloom of 'Golden Delicious'/M.9 (in 2002) and of 'Summerred'/M.9 (in 2004) apples following various thinning treatments.

Treatments (g l^{-1} or ml l^{-1})	Fruit number $tree^{-1}$	Fruit number 100 flower $clusters^{-1}$	Fruit weight (g)	Fruit number $tree^{-1}$ >68 mm	Russeting of fruit (0–10)[y]	Return bloom (1–10) [z]
'Golden Delicious'/M.9 in 2002						
Control	184 d [x]	76 d	107 a	66 abc	1.7 a	1.3 ab
Hand thin	102 b	43 b	152 e	87 abc	0.8 a	1.2 a
NaCl (10)	141 bcd	58 bcd	116 ab	62 ab	0.6 a	2.4 bc
NaCl (15)	149 bcd	63 bcd	136 bcde	100 bc	1.1 a	2.6 c
CH_3COOH (10)	149 bcd	64 bcd	120 abc	57 a	1.1 a	2.1 abc
CH_3COOH (30)	148 bcd	61 bcd	120 abc	77 abc	0.9 a	1.7 abc
CaS_x (30)	55 a	23 a	189 f	52 a	0.5 a	6.2 d
Rape oil (10)	174 cd	70 cd	127 abcd	103 c	3.0 b	1.2 a
Rape oil (30)	105 b	46 b	149 de	77 abc	5.0 c	1.9 abc
Sunflower oil (30)	131 bc	53 bc	142 cde	99 bc	3.8 b	1.0 a
Soya oil (30)	125 bc	49 bc	130 bcde	77 abc	3.7 b	1.0 a
Dextrin (50)	189 d	78 d	110 a	74 abc	1.4 a	1.4 ab
'Summerred'/M.9 in 2004						
Control	105 c [x]	77 d	97 a	21 a	1.0 a	1.7 abc
Hand thin	65 a	46 a	135 b	26 a	1.3 ab	0.9 a
NaCl (10)	84 abc	61 abcd	110 a	24 a	1.7 bcd	1.8 abc
NaCl (15)	75 ab	54 ab	116 a	25 a	1.4 ab	2.3 abc
CH_3COOH (10)	95 bc	68 bcd	105 a	18 a	1.3 ab	3.0 c
CH_3COOH (30)	73 ab	54 ab	116 a	25 a	1.3 ab	2.9 c
CaS_x (30)	95 bc	69 bcd	106 a	23 a	1.3 ab	2.7 bc
Rape oil (10)	79 ab	59 abcd	116 a	27 a	1.6 abc	1.1 ab
Rape oil (30)	65 a	50 a	112 a	21 a	2.3 de	1.4 abc
Sunflower oil (30)	87 abc	64 abcd	106 a	19 a	2.1 cde	1.4 abc
Soya oil (30)	67 a	48 a	110 a	21 a	1.8 bcd	0.7 a
Dextrin (50)	97 bc	72 cd	112 a	27 a	1.3 ab	2.8 bc
Emulsifiers (2.4)	79 ab	58 abc	112 a	21 a	2.6 e	1.7 abc

[x]Mean separation within column by Duncan's multiple range test, P≤0.05.
[y]0 = no russeting present; 10 = 100 % of fruit is covered by russet at harvest time.
[z]1 = no flowering; 10 = abundant flowering of trees next season.

compared with the control (fruit number tree^{-1}, fruit number 100 flower clusters^{-1}), while mean fruit weight was enhanced by NaCl 15 g l^{-1} (Table 1). NaCl application did not increase fruit russeting rating compared to control. NaCl 15 g l^{-1} significantly improved return bloom of 'Golden Delicious'. Also the application of NaCl 15 g l^{-1} significantly thinned 'Summerred' (Table 1). More russeting appeared in 'Summerred' with NaCl 10 g l^{-1} but the fruit were still marketable and could satisfy commercial standards. The return bloom of 'Summerred' trees was not improved after NaCl applications.

The CH_3COOH 10 ml l^{-1} or 30 ml l^{-1} treatments had no significant effect on final fruit number, fruit size or russeting of 'Golden Delicious' (Table 1). On 'Summerred' CH_3COOH 30 ml l^{-1} induced thinning but, like on 'Golden Delicious', fruit growth or fruit russeting was unaffected (Table 1). Both cultivars displayed an insignificant improvement in flowering the next season after CH_3COOH applications.

CaS_x 30 ml l^{-1} caused the greatest thinning and return bloom on 'Golden Delicious' (Table 1). The rest of the fruit on the tree were larger than 68 mm with essentially no russeting. When CaS_x 30 ml l^{-1} was applied to 'Summerred' trees insignificant thinning, fruit growth, russeting or return bloom occurred (Table 1).

The application of three different oil emulsions 30 g l^{-1} effectively thinned 'Golden Delicious' trees to the hand thinned level (Table 1). The rape oil 10 g l^{-1} treatment was not effective. There was no thinning efficacy difference between rape oil 30 g l^{-1}, sunflower oil 30 g l^{-1} or soya oil 30 g l^{-1} emulsions. Mean fruit weights were enhanced but russeting on fruit surface was increased compared to control apples. Similarly, adequate thinning of 'Summerred' apples occurred when rape oil 30 g l^{-1} or soya oil 30 g l^{-1} emulsions were sprayed on flowers, while sunflower oil 30 g l^{-1} emulsion did not thin sufficiently (Table 1). For oil emulsions fruit growth did not follow the thinning effect successfully, and, more fruit russeting appeared but not as severe as on 'Golden Delicious'. Return bloom was not enhanced in 'Golden Delicious' or 'Summerred' apple trees by these treatments.

Dextrin, a partly hydrolysed starch, had no effect on the thinning properties of 'Golden Delicious' or 'Summerred' apple trees (Table 1).

The application of emulsifiers alone 2.4 g l^{-1} (i.e. in the same amount as used when a factory-prepared rape oil emulsion 30 g l^{-1} was sprayed) thinned 'Summerred' to the same level as the rape oil emulsion 10 g l^{-1} treatment (Table 1). The fruit were no larger and a relatively strong russet covered the apples. Return bloom was not influenced.

The phytotoxic severity and recovery time on 'Summerred' apple trees was estimated at weekly intervals after spraying the thinning agents (Fig. 1). Above all, stunted growth of young leaves and burning of leaf edges and petals was estimated as a phytotoxic effect of the applied chemicals. The strongest phytotoxic effect was observed a week after the application of CH_3COOH 30 ml l^{-1} and NaCl 15 g l^{-1} and continued nearly a month after that. Six weeks after spraying, the effect of CH_3COOH and NaCl became less pronounced; from the growers view probably more acceptable compared to the first month aspect. After eleven weeks, phytoxicity was still observed; however, trees with this low damage level looked to be general healthy, with just a few stunted leaves or brown leaf edges could be seen. A week after CaS_x 30 ml l^{-1} application phytotoxicity was smaller compared with CH_3COOH 30 ml l^{-1} and NaCl 15 g l^{-1} treatments. The phytotoxic effect of CaS_x 30 ml l^{-1} was reduced to the minimum level seven weeks later. It should be noted that the phytotoxic response on CaS_x applications was different compared to CH_3COOH and NaCl treatments. Stunted growth of young leaves was mainly observed on CaS_x treated crowns while burning of leaf edges mainly stood out when CH_3COOH and NaCl was applied. Residues of CaS_x spray caused whitening of leaves and could be observed more then one month later, enhancing the appearance of phytotoxicity. Also, rape oil 30 g l^{-1} treatment induced a significant but less pronounced phytotoxic effect compared with CH_3COOH, NaCl or CaS_x application (Fig. 1). Spraying of soya oil 30 g l^{-1} or sunflower oil 30 g l^{-1} emulsions resulted in similar phytotoxicity as the application of rape oil 30 g l^{-1} while dextrin had no phytotoxic effect on 'Summerred' trees (data not presented). Phytotoxicity after oil emulsion applications was expressed as wrinkled leaf or stunted growth of leaves but not as burning of leaf edges. The application of emulsifiers 2.4 g l^{-1} alone caused similar phytotoxic effect as rape oil 30 g l^{-1} in the first three weeks after the application. After that the emulsifier spray decreased its phytotoxic effect much more quickly while leaf wrinkling was still present on rape oil treated trees for another two weeks. At lower concentrations of CH_3COOH (10 ml l^{-1}), NaCl (10 g l^{-1}) or rape oil (10 g l^{-1}) emulsions applied on 'Summerred', phytotoxicity was hardly noticeable compared to their higher concentrations (data not shown).

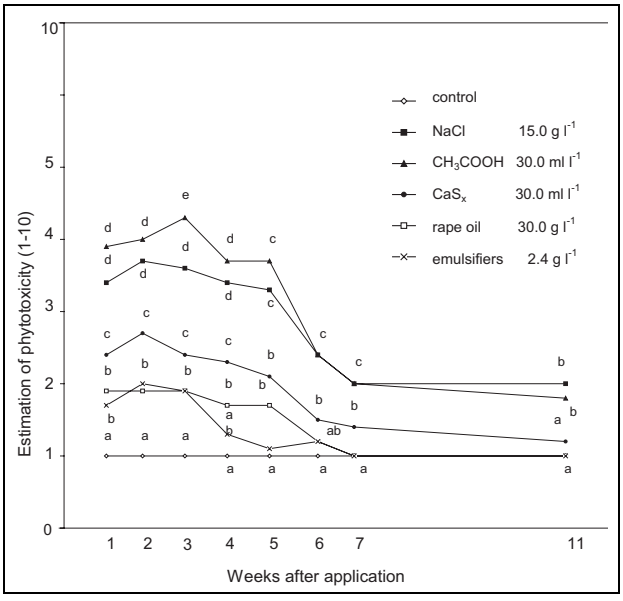


Fig. 1. Estimation of phytotoxicity in weekly intervals of 'Summerred'/M.9 apples following various thinning treatments in 2004. Estimation scale 1–10 was used; 1= no visual sign on the leaves, flowers or growth tips, 3 = injuries are visible but estimated as low importance, 5 = medium phytotoxicity severe enough to be unacceptable for growers, 10 = dead tree. Letters denote mean separation within each date of evaluation by Duncan's multiple range tests (P≤0.05).

Concentration response and fruit quality study after CH_3COOH, CaS_x and NaCl application

'Golden Delicious' and 'Elstar' apple trees were used to study the effect of high and low concentrations of acetic acid, lime sulphur and sodium chloride on phytotoxicity, thinning, fruit growth and return bloom.

A significantly negative linear regression trends between the CH_3COOH concentrations and fruit number per 100 flower clusters were found for 'Golden Delicious' (Table 2) and 'Elstar' apple trees (Table 3). The mean fruit weight was enhanced with increased CH_3COOH concentrations on 'Golden Delicious' (NS) while on 'Elstar' fruit weight increase was significant and rose with thinning intensity. Very dry summer in 2003 inhibited normal 'Golden Delicious' fruit growth and the share of bigger size fruit (>68 mm) was small and did not raise significantly with the thinning effect. No additional russeting appeared on 'Golden Delicious' and 'Elstar' apples, while the return bloom was significantly enhanced on both cultivars when the concentrations of CH_3COOH were increasing.

The response to increasing concentrations of CaS_x on 'Golden Delicious' and 'Elstar' was quite similar to CH_3COOH. Both cultivars showed higher thinning when stronger concentrations of CaS_x were used (Table 2, 3). Also, the mean fruit weights of both cultivars increased as CaS_x concentrations increased. On 'Elstar' over thinning could be estimated when CaS_x 30 ml l^{-1} or 50 ml l^{-1} applications decreased the number of (large) fruit >70 mm (53 or 44 respectively) below the level of hand thinned trees (75) (Table 3). No effect on russeting was found at harvest for both cultivars. Also both cultivars responded positively for return bloom when higher CaS_x concentrations were applied.

For NaCl concentration study only 'Elstar' was available (Table 3). As higher concentrations of NaCl were used, the stronger thinning occurred with better fruit growth. Similar to CaS_x applications, over thinning could be noticed in the case of NaCl 20 g l^{-1} application since the number of large fruit per tree (42) decreased remarkably compared with hand thinned trees (75). A significant increase in russeting was recorded but was not judged to be severe. When increasing concentrations of NaCl were applied on 'Elstar' a significant linear improvement of return bloom was documented.

At harvest analyses of inner fruit characteristics were assessed for 'Elstar' fruit samples when the highest concentrations of CH_3COOH, CaS_x and NaCl were applied (Table 4). Higher content of soluble solids was found when CaS_x 50 ml l^{-1} and NaCl 20 g l^{-1} were applied. Since these two treatments actually induced over thinning, the small number of fruit per tree could be the reason for better soluble solid content. STOPAR et al. (2002) proved higher soluble solids content, higher starch content and better flesh firmness in the fruit of low cropping 'Jonagold' apple trees. The application of thinning agents had no influence on the starch content while the fruit flesh was lightly firmer on heavily thinned NaCl 20 g l^{-1} treated trees.

Discussion

Literature showing CaS_x thinning results is contradictory as are the results from this trials. In France and Switzerland several chemical agents suitable for organic farming were tested and lime sulphur was found as one of the most promising (BERTSCHINGER et al. 2000; WARLOP 2002). In a three cultivar trial, MELAND (1998) found CaS_x 50 ml l^{-1} only thinned 'Aroma' effectively. In our experiment the concentration studies demonstrated concentration dependent CaS_x action on 'Golden Delicious' and 'El-

Table 2. Effect of CH_3COOH and CaS_x on phytotoxicity one week after spraying, fruit thinning, mean fruit size, russeting and return bloom of 'Golden Delicious'/M.9 apple trees, 2003.

Treatments (ml l^{-1})	Phytotoxicity (1–10) [x]	Fruit number 100 flower clusters^{-1}	Fruit weight (g)	Fruit number tree^{-1} >68 mm	Russeting of fruit (0–10)[y]	Return bloom (1–10)[z]
Control	1.5	116	65	13	0.1	1.6
Hand thin	1.8	55	95	43	0.1	1.5
CH_3COOH (10)	1.6	133	59	5	0.3	2.3
CH_3COOH (30)	2.8	114	69	14	0.1	2.3
CH_3COOH (50)	3.4	96	71	6	0.1	2.9
CaS_x (10)	2.3	99	75	15	0.1	2.5
CaS_x (30)	3.8	89	86	16	0.0	2.8
CaS_x (50)	4.8	85	90	40	0.1	3.4
Significance						
CH_3COOH	L***	L*	NS	NS	NS	L**
CaS_x	L***	L**	L**	L*	NS	L**

[x]Estimation on May 7th; 1 = no visual damage; 5 = medium phytotoxicity; 10 = dead tree.
[y]0 = no russeting present; 10 = 100% of fruit is covered by russet at harvest time.
[z]1 = no flowering; 10 = abundant flowering of trees next season.
NS,*,**,*** Non significant or significant linear (L) regression trends at P≤0.05, ≤0.01, or ≤0.001 respectively.

star' fruit abscission. However, differences existed in the severity of thinning when CaS_x 30 ml l^{-1} applications were done in four trials. On 'Summerred' not enough thinning was induced while on 'Golden Delicious' (year 2003) moderate fruit abscission was found, and a very strong thinning was observed on 'Golden Delicious' (year 2002) and on 'Elstar'. Whenever adequate thinning occurred it enhanced fruit growth and return bloom. No fruit russeting was induced by CaS_x treatments. When HOBL et al. (2003) evaluated the apple scab control effectiveness of CaS_x 20 g l^{-1} he concluded that organic growers would be forced to find a balance between good efficacy against scab and the phytotoxic effect of CaS_x which manifests as reduced leaf size. These experiments show CaS_x 30 ml l^{-1} phytotoxicity appears as stunted growth of young leaves and shoots a few days after CaS_x spraying and lasted about two month. Similar phytotoxic appearance and severity, as after CaS_x 30 ml l^{-1} on 'Summerred' (Fig. 1), was observed a week after the application of CaS_x 10 ml l^{-1} on 'Golden Delicious' and 30 ml l^{-1} or 50 ml l^{-1} on 'Elstar' (Table 2, 3). It can be concluded that CaS_x is a possible thinning agent for organic apple trees but inconsistent thinning occurred after its application and also that some phytotoxicity is expected with 10 ml l^{-1} or stronger concentrations.

Different uses of plant oil emulsions were mentioned for fruit growing practice, i.e. to protect the plant tissue from frost injury, as insecticides, to delay bloom or thin fruits (JU and DUAN 1991; STRIMMER et al. 1997; PENDERGRASS et al. 2000). Bloom thinning of 'Delicious' apple was effective by corn oil emulsion 30 g l^{-1} to 50 g l^{-1} between prebloom and 20 % full bloom; they were less effective when applied at 50 % full bloom or later; the effectiveness of oil treatments depended on concentration too (JU et al. 2001). Also, STRIMMER et al. (1997) reported satisfactory apple thinning by rape oil 20 g l^{-1} applied during full bloom. In the present experiments the full bloom application of rape oil emulsion 10 g l^{-1} did not thin sufficiently, but rape oil 30 g l^{-1} and soya oil 30 g l^{-1} emulsions thinned 'Golden Delicious' and 'Summerred' trees adequately and relatively consistent. Also sunflower oil 30 g l^{-1} thinned 'Golden Delicious' trees significantly. Better fruit growth was induced on 'Golden Delicious' thinned trees while the return bloom of both cultivars was not enhanced. All oil thinning agents induced low or moderate fruit russeting on both cultivars. Also, STRIMMER et al. (1997) and KELDERER et al. (1998) observed apple fruit russeting, fruit deformation and partial leaf necrosis following the application of plant oils. In the presented work the application of oil emulsion 30 g l^{-1} induced leaf wrinkling and stunted growth of young shoots and was less pronounced compared to CH_3COOH, NaCl or CaS_x.

It was necessary to use emulsifiers with the oil applications because oils alone would separate when mixed with water. JU et al. (2001) used a 10 % emulsifier in corn oil before dissolving in water for spraying purpose. Presented experimental rape oil agent was factory prepared with 8 % emulsifiers. When the same amount of emulsifiers was sprayed alone without oil (2.4 g l^{-1} emulsifier water solution), thinning occurred on 'Summerred' trees and also russeting and phytotoxicity was observed to a similar extent as oil treatments. It could be concluded from these results that the existence of emulsifiers in oil agents is one of the main causes of fruit thinning and fruit russeting when plant oil emulsions are applied. In addition, it should be mentioned that the factory prepared

Table 3. Effect of CH_3COOH, CaS_x and NaCl on phytotoxicity one week after spraying, fruit thinning, mean fruit size, russeting and return bloom of 'Elstar'/M.9 apple trees, 2004.

Treatments (ml l^{-1} or g l^{-1})	Phytotoxicity (1–10) [x]	Fruit number 100 flower clusters^{-1}	Fruit weight (g)	Fruit number tree^{-1} >70 mm	Russeting of fruit (0–10)[y]	Return bloom (1–10)[z]
Control	1.0	64	126	71	1.0	2.5
Hand thin	1.0	57	142	75	1.3	3.0
CH_3COOH (10)	1.8	71	132	76	0.9	2.4
CH_3COOH (30)	3.6	53	137	60	0.9	4.4
CH_3COOH (50)	4.4	43	150	64	0.9	5.1
CaS_x (10)	2.0	65	146	84	0.9	4.5
CaS_x (30)	2.3	33	169	53	0.9	6.9
CaS_x (50)	2.5	27	171	44	1.0	7.6
NaCl (10)	2.0	45	147	68	1.1	6.4
NaCl (15)	2.0	41	147	59	1.3	6.5
NaCl (20)	2.6	28	163	42	1.4	8.2
Significance						
CH_3COOH	L***	L**	L**	NS	NS	L***
CaS_x	L*** Q**	L***	L*** Q**	L**	NS	L*** Q*
NaCl	L***	L***	L***	L**	L*	L***

[x]Estimation on May 11th 2004; 1 = no visual damage; 5 = medium phytotoxicity; 10 = dead tree.
[y]0 = no russeting present; 10 = 100% of fruit is covered by russet at harvest time.
[z]1 = no flowering; 10 = abundant flowering of trees next season.
[NS,*,**,***] Non significant or significant linear (L) or quadratic (Q) regression trends at P≤0.05, ≤0.01, or ≤0.001 respectively.

Table 4. Analyses of variance for 'Elstar' fruit flesh characteristics at harvest following the strongest thinning treatments in 2004.

Treatments (ml l^{-1} or g l^{-1})	Soluble solids (°Brix)	Starch iodine pattern (1–10)[y]	Flesh firmness (N)
Control	11.4 ab [x]	3.2 b	63 a
Hand thin	11.0 a	2.5 a	63 a
CH_3COOH (50)	11.7 b	3.3 b	64 a
CaS_x (50)	12.3 c	3.5 b	63 a
NaCl (20)	12.3 c	3.0 ab	66 b

[x]Mean separation within column by Duncan's multiple range test, $P \leq 0.05$.
[y]1 = highest starch content; 10 = no starch present

rape oil agent consisted of 92 % rape oil and 8 % emulsifiers while the soya and sunflower oil mixture contained just 4 % emulsifiers. A relatively successful thinning by sunflower and soya oil emulsion 30 g l^{-1} indicate half the amount of emulsifiers in oil mixtures are enough to prepare an adequate oil thinning agent. Also, additional experiments with a range of different emulsifiers alone or in combination with oils should be performed to find a possible thinning agent that has a better thinning response and induces less russeting.

Few references on NaCl or CH_3COOH thinning are available. Pfeiffer and Ruess (2002) report on satisfactory thinning and severe leaf damage when NaCl 15 kg ha^{-1} was sprayed on 'Pinova' apple trees at full bloom stage. Presented experiments shown that 15 g l^{-1} NaCl application induce a light thinning in 'Golden Delicious' (NS) and in 'Summerred'. When NaCl 10 g l^{-1}, 15 g l^{-1} or 20 g l^{-1} was used on 'Elstar' thinning was much stronger and rising with concentration, also the return bloom. Taking into account that 'Elstar' is a difficult cultivar to thin; a non-consistent thinning response was observed. Also, light fruit russeting appeared after NaCl application on 'Elstar' and 'Summerred' apples. The CH_3COOH 30 ml l^{-1} application was found to be a poor thinning agent and, consequently, a lightly enhanced fruit growth and slightly better return bloom resulted. However, CH_3COOH application did not induce fruit russeting. When CH_3COOH 30 ml l^{-1} or NaCl 15 g l^{-1} were sprayed, the greatest phytotoxic effect occurred (compared to other thinners) and was evident mostly as burning of leaf edges and partly as stunted growth of young leaves. The phytotoxicity appeared a few days after spraying and lasted eleven weeks.

Before recommendation on the above tested chemicals as organic chemical thinning agents can be made, more experiments should be conducted to clarify the thinning response and possible phytotoxicity damage to other apple cultivars. Also, little is known about environmental influence (such as temperature or air humidity at the time of application) on the thinning action, and which may result in the inconsistency of thinning or fruit russeting after the application of the thinners tested.

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Addresses of authors: Matej Stopar, Agricultural Institute of Slovenia, Hacquetova 17, 1000 Ljubljana, Slovenia,
e-mail: matej.stopar@kis.si