Journal American Pomological Society 56(3):149-155 2002

Benzyladenine and Other Thinning Agents for Pear cv. 'Clara Frijs'

M.G. BERTELSEN[1]

Abstract

Various chemical thinning treatments were applied to 'Clara Frijs' pear trees. 1-naphthylacetic acid (NAA) sprayed with twice the normal concentration (45mg/L) did not reduce fruit set significantly, but fruit size distribution was improved. ATS was applied in concentrations of 0.5, 1 and 2%, and only the two highest concentrations reduced fruit set. Leaf damage was pronounced after 1 and 2% ATS application resulting in no improvement in fruit size and severe reductions in return bloom. A mixture of NAA and urea had no thinning effect. 6-Benzyladenine (BA) proved to be the most efficient thinner of 'Clara Frijs' when used in rates of 100 mg/L, fruit set was reduced and the number of large fruit was improved to the same extent as was obtained with the hand-thin treatment. Return bloom was significantly improved compared to all other treatments including hand thinning.

Introduction

In pear production, chemical thinning is not as widely used, as is the case in apple production. Pear flowers are more prone to frost damage and insufficient pollination, and several of the popular pear cultivars are not very fertile. However, cultivars like 'Conference' and 'Bon Chrétien Williams' often require thinning to reach a marketable size as do many local cultivars grown in the Scandinavian countries. Chemical thinning of pear is done primarily using NAA (or its amide, naphthaleneacetamide) (10,16,22,26). NAA is used from full bloom onwards and in some cases as late as June drop (14). Varying sensitivity to NAA is exhibited and recommended rates are cultivar specific (16,26). Thinning effectiveness is not assured when using NAA, and a reduced cropload is not always accompanied by a concomitant increase in fruit size (26). NAA is temperature dependent rendering it an unreliable thinning agent where spring temperatures are low and variable (25). Alternatives to NAA are needed for thinning of pears in cool climates.

One such alternative may be 6-benzyladenine (BA), which has been tested as a thinning agent on apples since the early 1980's (21). BA is a post-bloom thinner, successfully applied when fruitlets are between 4-17 mm (7). Results with apple have predominantly been positive, and the thinning effectiveness seems more consistent than with NAA (7, 8). However, a significant proportion of the trials show little or no effect of BA (8,9,20 . When effective, fruit size was increased, and in some experiments even beyond what can be attributed to the thinning effect alone (12,27). A higher cell number has been found in BA-treated fruit, while cell size remained unaffected, indicating that BA improved fruit size by stimulation cell division (21). BA positively influenced return bloom and an increased cold tolerance on the bud may be obtained (21).

Several new chemical thinning candidates are foliar fertilizers. Urea and calcium nitrate have been shown to thin both apples and 'Conference' (13,14). However, more caution is called for when thinning pears, because foliar fertilizers frequently cause phytotoxicity, and pear leaves appear to be more sensitive than apple leaves (14). Another foliar fertilizer that has gained interest in recent years is ammonium thiosulphate (ATS). ATS was first tested as a flower thinner on peach by Byers and Lyons in 1984. Since then, ATS has proved to be an efficient thinner of apples, peaches and plums (3,24). ATS is effective on flowers that have reached an-

[1]Department of Horticulture, Danish Institute of Agricultural Sciences, Research Centre Aarslev, P.O. Box 102, Dk-5792 Aarslev, Denmark.

thesis at time of application, and it is believed that it acts by interfering with the fertilization process (5,24).

The objective of the present work was to evaluate new thinning compounds as well as high rates of NAA on fruit set, yield, fruit size and return bloom of pear. The testing was done on the cultivar 'Clara Frijs' a common pear cultivar in Scandinavia. 'Clara Frijs' is hard to thin and is prone to over-cropping and biannual bearing.

Materials and Methods

Experiment 1. The trial was conducted in 1997 in a commercial orchard. Trees used were 7-year old 'Clara Frijs' trees on quince A rootstocks at a spacing of 2.25 x 4m. All trees were trained as spindles and all exhibited a moderate growth. The 150 experimental trees were blocked according to row and terrain into 15 blocks of 10 treatments, and treatments were randomized within a complete-block design. Flower cluster density (FD) was calculated from total cluster number on the tree and trunk cross-sectional area (TCA), as measured at 25 cm above the soil surface (1). Most of the trees flowered prolifically and all had a minimum FD of 4.0 clusters/cm^2 TCA. Trees had an average TCA of 46.9 cm^2 Yield, number of fruits per tree, and fruit-size distribution of all trees in the trial were determined by commercial grading (MAF RODA Electronic sizer) at harvest. The fruits were graded into six categories: 1) fruits <50mm, 2) fruits 50-55 mm, 3) fruits 55-60 mm, 4) fruits 60-65 mm 5) fruits 65-70 mm and 6) fruits 70-75 mm. The number of harvested fruit per tree was used to determine final fruit set, fruit density (no. of fruits per TCA), and average fruit size on the tree. In the spring of 1998, return bloom was determined by counting all flower clusters on the trees that had been moderately pruned beforehand. Trunk diameter was measured again and the flower density of the return bloom calculated.

All chemical treatments were applied as dilute sprays to runoff with a handgun sprayer using approximately 0,6 L per tree for flower thinners and 1 L (1500 L/ha) for fruitlet thinning.

ATS was applied at rates of 5, 10, and 20 g/L a.i., all combined with 0.1% Tween 20 as a wetting agent. The trees were treated at full bloom on an overcast day with a high temperature of 18 C and 85% RH. Four hours after application, it started to rain, and 4 mm precipitation was recorded. NAA, at twice the standard concentration (45 mg/L a.i.), was applied at petal fall, on a day when temperatures ranged from 9 C in the morning to a max of 16 C. Pommit, a Polish thinning agent, consisting of a mixture of NAA (80 g/L a.i.) and urea (30 g/L a.i.), was applied at concentrations of 16 mg/L and 32 mg/L NAA on the the same day as the the pure NAA treatment. Warmer weather with a max temperature of 25 C was recorded when Paturyl 10 WSC containing 10% a.i. BA was sprayed at 12 mm fruit size at concentrations of 50 and 100 mg/L + 0.1% Tween 20. Both an untreated control and a hand-thinned treatment were included in the trial. Hand thinning was done at the end of the June-drop period when fruit diameter was about 30mm.

Experiment 2. The same year, a second experiment was conducted with 'Clara Frijs' in an other commercial orchard. Single whole-tree plots in a randomized complete-block design with 14 replicates were used. The trees were 8-year-old spindles on Quince A with an average TCA of 49 cm^2. All trees had been pruned heavily just prior to flowering. All trees flowered moderately with an average of 2.5 flower clusters per cm^2 TCA. NAA at double the standard dosage (45 mg/L) was sprayed at either full bloom or petal fall, on both occasions the weather was cool as was the whole period from full bloom until well after petal fall. Spray application and data collection was similar to experiment 1.

All data was subjected to analysis of variance using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS Institute, Cary, NC).

Results

The number of flower clusters did not differ between controls and the chemical treatments, but differences in flower density proved significant (Table 1). FD with-

Table 1. Flower density of 'Clara Frijs' pear trees and the correlation coefficients between flower density and fruit set in a 1997 chemical thinning trial (Experiment 1).

Treatment	Flower cluster per tree	Flower density[Z]	Correlation coefficients between fruit set and fruit density
1. Control	309	6.3	-0.79***
2. Hand-thin	307	6.6	-0.65**
3. ATS 5 g/L	331	7.4	-0.72**
4. ATS 10 g/L	335	7.2	-0.14ns
5. ATS 20 g/L	308	6.5	-0.66*
6. Pommit[Y]0.02%	307	6.3	-0.52*
7. Pommit[Y]0.04%	245	5.4	-0.75**
8. NAA 45 mg/L	318	7.1	-0.71**
9. BA 50 mg/L	298	6.7	-0.63**
10. BA 100 mg/L	329	7.2	-0.82***
Treatment	ns	*	
$LSD_{0.05}$		1.4	

ns,*,**,*** Nonsignificant or significant at P=0.05, 0.01 or 0.001, respectively.

[Y]0.02% Pommit corresponds to 16 mg/L NAA and 6mg/L urea, 0.04% to 32 mg/L NAA and 12 mg/L urea.

[Z]Flower clusters/mc² TCA

in a treatment varied from 4 to10 clusters/cm² TCA and linear regression showed fruit set to be significantly dependent on flower density (Table 1). It was therefore decided to adjust fruit set and cropping effects for inequalities of FD, by employing FD as a covariate, and when significant, means were adjusted accordingly, similar to (19).

Hand-thin. An average of 2.0 fruit per TCA was removed in the hand-thin treatment resulting in a final fruit set of 67% of the control (Table 2). Average fruit size and the proportion of medium and large fruits were increased in comparison to the unthinned control, but total yield was reduced because of significantly fewer small fruit (Figure 1). Hand thinning did not affect return bloom (Table 3).

ATS. Both the 1 and 2% ATS treatments caused unacceptable damage to the primary spur leaves. Practically all leaves unfolded at time of application showed leaf burn and necrotic spots. Leaves developing after application were not affected. Damage from the lowest concentration (0.5 g/L) was insignificant, as was the thinning effect. The two higher concentrations both reduced fruit set relative to the unthinned control, but neither caused thinning comparable to what was achieved by hand thinning (Table 2).

Average fruit size and number of large fruit were not positively influenced by the

Table 2. Influence of thinning treatments on fruit set and fruit and crop size of 'Clara Frijs' pears in 1997, Denmark (Experiment 1).

	Fruit set	Yield Data				Size distribution (kg/tree)		
Treatment	No. fruits/ 100 clusters	Fruits per tree	Fruit density (No./cm²TCA)	Kg/tree	Mean fruit weight	Small <55mm	Medium 55-65 mm	Large 65-80 mm
1. Control	105	327	6.7	34	102	10.3	20.0	3.3
2. Hand-thin	70	214	4.6	28	129	1.5	17.1	9.0
3. ATS 5 g/L	97	296	6.5	30	105	8.6	18.4	3.4
4. ATS 10 g/L	88	293	5.9	29	104	10.4	14.9	3.2
5. ATS 20 g/L	83	250	5.3	27	111	6.3	16.3	4.8
6. Pommit[Y] 0.02%	95	298	6.3	31	106	8.4	19.6	3.3
7. Pommit[X] 0.04%	90	247	5.7	27	105	7.2	16.9	2.8
8. NAA 45 mg/L	92	272	6.0	30	115	5.3	19.1	6.0
9. BA 50 mg/L	90	258	5.7	29	116	5.0	19.4	5.1
10. BA 100 mg/L	85	249	5.3	30	121	3.3	19.4	7.1
Treatment	*	***	***	*	***	***	*	***
FD covariate	***	ns	***	ns	***	***	*	***
$LSD_{0.00=5}$	13	51	0.9	4.4	9	3.1	3.5	2.1

ns,*,**,*** Nonsignificant or significant at P=0.05, 0.01 or 0.001 respectively.

[Y] dosage corresponds to 16 mg/L NAA and 6 mg/L urea.

[X] dosage corresponds to 32 mg/L NAA and 12 mg/L urea.

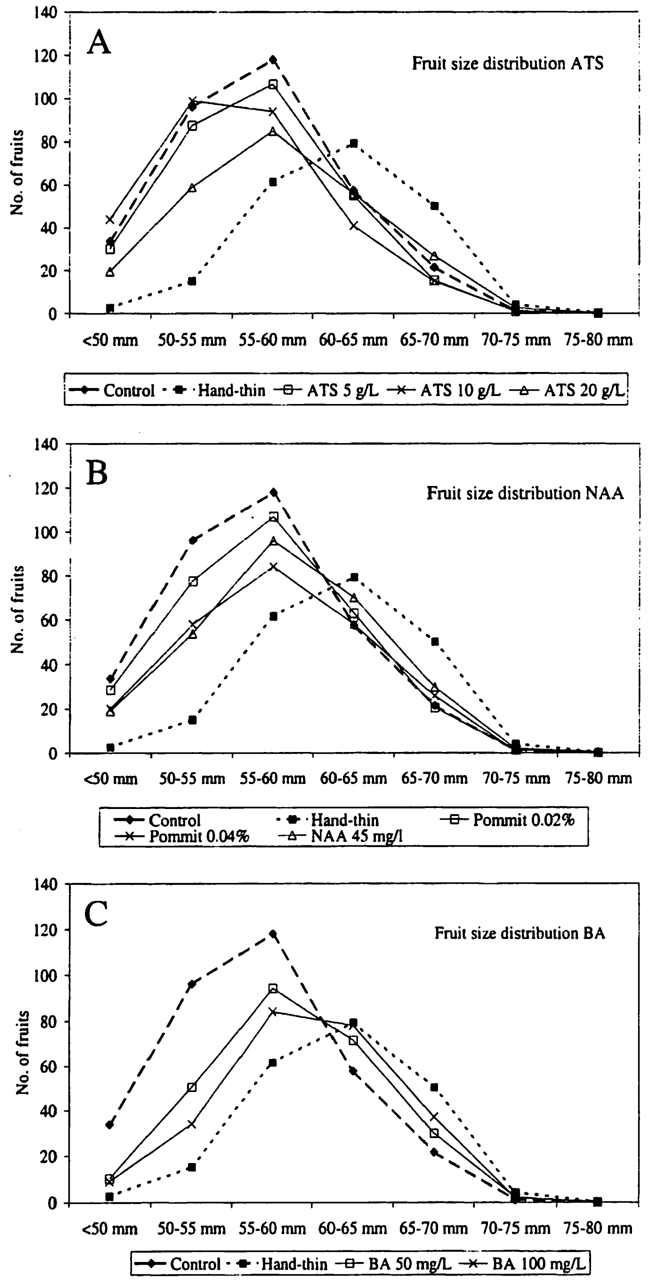

Figure 1. Fruit size distribution on 'Clara Frijs' trees thinned with: A. ATS applied at either 5, 10 or 20 g/L at full bloom. B. NAA at 45 mg/L or a mixture of NAA and urea in concentrations corresponding to 16 and 32 mg/L NAA applied at petal fall. C. BA at 50 or 100 mg/L applied at 12 mm fruit size.

Table 3. Influence of thinning treatments on return bloom (1998) of 'Clara Frijs' pear (Experiment 1).

Treatment	Flower clusters per tree	Flower density[Z]
1. Control	99	1.7
2. Hand-thin	121	2.2
3. ATS 5 g/L	117	2.6
4. ATS 10 g/L	21	0.4
5. ATS 20 g/L	24	0.5
6. Pommit[Y] 0.02%	120	2.2
7. Pommit[X] 0.04%	123	2.5
8. NAA 45 mg/L	124	2.5
9. BA 50 mg/L	141	3.0
10. BA 100 mg/L	179	3.6
Treatment	***	***
$LSD_{0.05}$	40	0.8

Significant at P= 0.001.
Y dosage corresponds to 16 mg/L NAA and 6 mg/L urea.
X dosage corresponds to 32 mg/L NAA and 12 mg/L urea.
Z Flower culsters/cm²TCA.

reduced cropload (Table 2), but the 2% ATS reduced the amount of small fruits relative to both the control and the other ATS treatments (Figure 1). The 1 and 2% ATS treatments nearly eliminated return bloom, whereas no negative effect on return bloom was caused by 0.5% ATS (Table 3).

NAA and Pommit. A significant effect of NAA on fruit set and fruit density could not be shown, but average fruit size and the amount of fruit larger than 65 mm were increased after NAA application (Table 2, Figure 1). The NAA treatment fell just short of significantly increasing return bloom at P=0.05. Neither of the two Pommit treatments reduced fruit set nor did they improve average fruit size, fruit size distribution, or return bloom (Table 3). The highest concentration of Pommit reduced fruit density, but that is likely to have been a side effect of a low initial flower density rather than a genuine thinning effect (Tables 1 and 2).

In experiment 2, the need for thinning was less pronounced as could be seen from the fact that only an average of 0.6 fruits/cm^2 TCA were removed from the hand thinned control (Table 4). Fruit set in this experiment was not significantly affected by the NAA treatments, but the fruit density was significantly lower on the NAA-treated trees.

Both NAA treatments reduced the total yield. Conversely, the number of small and intermediate sized fruits were decreased and average fruit size increased, but an increase in the amount of large fruit was not significant (Table 4). No difference in thinning response could be ascribed to time of application.

BA. Both BA treatments reduced fruit set and fruit density and increased average fruit size compared with the control. The highest concentration of BA was the treatment best capable of shifting the fruit size distribution towards the result achieved by hand thinning (Figure 1). In the case of the 50 mg/L treatment, the shift to a higher mean fruit weight was mainly a consequence of a reduced number of small fruit (Table 2).

Return bloom was significantly higher on trees treated with BA at 100 mg/L than

Table 4. Effect of NAA applied at full bloom (FB) or petal fall (PF) on fruit set, yield and fruit size distribution of 'Clara Frijs' pear (Experiment 2).

Treatment	Fruit set			Yield		Size distribution (No. of fruits/tree)		
	Flower density[Z]	No. Fruits/ 100 clusters	Fruit density[Z]	Kg/tree	Mean fruit wt (g)	Small <50-55 mm	Medium 55-65 mm	Large 65-80 mm
1. Control	2.4	154	3.5	22	127	18	122	34
2. Hand-thin	2.4	138	3.0	18	132	9	92	36
3. NAA 45 mg/L, FB	2.3	134	2.7	17	139	8	73	40
4. NAA 45 mg/L, PF	2.2	140	2.9	18	138	8	79	45
Treatment	ns	ns	*	***	*	*	**	ns
$LSD_{0.05}$	-	-	0.5	3	10	0.7	3.6	-

ns,*,**,*** Nonsignificant or significant at P=0.05, 0.01 or 0.001, respectively.
Z No. of flower clusters or fruit/cm²TCA.

on trees of all other treatments (Table 3). Also the lower BA application rate increased return bloom, but the effect was not as pronounced and was only significant compared to the control and the 1 and 2% ATS treatments.

Discussion

ATS at 1 and 2% reduced fruit set, but in contrast to results on apple (1,3) no concurrent fruit-size response was recorded. This, as well as the adverse effect on return bloom, is a likely consequence of severely damaged and dysfunctional spur leaves. It is known that the removal of spur leaves soon after bloom inhibits flower bud formation in pear (15). Leaf damage after the use of ATS has been recorded in apple, when concentrations higher than 1% were used (1,17). Preliminary tests show that leaf damage can be increased by high humidity and prolonged drying (1). The damage may also have been intensified by the use of a handgun sprayer where the wetting is more thorough and ATS activity generally higher than when the same rates are applied with an air-blast sprayer (6). Adding a wetting agent is also likely to have increased the problem. After the damage became obvious a test was performed applying ATS 1% with or without Tween 20 to a couple of trees, and damage was found to be less severe where no wetting agent was applied. Phytoxicity caused by wetting agents when used for thinning peach at full bloom has previously been reported (4). More trials aimed at reducing phytotoxicity are needed before the thinning potential of ATS can be exploited in 'Clara Frijs' pear.

NAA has for 3 decades been used on 'Clara Frijs', and numerous trials have shown the cultivar to be NAA tolerant (16,23) much more so than 'Conference' and 'Fondante de Charneu' for example. Fruit set in 'Clara Frijs' has also been found to decrease linearly in response to increasing concentrations of NAA (23), and fruit set reduction of up to 50% has previously been recorded after the use of 45 mg/L NAA (16). The high tolerance to NAA was confirmed in the present experiments. where the 45 mg/L application rate was not as effective as found by Ohlers (1966). The cool weather during the full-bloom period is likely to be the cause, indicating that even a doubling of the standard concentration (22.5 mg/L) is not enough to compensate for adverse weather conditions. None of the experiments showed reduction in fruit size as found in some apple trials (11,18) instead fruit size was increased in concurrence to fruit-density reduction.

Not much information is available on Pommit, but NAA is likely to be the most active part of the mixture. The concentrations used equaled 16 and 32mg/L NAA respectively, corresponding to applications rates close to what is normally recommended for use on 'Clara Frijs'. No thinning was achieved by either of the Pommit treatments, indicating that the NAA concentration was too low to be effective under the prevailing weather conditions. and no benefit was gained from the addition of urea.

BA was applied under optimal weather conditions. As is the case with NAA, BA requires minimum temperatures in the vicinity of 18 degrees to be effective (2,11). The thinning effect on 'Clara Frijs' was enhanced and proved that pears also can be thinned successfully by BA. As in numerous apple trials, the thinning response was found to be concentration-dependent, and the 100 mg/L treatment was the most favorable (7,8). It was also shown that BA can increase return bloom in pears and this may prove to be of great importance for cultivars such as 'Clara Frijs', where biannual bearing is a major problem.

The author acknowledges S.J. Wertheim for arranging donation of the chemical compounds used, and Mø ller Voight-Petersen, and Jan Jäger for making their orchards available for the experiments.

Literature Cited

1. Balkhoven, Baart JMT and S. J. Wertheim. 1998. Thinning response of Elstar to the flower thinner ammonium thiosulphate (ATS). Acta Hort. 463:481-486.
2. Bound, S. A., K. M. Jones, and M. J. Oakford.

1998. Post-bloom thinning with 6-benzyladenine. Acta Hort. 463:493-499.
3. Byers, R. E. 1997. Effects of bloom-thinning chemicals on apple fruit set. J.of Tree Fruit Production 2:13-31.
4. Byers, R. E. and C. G. J. Lyons. 1982. Flower bud removal with surfactants for peach thinning. HortScience 17:377-378.
5. Byers, R. E. and C. G. J. Lyons. 1985. Peach flower thinning and possible sites of action of desiccating chemicals. J. Amer. Soc. Hort. Sci. 110:662-667.
6. Byers, R. E., C. G. J. Lyons, and S. J. Donohue. 1985. Effect of chemical deposits from spraying adjacent rows on efficacy of peach bloom thinners. HortScience 20:1076-1078.
7. Elfving, D. C. and R. A. Cline. 1993. Benzyladenine and other chemicals for thinning 'Empire' apple trees. J. Amer. Soc. Hort. Sci. 118:593-598.
8. Ferree, D. C. 1996. Performance of benzyladenine as a chemical thinner on eight apple cultivars. J. of Tree Fruit Production 1:33-50.
9. Graf, V. H. and J. Hilbers. 1995. Ausdünnungsbehandlungen, beurteilt anhand von fruchtgrösse und Fruchtertrag. Mitteilungen des Obstbauversuchsringes des Alten Landes 50:152-159.
10. Grauslund, J. 1993. Udtynding af paeresorten Clara Frijs. Frugt og Baer 22:140-141.
11. Greene, D. W. and W. R. Autio. 1994. Combination sprays with benzyladenine to chemically thin spur-type 'Delicious' apples. HortScience 29:887-890.
12. Greene, D. W., W. R. Autio, J. A. Erf, and Z. Y. Mao. 1992. Mode of action of benzyladenine when used as a chemical thinner on apples. J. Amer. Soc. Hort. Sci. 117:775-779.
13. Handschack, M. 1994. Ausdünnung von Apfelbäumen mit konzentrierten Düngern. Obstbau 4:186-189.
14. Handschack, M. 1995. Ausdünnung bei Biernen. Rheinische Monatsschrift für Gemüse, Obst, Zierpflanzen 83:140-141.
15. Huet, J. 1973. Floral initiation in pear trees. Acta Hort. 34:193-198.
16. Ohlers, H. 1966. Forsog med kemisk frugtudtynding af paerer ved sprojtning med plantehormoner. Tidsskrift for Planteavl 70:254-260.
17. Jäger, J. 1999. Ausdünnung mit ATS. Obstbau 23:188-190.
18. Jones, K. M., M. Koen, M. J. Oakford, and S. A. Bound. 1989. Thinning Red Fuji apples with ethephon and NAA. J. Hort. Sci. 64:527-532.
19. Luckwill, L. C. and J. M. Silva. 1979. The effects of daminozide and gibberellic acid on flower initiation, growth and fruiting of apple cv. Golden Delicious. J. Hort. Sci. 54:217-223.
20. McArtney, S. J. and G. H. Wells. 1995. Chemical thinning of Asian and European pear with ethephon and NAA. N.Z. J. Crop and Hort. Sci. 23:73-84.
21. McLaughlin, J. M. and D. W. Greene. 1984. Effects of BA, GA4+7, and daminozide on fruit set, fruit quality, vegetative growth, flower initiation, and flower quality of 'Golden Delicious' apple. J. Amer. Soc. Hort. Sci. 109:34-39.
22. Meheriuk, M. and N. E. Looney. 1985. Quality of 'Bartlett' pears thinned chemically and by hand. HortScience 20:949-950.
23. Meland, M. and B. Gjerde. 1996. Thinning apples and pears in a Nordic climate. I. The effect of NAA, ethephon and lime sulfur on fruit set, yield and return bloom of four pear cultivars. Norwegian J. Agr. Sci. 10:437-452.
24. Webster, A. D. and M. S. Hollands. 1993. Thinning 'Victoria' plums with ammonium thiosulphate. J. Hort. Sci. 68:237-242.
25. Wertheim, S. J., J. L. Guardiola, Martinez JL Garcia, and J. D. Quinlan. 1998. Chemical thinning of deciduous fruit trees. Acta Hort. 463:445-462.
26. Williams, M. W. 1982. Fruit thinning. 285-289 In: Zwet, T. van-der and Childers, N. F. (eds.), The Pear. Horticultural Publications, Gainesville, FA,
27. Wismer, P. T., J. T. A. Proctor, and D. C. Elfving. 1995. Benzyladenine affects cell division and cell size during apple fruit thinning. J. Amer. Soc. Hort. Sci. 120:802-807.

Aroma Volatiles in Small Fruit

Strawberry aroma is composed predominantly of esters, although alcohols, ketones and aldehydes are present in small quantities. Raspberry aroma is a mixture of ketones and terpenes. Highbush blueberry aroma is dominated by aromatic hydrocarbons, esters, terpenes, and long chain alcohols while lowbush aroma is predominantly esters and alcohols. Aroma compounds are affected by cultivar, fruit maturity and storage conditions. As fruit ripen, aroma volatiles rapidly increase closely following pigment formation. From Forney 2001 Hort Technology 11(4):529-538.