Thinning 'Elstar' Apple with Benzyladenine

F. Maas
Wageningen University and Research Centre
Applied Plant Research, Research Unit Fruit
Lingewal 1, 6668 LA Randwijk
The Netherlands

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Abstract

'Elstar', the main apple cultivar grown in the Netherlands, requires adequate thinning to reach marketable fruit sizes and to achieve regular yields by preventing alternate bearing. At the moment, chemical thinning of 'Elstar' is the only economically feasible way of thinning. Thinning by hand is labour intensive and thus too expensive. Furthermore, hand thinning is usually carried out after June-drop, by which time only increases in fruit size are achieved and no reduction in alternate bearing. Up to 2004, carbaryl was the only effective fruit-thinning chemical Dutch growers had at their disposal. However, carbaryl is no longer officially registered for thinning apples. Thus, another agent for thinning 'Elstar' and other apple cultivars is urgently needed. This paper reports on two trials made with the thinning agent MaxCel containing 6-benzyladenine (BA) as the active ingredient. Generally, MaxCel applied at 10-12 mm fruit diameter thinned well, yielded bigger fruits and improved return bloom. However, thinning efficacy of MaxCel was negligible for weak growing trees or branches and increased with the vigour of the tree or branch. Adequate thinning and target fruit sizes were obtained with BA-concentrations in between 100 and 300 mg L^{-1} active ingredient. Results of thinning on pack-out and fruit quality are also presented.

INTRODUCTION

'Elstar', the main apple cultivar grown in the Netherlands, requires adequate thinning to reach marketable fruit sizes and to achieve regular production by preventing alternate bearing. At the moment, chemical thinning of 'Elstar' is the only economically feasible way of thinning. Thinning by hand is labour-intensive and therefore too expensive. Furthermore, hand thinning is usually carried out after June-drop, by which time, generally, only increases in fruit size are achieved with no reduction in alternate bearing.

Up to 2004, carbaryl was the only effective fruit thinning chemical Dutch growers had at their disposal. However, carbaryl is no longer officially registered for thinning apples. Thus, another agent for thinning 'Elstar' and all other thinning-requiring apple cultivars is urgently needed. Although ammonium thiosulfate (ATS) and ethephon can be effectively used as flower thinning agents (Maas and Peeters, 2002), the climatic conditions in the Netherlands during bloom often do not favour the use of these agents. Therefore, growers need to have a thinning agent at their disposal that is able to thin after fruit set has taken place and that can be applied early enough during fruit development to promote consistent flower bud development. Benzyladenine (BA), a plant growth regulator, has been shown to be a potential candidate for fruit thinning in several apple varieties (Bound et al., 1991, 1997; Bubán, 2000; Ferree, 1996; Greene and Autio, 1989, Greene, 1993; Maas, 2004a). So far, trials made in several European countries have indicated that the thinning efficacy of BA varies with cultivar, time of application, and climatic conditions (Wertheim, 2000; Wertheim, 2005). More recently, BA has also been tested for thinning the recently introduced cultivar 'Junami®' (Maas, 2004b; Maas, 2005).

This report describes the results of an efficacy study of MaxCel, a product containing 6-benzyladenine (BA) as the active ingredient, for thinning 'Elstar' apples in

The Netherlands

MATERIALS AND METHODS

Characteristics Experimental Site

The Netherlands are situated between 50 and 53° North latitude, with the trial site, Randwijk, at 51° North. The local soil of the experimental garden at Randwijk is a river clay soil. The top layer (0-30 cm) has a lutum percentage between 12 and 30% (lutum: particles < 2 μm), an organic matter content between 2 and 4 % and a calcium carbonate percentage of 0.3 and 1.4%. Locally, sand can be found in the subsoil (between 60 and 120 cm depth). The subsoil at 75 cm and deeper, consists of heavy river clay (lutum percentage > 50 μm). The trial was carried out on a plot with fertigation. The average rainfall is 800 – 1,000 mm per year. For spring frost protection, overhead sprinklers are used.

Experiments

1. Trial 1. 'Elstar' 'Elshof' trees, grafted on a 'Summerred' interstem and a M.9 rootstock, were planted in 1999 in single rows at a planting distance of 3 x 1 m. Trees were grown as slender spindles according to the standards of integrated fruit production used in the Netherlands. The growth vigour of the trees was moderate. Tree height was maintained at 2.25 m. Rows of 'Elstar' trees were alternated by rows of 'Santana' to ensure good pollination. The trial consisted of 6 treatments on single tree plots in 8 replications. The experimental setup was a randomised block design, each block containing the 5 treatments listed in Table 1. The chemicals used for thinning were: "Luxan late val" (LUXAN b.v., Elst, The Netherlands) containing 100 g L^{-1} 1-naphtyl acetic acid (NAA) as the active ingredient and MaxCel (Valent Biosciences Corporation, Libertyville, USA) containing 19 g L^{-1} 6-benzyladinine (BA) as the active ingredient. Tree phenology and climatic conditions at the times of application are listed in Table 2. Thinning agents were applied by means of a Knapsack sprayer as dilute solutions till runoff, equivalent to a spray volume of 1000 L/ha. No wetting agent was added.

2. Trial 2. 'Elstar' 'Elshof' trees, grafted on a M.9 rootstock directly or via a 'Summerred' interstem, were planted in 1998 and 1999, respectively, in single rows at a planting distance of 3 x 1.25 m. Trees were grown as slender spindles according to the standards of integrated fruit production used in the Netherlands. To ensure pollination 'Prof. Sprenger' and 'Delcorf' trees were planted within the row at every 4^{th} and 10^{th} position, respectively. The growth of the trees with the 'Summered' interstem was weak, that of trees grafted directly on M.9 was moderately vigorous. The trial consisted of 5 treatments carried out on single tree plots in 8 replications, both in trees without and with interstem. The experimental setup was a split plot with tree vigour as the main factor. The thinning treatments listed in table 3 were randomly divided within both subplots. Tree phenology and climatic conditions at the times of application are listed in Table 2. Thinning agents were applied by means of a Knapsack sprayer as dilute solutions till runoff, equivalent to a spray volume of 1000 L/ha. No wetting agent was added.

Fruit Quality Measurements

Fruits were graded for russeting, colour and size. Firmness, sugar content and acid content of the fruits were measured after two months of cold storage. (see legend of table for details of measurements). Fruit quality measurements were only made for the most effective thinning treatments and their untreated and hand-thinned controls.

Statistical Analysis

The data were statistically analyzed with the statistical software package Genstat (Hemel Hempstead, UK). In case of significant differences ($P<0.05$), LSD values were calculated and used for comparing treatment means in pairs.

RESULTS AND DISCUSSION

Trial 1

Results are listed in Table 4. The trees selected for the trial flowered homogeneously. On average the trees had 237 flowers. At harvest the untreated trees had produced 225 fruits with an average fruit weight of 134 g, yielding a total production of 29.9 kg per tree. Only 65% of this production consisted of fruits larger than 70 mm. Trees thinned to 94 fruits per tree by hand eight weeks after full bloom, yielded 16.6 kg and an average fruit weight of 179 g. Treatment with NAA resulted in some thinning but gave a similar fruit weight as the untreated trees.

The treatments 100 mg L^{-1} BA + 10 mg L^{-1} NAA, 150 mg L^{-1} BA + 10 mg L^{-1} NAA and 150 mg/l BA all thinned equally well. Fruit production per tree was reduced to about 100 fruits and to 17 to 20 kg. Consequently, average fruit weight increased from 134 g to 182 to 189 g and the percentage of fruit >70 mm increased to 94% (BA + NAA treatments) and 97% (150 mg L^{-1} BA) of the total production. Flower bud development, as judged by the number of flower buds in 2004, was very strongly inhibited when thinning was inadequate or, in case of hand thinning, carried out too late after fruit set. Return bloom in untreated, hand-thinned and NAA-thinned trees was only 6%, 52% and 38% of the number of flower clusters in 2003, respectively. Although return bloom in hand-thinned and NAA-treated trees was significantly higher than in the untreated trees, growers prefer higher numbers of flower clusters as they consider profuse flowering as the best guarantee for achieving a good crop. All thinning treatments containing BA resulted in much better flower bud development, giving return blooms in 2004 of 80 and 95% of the bloom in 2003.

Trial 2

The results of this trial are shown in Tables 5 and 6. The trees selected for this trial flowered homogeneously in 2003 with on average 269 flower clusters per tree. Fruit production of the untreated trees grown with and without 'Summerred' interstems was similar and amounted to about 310 fruits with an average weight of 121 g and a yield of approximately 36 kg per tree. Fruit load in the hand-thinned trees was manually reduced to 115 fruits per tree, resulting in yields of 16 and 19 kg and average fruit weights of 180 and 162 g for trees grown with and without interstems. Although the target fruit weight of 160 g was obtained by hand thinning for both types of trees, only in the trees without interstem was flower development stimulated significantly by hand thinning, resulting in a return bloom in 2004 of 92% of the bloom of 2003. Return bloom of trees with interstem 'Summerred' thinned by hand or BA was on average 40 to 55 % of the bloom of 2003 and not significantly higher than the return bloom of the untreated trees.

All three concentrations of BA used on both types of trees significantly thinned 'Elstar'. However, the degree of thinning by BA in trees with an interstem was less than in trees without an interstem. For all three BA concentrations used in trees with an interstem, BA thinned about half the number of fruits that had to be removed manually in the hand thinning treatment in order to obtain the desired fruit load of around 115 fruits per tree. Consequently, these BA-treatments were insufficient to obtain the target fruit weight of at least 160 g and to prevent inhibition of flower bud development. In trees without an interstem, however, thinning increased with BA concentration. Applications of 100, 200 and 300 mg L^{-1} BA thinned out 72, 116 and 142 apples per tree on average, respectively. Only 200 and 300 mg L^{-1} BA thinned sufficiently to increase average fruit weight to just above the target weight of 160 g and prevent inhibition of flower bud development. Return bloom in 2004 in these two BA-treatments was 82 and 92% of the bloom in 2003, respectively.

Fruit quality characteristics (Table 7) were only determined for fruits harvested from the trees without an interstem that showed the best thinning responses to the treatments with BA. Application of 300 mg L^{-1} BA at 10-12 mm fruit size increased the percentage of the production of apples with a diameter of 70 mm from 42% (untreated

trees) to 90%, equivalent to the effect of hand thinning.

'Elstar' apples are prone to russeting of the skin. In this trial all thinning treatments, except 100 mg L^{-1} BA, significantly increased the russeting of the fruits. Since this was also the case for the hand thinned trees, the largest and best coloured apples positioned on the more light-exposed sides of the tree were apparently more russeted than the smaller fruits thinned out by hand or BA. Russeting increase with BA concentration was significantly higher at 300 mg/l BA than at 100 mg L^{-1} BA. Wertheim (2000) also reported an increased risk of russeting when using BA concentrations above 100 mg L^{-1} but Bound et al. (1991) saw no effect on fruit russet with concentration up to 200 mg L^{-1}.

Fruit colour, determined as % of fruits in the size class 70-85 mm with more than 33% blush area and by scaling on a colour index, was most intense for the apples of hand-thinned trees, intermediate for trees treated with 300 mg L^{-1} BA and least for untreated trees. Fruit firmness after 2 months cold storage was similar for untreated and BA-treated trees and significantly less than for hand-thinned trees. Sugar content after storage differed significantly between untreated, hand-thinned and BA-treated tree, with the lowest value for the untreated and the highest value for the hand-thinned trees. Acidity of the apples after storage was similar for untreated and BA-treated trees. Apples from hand-thinned contained significantly more acids than those from the other treatments.

CONCLUSIONS AND RECOMMENDATIONS

MaxCel is a good alternative to carbaryl for thinning 'Elstar' apples under Dutch growing conditions. Average fruit size, pack-out, return bloom, fruit colour and sugar content were all higher in trees thinned adequately by BA. To obtain good thinning, tree and branch vigour should be maintained, as BA thinning efficacy is low when tree or branch vigour is very weak. BA thins better at higher temperatures (Tmax ≥ 18 °C, Bound et al. 1997, Greene and Autio, 1989) and growers are recommended to give priority to temperature, rather than precise fruit size of 10-12 mm, at the time of application.

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Tables

Table 1. Treatments in thinning trial nr. 1.

1.	Untreated control
2.	Hand thinned, 8 weeks after full bloom
3.	10 mg L^{-1} NAA, applied at 10-12 mm fruitlet diameter
4.	150 mg L^{-1} BA, applied at 10-12 mm fruitlet diameter
5.	100 mg L^{-1} BA + 10 mg L^{-1} NAA, applied as tank mix solution at 10-12 mm fruitlet diameter
6.	150 mg L^{-1} BA + 10 mg L^{-1} NAA, applied as tank mix solution at 10-12 mm fruitlet diameter

Table 2. Orchard conditions at time of thinning treatments trials 1 and 2 in 2003.

Treatment	Date (FB)[1]	Phenology[2] (fruitlet ∅)	Time (h)	Temp. (°C)	RH (%)	Wind[3]	Sky[4]	Volume (l/tree)
Trial 1 2, 3, 4, 5	May 26 (Apr 28)	12,1 mm	9:45-12:45	16.6-19.6	84-68	West 0-1	lightly -clear	0.35
Trial 2 3, 4, 5	May 26 (Apr 28)	12,4 mm	13:00-15:45	19-21	68-62	Variable 0-1	lightly -clear	0.37

[1]Date of treatment and Date of Full Bloom; [2)] Average diameter of 25 fruitlets on old wood and 10 fruitlets on first-year wood. Application of BA was aimed at 10-12 mm fruitlet diameter, but was postponed a few days because of cold tempe-ratures. [3)]Direction and wind speed (m/s). [4)]Cloudiness of the sky ranging between: clear, lightly, moderately or very cloudy

Table 3. Treatments thinning trial nr. 2.

1.	Untreated control
2.	Hand thinned, 8 weeks after full bloom
3.	100 mg L^{-1} BA, applied at 10-12 mm fruitlet diameter
4.	200 mg L^{-1} BA, applied at 10-12 mm fruitlet diameter
5.	300 mg L^{-1} BA, applied at 10-12 mm fruitlet diameter

Table 4. Trial 1: flower clusters, trunk circumference and fruit load in 2003[1].

Treatments Trail 1	Flower clusters/tree 2003	Fruits/ tree	Fruits/100 flower clusters	Yield kg/tree	Fruit weight (g)	Fruits > 70 mm (% yield)	Return bloom (Flower clusters/ tree 2004)
Untreated	243	225 c	101 c	29.9 c	134 a	65 a	10 a
Hand thinned	243	94 a	39 a	16.6 a	179 b	-	126 bc
10 mg L^{-1} NAA	231	176 b	80 b	23.5 b	138 a	68 a	82 b
150 mg L^{-1} BA	240	106 a	45 a	19.8 ab	189 b	97 b	188 cd
100 mg L^{-1} BA + 10 mg L^{-1} NAA	240	105 a	46 a	18.5 a	184 b	94 b	196 d
150 mg L^{-1} BA + 10 mg L^{-1} NAA	225	95 a	44 a	17.0 a	182 b	94 b	206 d
F-test	ns	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
lsd 0.05	-	26	15	4.2	20	15	63

[1)]data represent the means of 8 replicates of one tree each. Values within a column followed by different letters differ significantly; ns = not significant

Table 5. Trial 2: flower clusters, trunk circumference and fruit load and growth in 2003[1].

Treatments Trial 2	Flower clusters/tree 2003	Trunk circum-ference spring 2003 (cm)[2]	Fruits/tree	Fruits/100 flower clusters	Fruits/ TCSA[3]	cm² Growth vigour[4]
			'Elstar'/Summerred, M.9 (weak growth)			
Untreated	295	16.5	322 e	111 d	15.1 e	3.2 ab
Hand thinned	279	16.1	115 a	43 a	5.7 ab	4.0 b
100 mg L^{-1} BA	289	15.5	221 d	82 c	11.8 cd	2.9 a
200 mg L^{-1} BA	257	14.5	214 cd	85 c	13.7 de	3.1 ab
300 mg L^{-1} BA	259	14.9	227 d	90 c	13.0 d	3.2 ab
			'Elstar'/ M.9 (vigorous growth)			
Untreated	234	20.1	303 e	129 d	10.2 c	5.4 c
Hand thinned	259	19.8	116 a	48 ab	3.8 a	6.4 cd
100 mg L^{-1} BA	290	21.5	231 d	82 c	6.5 b	6.8 d
200 mg L^{-1} BA	268	21.5	187 bc	78 bc	5.1 ab	7.1 d
300 mg L^{-1} BA	263	19.2	161 b	63 b	5.6 ab	6.4 cd
F-test	ns	ns	p<0.001	p<0.001	p<0.001	p<0.05
LSD 0.05			30	13	2.0	1.0
			Rootstock/interstem			
Summerred/M.9	276	15.5 a	220	82	11.8 b	3.3 a
M.9	263	20.4 b	199	80	6.3 a	6.4 b
F-test	ns	p<0.001	ns	ns	p<0.001	p<0.001
LSD 0.05		0.7			1.2	0.5

[1)]data represent the means of 8 replicates of one tree each. Values within a column followed by different letters differ significantly, ns = not significant; [2)]measured 10 cm above the graft union between interstem and scion variety; [3)]trunk cross sectional area; [4)]estimated on scale 1 (no growth) to 9 (extremely vigorous growth)

Table 6. Trial 2: Yield, average fruit weight, trunk growth and return bloom[1].

Treatments Trial 2	Yield/ tree (kg)	Fruit weight (g)	Trunk circum-ference spring 2004 (cm)[2]	Increase trunk circumference '03-'04 (cm)	Flower clusters/tree 2004	Return bloom 2004 (% of 2003)
			'Elstar' / Summerred, M.9 (weak growth)			
Untreated	37.9 d	120 a	17.0 b	0.48	48 ab	17 a
Hand thinned	20.5 a	180 e	17.2 b	1.10	130 cd	52 ab
100 mg L^{-1} BA	30.7 c	141 bc	15.9 ab	0.45	92 bc	39 ab
200 mg L^{-1} BA	30.5 c	142 c	15.1 a	0.61	131 cd	55 ac
300 mg L^{-1} BA	30.2 c	134 ab	15.4 ab	0.50	101 c	40 ab
			'Elstar' / M.9 (vigorous growth)			
Untreated	35.4 d	122 ab	20.5 cd	0.36	42 a	20 a
Hand thinned	18.9 a	162 d	20.9 cde	1.08	191 e	92 cd
100 mg L^{-1} BA	34.9 cde	153 cd	22.2 de	0.69	177 de	60 bc
200 mg L^{-1} BA	31.0 c	166 de	22.3 e	1.01	202 e	100 d
300 mg L^{-1} BA	25.6 b	164 d	20.2 c	1.03	254 f	107 d
F-test	p<0.001	p<0.001	p<0.001	ns	p<0.01	p<0.05
LSD 0.05	3.5	15	1.7	-	47	38
			Rootstock/interstem			
Summerred/M.9	30.0	144 a	16.1 a	0.63	101	40 a
M.9	29.2	153 b	21.2 b	0.83	173	76 b
F-test	ns	p<0.05	p<0.001	ns	p<0.01	p<0.01
LSD 0.05		8.8	0.7	-	47	21

[1]data represent the means of 8 replicates of one tree each. Values within a column followed by different letters differ significantly; ns = not significant; [2]measured 10 cm above the graft union between interstem and scion variety.

Table 7. Trial 2: Fruit quality characteristics 'Elstar' on M.9 without interstem 'Summerred'[1].

Treatments	Fruits >70 mm (% yield)	Russeting Index[2]	% Fruits 70-85 mm >33% blush	Colour index[3]	Firmness[4]	Sugars (%)[4]	Acids (%)[4]
Untreated	41.6 a	337 a	32.4 a	355 a	3.8 a	12.8 a	0.64 a
Hand thinned	89.9 b	359 bc	83.5 c	534 b	4.6 b	14.7 c	0.78 b
100 mg L^{-1} BA	-	350 ab	-	-	-	-	-
200 mg L^{-1} BA	-	361 bc	-	-	-	-	-
300 mg L^{-1} BA	89.6 b	375 c	52.5 b	407 a	3.9 a	13.3 b	0.66 a
F-test	p<0.001	p<0.01	p<0.001	p<0.001	p<0.001	p<0.001	p<0.01
LSD 0.05	19.9	19	14.8	62	0.3	0.4	0.05

[1)]determined after two months cold storage; [2)]calculated after grading in classes smooth (no russeting), light, moderate and strong russeting and using the formula: russeting index = (% smooth) + (3x % light russeting) + (5x % moderate russeting) + (7x % strong russeting); [3)]calculated after grading in classes <10%, 10-25%, 25-33%, 33-50%, 50-75% and >75% of surface with red blush and using the formula: colour index = (<10% blush) + (10-25% blush x 2) + (25-33% blush x 3) + (33-50% blush x 4) + (59-75% blush x 5) + (>75% blush x 6); [4)]determined by Instron 4301 penetrometer equipped with 11-mm diameter piston at green side of apple.. Values within a column followed by different letters differ significantly.