APRC PROJECT SP105

THINNING OF APPLES & PEARS

FINAL REPORT

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1. INTRODUCTION

Most cultivars of dessert apple grown commercially in the UK have the potential to set too many fruits. This leads to small fruit size at harvest and poor fruit quality. It may also cause branch breakage and reduced numbers and quality of floral buds developing in the subsequent season. Excessive fruit set and the associated problems may also prove a problem in some seasons on the culinary apple cultivar Bramley's Seedling and on pear cultivars, such as Conference.

Traditionally, commercial fruit growers practise some form of fruit thinning to reduce potential crop loads and alleviate the problems associated with overcropping. Fruit thinning is achieved either by hand, or by using a chemical that stimulates fruitlet abscission. Although hand thinning of fruitlets is the most precise method of achieving optimum crop loads, it requires much labour and is, therefore, very expensive. Chemical thinning is achieved by using carbaryl ('Thinsec') which should be applied when the fruitlets are approximately 12 mm in diameter. Carbaryl is sometimes applied earlier in the growing season in attempts to advance the timing of fruitlet abscission and to reduce competition between fruitlets for the trees assimilates.

In the UK, other chemical thinners such as α-naphthylacetic acid (NAA - Planofix), naphthylacetamide (NAA-Amidthin) and ethephon (Ethrel C) were all used for apple fruitlet thinning in the past but have now been withdrawn and are not approved for use as thinners in the UK.

Carbaryl (Thinsec) is a carbonate insecticide that has broad spectrum activity against insects and is very damaging to bees. Currently, there is strong pressure from the environmental lobby for the withdrawal of carbaryl as a fruitlet thinner and it has already been withdrawn from approved use in several European countries. There is a significant possibility, therefore, carbaryl will not be available to UK growers, within the next few years.

There is an urgent need for new thinning chemicals or other fruit thinning strategies that will replace the use of carbaryl.

2. METHODS OF REDUCING EXCESSIVE FRUIT SET AND CROP LOADS

Most temperate tree fruits produce far more flowers than are required to set an optimum crop load. If weather conditions are favourable at, and shortly after, flowering and there are adequate pollen vectors (e.g. bees) in the orchard, far more fruitlets than the tree is able to develop to adequate market sizes will be set.

The problem can be reduced by:

- Reduction of potential for overset by inhibition of initiation and development of floral buds
- Removal of floral clusters or flowers
- Preventing a proportion of the flowers from setting (Blossom Thinning)
- Inducing a proportion of the fruitlets to drop off (abscind) (Fruitlet Thinning)
- Removal of a proportion of the small fruitlets (Hand or Mechanical Thinning)

2.1 Reduction of the potential for overset by inhibition of the initiation and development of floral buds

Applications of gibberellins to trees in the season prior to flowering, i.e. when the flower buds are initiating (June – September) may cause floral buds to abort. This technique has been used on peach trees in California as an alternative to conventional thinning strategies. No attempts have been made to thin apples or pears using this strategy.

The concentrations of gibberellins needed are difficult to judge and as well as reducing numbers of flower buds, the 'quality' of the remaining buds is sometimes diminished. Applications of gibberellins at the concentrations necessary to cause flower abortion may also stimulate excessive shoot growth. If such applications are made late in the summer, problems of poor acclimation in the late autumn and winter frost damage may arise.

If the gibberellins could be applied to some, but not all, the floral spurs within the tree canopy the technique could have greater potential. The 'scatter drop sprayer' developed some years ago by HRI was capable of achieving this aim.

The strategy of inhibiting floral bud production was not pursued in this project.

2.2 Removal of flower clusters or flowers

Pruning, conducted in the dormant winter period, is the most frequent method of achieving this objective. Trees bearing too many floral spurs, which also often produce inadequate new shoot growth, should be pruned in the winter to reduce the numbers of floral buds and stimulate new vegetative shoot growth. Although a most effective method, most growers are reluctant to remove too many flower buds, fearing frost damage and insufficient fruit set on the flowers remaining.

Removal of flowers at the time of blossoming is a similar, but more labour intensive and, therefore, more expensive, extension of the same strategy. Mechanical thinning of peach flowers has been achieved in US trials by a tractor pulling knotted ropes attached to a frame suspended over the rows through the trees at the time of full bloom. This causes damage to the flowers or causes them to detach from the branches.

Currently, none of these mechanical/physical methods of removing flowers is considered of sufficient promise for use with trees which are trained in conventional shapes. Such a strategy could be more promising on trees with more simple architecture.

2.3 Prevention of a proportion of the flowers from setting fruits

This is similar to the above strategy, but differs from it in that the flowers are not removed from the trees prior to, or at the time of, their opening. The flowers are in some way prevented from setting fruits.

Flower or blossom thinning is usually achieved by spraying the flowers with chemicals at or around the time of anthesis (flower opening). Such treatments damage part or all of the floral organs such that they are prevented from being pollinated and/or fertilised. Many of the chemicals used in the past as flower thinners have brought about their thinning action by desiccating the stigmas, styles or pollen. Lime sulphur and dinoseb amine, both used as thinners for plums in the past but now withdrawn from use, are thought to work in this way.

The fertiliser urea, may also act as flower thinner, but part of its action is thought to be due to the significant damage caused to the primary leaves on fruiting spurs.

Many of the trials conducted as part of this project have focused on testing new potential flower thinning chemicals for apples and pears.

2.4 Inducing a proportion of the fruitlets to drop off (abscind)

This, the most usual method of chemical thinning, is achieved by spraying flowers or fruitlets with chemicals which enhance and may also advance the natural abscission of fruitlets ('June drop'). Many different chemicals have been shown to have activity as fruitlet thinners. Synthetic auxins such as NAA (α-naphthylacetic acid) its amide NAAM have been used on the continent for many years as thinners for apples, but are no longer approved for use in the UK. It has been suggested that they bring about thinning by reducing, temporarily, the translocation of assimilates to fruitlets.

Other chemicals such as 5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1H,3H)-pyrimidinedione (Terbacil) which cause a reduction in photosynthesis also thin fruitlets, but may also cause significant damage to leaves. Carbaryl, a carbonate insecticide, is used as a fruitlet thinner for apples in the UK – the mode of action of carbaryl is not understood. Currently, there is considerable pressure to withdraw Carbaryl for use as a fruitlet thinner for apples. If this happens, UK growers will be left with no approved chemical method of thinning their apple fruits.

Some of the trials conducted as part of this project have focused on testing a new potential fruitlet thinning chemical for apples and pears.

2.5 Removal of a proportion of the small fruitlets

This is the most traditional method of fruitlet thinning and is usually achieved by hand thinning. It is a reliable method, in that thinning is delayed until after any chance of frost damage and is not done until an adequate fruit set is assured. Hand thinning also facilitates accurate spacing of fruitlets on the tree branches. However, hand thinning is labour intensive and, therefore, often very expensive.

Attempts have been made to mechanise hand thinning using machines which either shake or comb fruitlets from the tree. Unfortunately, none of these techniques have proved reliable to date.

Hand thinning at the 12mm fruitlet diameter stage was used as the control treatment in most of the trials described below.

3. THINNING TRIALS ON APPLES

3.1 Methods used

Most of the trials were conducted on semi-mature trees of either Royal Gala or Queen Cox apples growing on M.9 rootstocks in orchards situated at HRI-East Malling. A few experiments were also conducted on Bramley's Seedling and Jonagold. No trials were conducted on the farms of fruit growers; the requirement to destroy all fruits from trees sprayed with an unapproved chemical, for a period of five years following spraying, was unacceptable to growers. This is not a requirement in other European countries.

The trials focused on testing several new chemicals as flower thinners and also one new fruitlet thinning chemical as a replacement for carbaryl. In all trials, the trees treated with chemical thinners were compared with trees hand-thinned at the 12mm fruitlet diameter stage and with unthinned trees.

Many of the trials were carried out as part of a European coordinated effort in which 6 to 9 different countries participated. Where appropriate, the results from the trials abroad were used to modify or refine the treatments in the UK trials. This European collaboration continued in 1999, but in the absence of any UK collaboration.

All sprays were applied using a knapsack sprayer at volumes equivalent to 100 gallons/acre (100 litres/ha). Where appropriate, the wetter (surfactant) polyoxethylene sorbiton monolaurate (Tween 20) was added to the sprays at a rate of 0.1%(v/v).

Numbers of floral buds were counted on each tree in the spring and initial and final fruit set recorded post petal fall and pre-harvest respectively. Visual assessments were made of any damage caused to the leaves or fruits. At harvest, fruits were weighed and graded. Samples were taken from some of the trials for analysis of ripeness (soluble solids, starch and pressure) and mineral content. Fruits from some of the trials were stored for up to six months prior to assessment of their condition and quality.

3.1.1 Chemicals tested

Preliminary trials conducted as part of a previous project funded by APRC (SP 74) showed that four chemicals, ammonium thiosulphate, endothallic acid, pelargonic acid and sulfcarbamide (Wilthin) all showed some promise as flower thinners on self-fertile clones of the apple cultivar Cox's Orange Pippin. Trials were conducted using all of these chemicals in 1995. Thereafter, the two most promising blossom thinners, namely ammonium thiosulphate (ATS) and endothallic acid (TD) were selected for further trialling in 1996-1998. In 1998, a further chemical with activity as a blossom thinner on stone fruits, Armothin, was also tested.

Paturyl, a formulation of benzyl adenine, manufactured in Hungary was tested between 1995 and 1998 as a potential replacement for carbaryl as a fruitlet thinner. In 1998, two other formulations containing benzyl adenine, Accel and Perlan, were also tested as fruitlet thinners.

3.2 Thinning Trials on Royal Gala

3.2.1 ATS as a flower thinner for Royal Gala

1995 Trials:

In 1995, ATS was sprayed at high volume (1000 l/ha) to five-year-old Royal Gala trees planted on M.9 rootstock at Horticulture Research International – East Malling (HRI-EM). Concentrations of 5000, 10000 and 15000 ppm (0.5%, 1.0% and 1.5%) were compared. The surfactant, polyoxyethylene sorbitan (Tween 20) was added to the sprays at 0.1% active ingredient (a.i). The sprays were applied at 80% open flower (full bloom) on 3 May and treated trees were compared with unsprayed trees and trees hand-thinned to 2 fruits/cluster on 26 May, when the average fruitlet diameter was 12 mm. The trial was designed in six randomised blocks of single tree plots.

Natural fruit set on these trees was very high in 1995 with more than 5 fruits setting on each cluster on the unthinned controls (Table 1). All the ATS sprays reduced initial fruit set; sprays at 1.5% were more severe in their effect than sprays at 0.5% or 1.0%. The effects of the 1.5% sprays on initial fruit set were similar to hand thinning. The unthinned trees shed 36% of their fruits between initial and final set. Nevertheless, all the ATS sprays reduced final set more than on the unsprayed controls.

Table 1. Effects of ammonium thiosulphate (ATS) sprays on the fruit set and % abscission of Royal Gala in 1995

Treatment	Fruit set/100 clusters Initial	Fruit set/100 clusters Final	% abscission initial to final set
Control	584	370	36
Hand-thinned	232	243	-5*
ATS 0.5%	330	284	13
ATS 1.0%	333	276	17
ATS 1.5%	199	165	16
LSD (5%)	78.8	47.2	10.6

* the negative value is thought to be attributable to extra fruits setting on late flowering axillaries which were not recorded at the time of initial fruit set

Fruit set was similar on the hand-thinned trees and those treated with ATS at 0.5% or 1.0%. Trees treated with ATS at 1.5% had lower final sets than the hand-thinned trees.

Table 2. Effects of ATS sprays on the yields and fruit grades of Royal Gala in 1995

Treatment	Total yield/tree kg/tree	Mean fruit wt (g)	% kg class I > 65 mm diameter
Control	22.2	67.8	1.7
Hand-thinned	20.8	94.6	25.6
ATS 0.5%	19.6	75.8	6.2
ATS 1.0%	21.1	83.7	11.9
ATS 1.5%	15.2	103.4	24.6
LSD 5%	3.7	12.3	10.7

Total yields/tree were reduced significantly by the ATS sprays at 1.5% but not by sprays at 0.5% or 1.0% (Table 2). The mean weight of individual fruits was increased most by ATS sprays at 1.5% and by hand-thinning, although ATS 1.0% also significantly increased mean fruit size. The unthinned controls produced less than 2% of fruits in the desired size/quality grade (Class I > 65 mm diameter). Only the highest concentration of ATS (1.5%) significantly improved this grade out (to 24%) and this effect was similar to hand-thinning (25.6%). The two lower concentrations of ATS produced smaller effects on grade out and these differences were not statistically significant.

1996 Trials:

In 1996, the trees sprayed in 1995 were again used for the trial. ATS was again applied in high volume sprays at concentrations of 0.5%, 1.0% and 1.5% to trees at 80% open flower (15 May). The surfactant Tween 20 (0.1%) was again added to the sprays. Comparisons were made with unthinned trees and also with trees hand-thinned to 1 fruit/flower cluster when fruitlets were approximately 12 mm in diameter (10 June). The trial was designed in six randomised blocks of single tree plots.

Table 3. Effects of sprays of ATS on the fruit set of Royal Gala in 1996

	Fruits/100 clusters		Fruits/cm^2+	
Treatment	Initial	Final	initial	Final
Control	328.4	312.9	18.1	17.3
Hand-thinned	96.5	114.6	9.4	11.2
ATS 0.5%	171.9	154.8	13.1	11.7
ATS 1.0%	155.8	133.4	14.4	11.9
ATS 1.5%	146.0	94.7	21.3	13.0
LSD 5%	43.58	44.60	11.54	6.42

+ per cm^2 trunk cross sectional area

Trees treated with either 1.0% or 1.5% ATS in 1995 developed significantly more flower clusters in spring 1996; numbers on the 1.0% treatment were similar to those on the hand-thinned controls, whilst those on the 1.5% treatment were greater (Table 3). Similar effects were noted when flower cluster numbers were expressed per unit trunk cross sectional area.

Initial fruit set/100 flower clusters was reduced by all three concentrations of ATS applied in 1996 and there were no significant differences between the three ATS concentrations. However, at initial set, none of the spray treatments thinned as effectively as the hand-thinning. Final fruit set/100 flower clusters, measured just prior to harvest, was reduced greatly by all three ATS sprays. The 1.5% sprays, which were similar in effect to the hand-thinning, produced significantly fewer fruits per 100 clusters than the 0.5% sprays. The apparent anomaly of fruit set increasing between initial and final set on the hand-thinned controls was attributable to the setting of late-flowering axillary blossoms, not included in the counts of initial set.

Treatment effects on final fruit numbers per unit trunk cross sectional area were much more variable and, although all treatments appeared to reduce final set/tree (adjusted for tree size), these differences were not statistically significant.

Although total yields/tree were slightly reduced by all ATS treatments, this effect was only statistically significant for the lowest concentration sprays (0.5%) (Table 4). Only on the hand-thinned trees was mean individual fruit weight increased; none of the ATS treatments applied in 1996 increased mean fruit weight compared with the unsprayed controls. Similarly, only the hand-thinning increased significantly the yield of fruits in the Class I > 70 mm diameter category.

Table 4. Effects of sprays of ATS on the yield and fruit grades of Royal Gala in 1995

Treatment	Tot. yield/tree (kg)	Mean fruit wt. (g)	Class 1 yield/tree (kg) > 70 mm	Class 1 yield/tree (kg) > 65 mm	Class 1 yields (%) > 70 mm	Class 1 yields (%) > 65 mm
Control	20.2	91.9	2.8	16.4	0.3	2.3
Hand-thinned	17.7	111.8	9.5	49.8	1.5	8.5
ATS 0.5%	14.8	100.0	8.5	32.1	1.2	4.6
ATS 1.0%	17.4	98.5	5.2	21.6	0.7	3.2
ATS 1.5%	17.1	90.8	0.6	10.4	0.1	1.6
LSD 5%	5.64	15.29	7.36	20.35	0.98	2.79

1997 Trials:

In 1997, a trial was designed to assess the effects of re-wetting trees, shortly after applying sprays of ATS, on the efficacy of the thinning and on spray phytotoxicity. Observations on trials in Canada had suggested that overthinning and excessive leaf scorch often occurred when ATS was applied in slow drying conditions.

ATS ('Thio-sul' formulation) at either 1.0% or 1.5% was applied at 80% open flower in the afternoon. One third of the trees were re-wetted with water using a fine mist sprayer in late afternoon. Early the following morning another third of the trees were re-wetted using the same technique.

A severe frost occurred in April 1997 affecting the results of this trial, even though overhead irrigation was applied to the orchard in an attempt to reduce damage.

Table 5 Effects of ATS sprays + or – re-wetting on the yields of Royal Gala in 1997

Treatment	Re-wetting (hours after spraying)	Floral bud nos/tree	Final set/100 floral buds	Total number of fruits harvested/tree
Control – unsprayed	None	255	101	255
ATS (Thiosul) 1.0%	None	232	72	161
ATS (Thiosul) 1.5%	None	177	59	114
ATS (Thiosul) 1.0%	Same day (6 hours)	199	75	151
ATS (Thiosul) 1.5%	Same day (6 hours)	194	53	111
ATS (Thiosul) 1.0%	Next day (24 hours)	198	84	168
ATS (Thiosul) 1.5%	Next day (24 hours)	196	62	123
LSD 5%		50.6	15.3	49.3

The ATS sprays reduced final fruit set and the total numbers of fruit harvested/tree and sprays at 1.5% thinned more severely than sprays at 1.0% (Table 5). Re-wetting the trees had no effect on the level of thinning or the degree of phytotoxicity to leaves, which was in all instances slight.

The 1.5% sprays of ATS reduced total yields/tree more than the 1.0% sprays (Table 6). The treatments increased onlyslightly the weight of fruits > 70 mm diameter harvested from the trees and this effect was not statistically significant .

Table 6 Effects of ATS sprays + or – re-wetting on the yield and fruit size of Royal Gala trees in 1997

Treatment	Re-wetting (hours after spraying)	Yields tree (kg)		
		Total	>70mm	>65mm
Control unsprayed	None	28	2.0	10.9
ATS (Thiosul) 1.0%	None	20	3.7	11.6
ATS (Thiosul) 1.5%	None	15	4.6	10.3
ATS (Thiosul) 1.0%	Same day (6 hours)	19	4.8	11.3
ATS (Thiosul) 1.5%	Same day (6 hours)	15.0	6.0	11.7
ATS (Thiosul) 1.0%	Next day (24 hours)	21	4.7	14.2
ATS (Thiosul) 1.5%	Next day (24 hours)	16	4.5	11.2
LSD 5%		5.5	3.33	

A second experiment conducted on Mondial Gala in 1997 was affected severely by the spring frost. Although the sprays of 1.0% or 1.5% ATS ('Thio-sul' formulation) caused browning of blossoms, a usual indication of effective thinning activity, they did not add to the severe thinning effect caused by the frost (Table 7).

Table 7. Effects of ATS sprays on the fruit and yield on frost affected Mondial Gala trees in 1997

Treatments (% v/v)	Floral bud nos./tree	Final fruit number 100 flower clusters	Total fruit number at harvest/tree
Control (unthinned)	203	73	152
Hand-thinned	206	43	90
ATS 1.0%	203	68	139
ATS 1.5%	205	59	126
ATS 1.0% at 40% and again at 90% open flower	208	63	130

1998 Trials:

In 1998, ATS sprays of 0.5% or 1.0% were compared with unthinned trees or hand-thinned to 1 fruit/cluster. In addition, combinations of the ATS treatments together with hand-thinning at the 12 mm stage were compared. The spray treatments (Thiosul) were applied at full bloom on spur blossom clusters (May 1) on a day of low average temperature (9°C) but high relative humidity (89%). A final treatment compared use of sprays of 0.5% ATS applied twice, once at full bloom on spur wood (May 1) and once at full bloom on axillary wood (11 May). The spray of ATS at 1.0% applied without additional hand-thinning reduced final fruit set significantly but the effect of the 0.5% spray without hand-thinning on set was not statistically significant (Table 8). The spray of 1.0% ATS reduced total yields by 31% but doubled the percentage of fruits harvested in the Class I > 65 mm diameter grade and increased mean fruit weight by 18 g. However, the 0.5% spray had only a small and non-significant effect on yields, fruit size and grades.

Hand-thinning on its own reduced final set and total yields but increased mean fruit weight and the percentage of fruits in the Class I > 65 mm grade, more than the sprays of ATS at 1.0%.

Table 8 Effects of ATS sprays and hand-thinning applied in spring 1998 on the fruit set, yields and fruit size of Royal Gala

Treatment	Fruit set/100 clusters	Total yield/tree (kg)	% Class I > 65 mm	Mean fruit wt (g)
Control	183	27.7	25.2	101
Hand-thinned	66	14.2	78.1	138
ATS 0.5%	150	23.8	37.7	107
ATS 0.5% + hand-thinning	54	12.3	73.4	147
ATS 1.0%	106	19.2	51.0	119
ATS 1.0% + hand-thinning	44	10.1	79.8	154
ATS 0.5% at full bloom on spur	109	21.2	53.9	120
LSD (5%)	39	5.8	15.8	14.9

When the sprays of ATS were combined with subsequent hand-thinning, the treatment effects were similar to those of hand-thinning on its own. However, the time needed to carry out the hand-thinning was reduced slightly on trees treated previously with ATS.

The effects of combining treatments of ATS with sprays of the fruitlet thinner benzyl adenine are presented in section 3.2.7

Two sprays of ATS, one at full bloom on spur wood and one a few days later when full bloom occurred on the one-year-old axillary wood reduced final set to similar levels to those achieved by single sprays of 1.0% ATS. Effects on fruit yields and size were also similar to those achieved with the single 1.0% sprays.

3.2.1.1 Studies on the sensitivity of Royal Gala blossoms to ATS in relation to their time of opening

In 1998, a study was made using one eight-year-old tree of Royal Gala to determine if flowers sprayed at different stages of development differed in their sensitivity to ATS.

At full bloom (May 1st) whole trees of Gala were treated with high volume sprays of ATS (1.5% a.i. ‘Thiosul’ formulation). Just prior to spraying, each flower bud on the tree was labelled according to its type (spur, terminal, axillary) and stage of development. Four categories of blossoms were apparent at the time of spraying: 1) spur or terminal clusters fully open; 2) spur or terminal clusters king blossom only open; 3) spur or terminal clusters all flowers at balloon stage and 4) axillary clusters at late pink bud.

The effects of the sprays on fruit set were recorded in late June and the results are shown in Table 9. This shows that sprays to clusters on which all the flowers were open reduced fruit set severely (to 8.0%). Sprays to clusters with only the king blooms open also reduced fruit set severely (to 7.7%). However, where clusters were either at balloon (spur and terminal) or the late pink bud (axillary) stages, fruit set was much higher (46-60%). This is despite the apparent severe petal necrosis observed on all flowers two days after spraying. More than half of the persisting fruitlets remained as the desired singles (i.e. as one fruit/floral bud).

Table 9 Sensitivity of Royal Gala flowers to sprays of ATS

	Full open	King only open	Balloon	Pink bud
<u>Royal Gala</u>				
% of clusters setting fruits	8.0	7.7	46.0	52.6
% of fruits/flower bud:				
singles	8.0	7.7	38	52.6
doubles	-	-	8	-
> doubles	-	-	-	-

Each Royal Gala flower bud developed between 1-7 flowers. On each recorded branch there was an average ranging from 4.9-5.5 flowers/bud on spurs (two-year or older wood), from 4.7-6.2 flowers/bud on the terminals and from 4.2-5.1 flowers/bud on the axillaries (one-year-old wood). Detailed records were made of the numbers of flowers produced on the recorded branches. These varied slightly from branch to branch, as did the proportions of each floral bud type.

Of the total numbers of flowers on each branch:

9.7%-13.2% were king flowers on spur and terminal buds.
43%-58% were lateral flowers (i..e. all flowers other than king flowers) on spur and terminal buds.
7.7%-9.0% were king flowers on one-year-old axillary buds.
20.5%-34.3% were lateral flowers from one-year-old axillary buds.

Records were made also on the timing and sequence of flower opening in 1998. The flowers opening each day were recorded on representative branches on five trees of each variety. The cumulative percentages of each blossom type opening on each day are shown in Figure 1. King flowers on spur or terminal buds began opening on April 22nd and finished on 9th May. The lateral flowers on spurs and terminals began opening only 1 day later, on April 23rd, but continued until 13th May. Axillary blossoms opened much later, beginning on May 3rd and 4th (king and lateral respectively) and finishing on May 10th and 16th (king and lateral respectively). This extended flowering season resulting in quite small percentages of the total blossoms on the trees opening on any one day.

It can be seen that, at the time of spraying ATS, on May 1st, 81% of the king flowers and 44.5% of the lateral flowers on spur and terminal clusters had opened. In contrast, none of the axillary blossoms had opened by May 1st. From the sensitivity tests conducted using ATS (see above), clusters with at least one flower open seemed to be the most sensitive and few fruits set on such clusters when sprayed with ATS. The flowering records on Royal Gala show that at the time of spraying on May 1st, between 66-88% of the spur and terminal clusters on the trees were at this vulnerable stage, whereas no axillary cluster was.

The information on flower-opening times was also used, in combination with climate data, to assess the potential for successful pollen transfer, germination and growth down the style. It can be seen from Figure 2 that, during the period when most spur and terminal blossoms were opening (26 April - 4 May), mean daily temperatures were less than 10^{o}C, much lower than desirable. Only later, when the axillary blossoms comprised the majority of blossoms opening, did temperatures climb to higher and more desirable levels.

Figure 1

Fig 2

3.2.1.2. Conclusions

- ATS sprays at 0.5%, 1.0% or 1.5% reduced initial and final fruit set on Royal Gala in 1995
- Full bloom sprays of ATS 1.5% to Royal Gala trees in 1995 increased the % grade-out of Class I > 65 mm fruits and mean fruit size compared to unthinned controls.
- The effects on grade-out and mean fruit size in 1995 were similar to hand-thinning.
- The ATS sprays at 1.5% in 1995 reduced yields 25% compared with hand-thinning.
- ATS sprays at 1.0% in 1995 also increased mean fruit size, albeit less than that achieved with 1.5%, and had no deleterious effects on yield.
- The beneficial effects of sprays of ATS at 0.5% in 1995 were smaller and not statistically significant.
- ATS sprays at either 1.5% or 1.0% in 1995 significantly increased the numbers of flowers (by 33% to 73%) formed on the trees in spring 1996.
- ATS sprays at 0.5%, 1.0% or 1.5% reduced initial and final fruit set of Royal Gala in 1996.
- ATS sprays at 1.5% in 1996 thinned fruits to similar final levels of set to hand-thinning.
- None of the ATS treatments in 1996 reduced yields compared with the unthinned controls
- None of the ATS treatments in 1996 increased mean fruit size or grade-out. Hand-thinning gave the best effects in 1996.
- The poor response to the ATS sprays in 1996, in terms of effects on fruit size, was attributable to the much higher numbers of flowers on the trees compared to unthinned controls following their effective thinning in 1995. Although the sprays did reduce fruit set in 1996, this was insufficient to increase fruit size on trees with over abundant blossoms.
- Rewetting trees shortly after spraying in 1997 with ATS did not increase the thinning effect or leaf phytotoxicity.
- Sprays of 1.0% or 1.5% ATS applied to Royal Gala in 1997 thinned trees and increased the grade-out of > 70 mm fruits on a frost protected plot.
- Sprays of 1.0% or 1.5% ATS applied to Mondial Gala in 1997 did not exacerbate the severe thinning caused by the frost spring damage.
- Sprays of ATS at 1.0%, but not 0.5%, reduced final set and total yields but increased mean fruit size and the percentage of fruits in Class I > 65 mm on Royal Gala trees in 1998.
- Combining ATS sprays with hand-thinning reduced the time required for hand-thinning.

3.2.2 Endothallic acid (TD232337-2) as a flower thinner for Royal Gala

1995 Trials:

In 1995, endothallic acid was sprayed at high volume (100 l/ha) to five-year-old Royal Gala trees planted on M.9 rootstock at HRI-EM. Concentrations of 500, 1000 and 2000 ppm were compared when sprayed at 80% flower opening (full bloom) on 3 May. The treated trees were compared with unthinned trees and trees hand-thinned to two fruits/cluster at the stage when fruitlets had an average diameter of 12 mm on 26 May 1995. The trial was designed in six randomised blocks of single tree plots.

Table 10 Effects of endothallic acid (TD) sprays on the fruit set and % abscission of Royal Gala in 1995

	Fruits set/100 floral buds		% abscission
Treatment	Initial	Final	Initial – Final Set
Control	584	370	36
Hand-thinned	232	243	-5
TD 500 ppm	354	283	20
TD 1000 ppm	287	234	19
TD 2000 ppm	233	175	25
LSD 5%	78.8	47.2	10.6

All of the TD sprays reduced initial fruit set of Royal Gala in 1995; the severity of effect was associated positively with spray concentration (Table 10). A high proportion of fruitlets (36%) dropped from the unthinned controls between initial and final set but no extra fruits were lost from the hand-thinned trees (the negative value indicates small counting errors at initial set attributable to very late blossoming on some axillaries). Twenty to 25% of initial fruits dropped from the TD sprayed trees between initial and final set. Final set/100 floral clusters was reduced by all the TD treatments; sprays at 1000 ppm matched most closely the set levels achieved by hand-thinning.

Total yields/tree were reduced slightly by TD 1000 ppm sprays and more severely by TD 2000 ppm sprays (Table 11). Mean fruit size and the percentage Class 1 (> 65 mm diameter) grades were increased significantly by the TD 1000 ppm and 2000 ppm sprays. However, none of the TD treatments were as effective as hand-thinning in improving fruit grade-out.

Table 11 Effects of endothallic acid (TD) sprays on the yields and fruit grades of Royal Gala in 1995

Treatment	Total yield/tree (kg)	Mean fruit wt (g)	Class 1 fruits > 65 mm diameter (%)
Control	22.2	67.8	1.7
Hand-thinned	20.8	94.6	25.6
TD 500 ppm	19.9	76.6	3.6
TD 1000 ppm	18.1	87.8	16.7
TD 2000 ppm	13.3	88.2	14.6
LSD 5%	3.7	12.3	10.7

1996 Trials:

In 1996, endothallic acid (TD2337-2) was sprayed at high volume (1000 l/ha) as a blossom thinner at 500, 1000 or 2000 ppm (0.05%, 0.10% or 0.20%) at the 80% open flower (15 May) stage. No additional wetter was included. Comparisons were made with unthinned trees and trees thinned to one fruit/cluster at the 12 mm stage (10 June). The trial was designed in six randomised blocks of single tree plots.

Table 12. Effects of sprays of endothallic acid (TD) on the fruit set of Royal Gala in 1996

	Fruits/100 clusters		Fruits/cm^2+	
Treatment	Initial	Final	Initial	Final
Control	328.4	312.9	18.1	17.3
Hand-thinned	96.5	114.6	9.4	11.2
TD 500 ppm	252.8	210.4	21.9	16.9
TD 1000 ppm	148.8	134.1	16.2	14.6
TD 2000 ppm	123.0	106.5	13.8	12.0
LSD 5%	43.58	44.60	11.54	6.42

+ per cm^2 trunk cross sectional area

Trees treated with either 1000 ppm or 2000 ppm TD in 1995 developed significantly more flower clusters/tree in 1996 than unsprayed controls, and were similar in this respect to the hand-thinned trees (Table 12). A similar response was noted when these values were adjusted to take account of differences in tree size, using the trunk cross sectional areas.

Although all three concentration sprays of TD applies in 1996 reduced initial set/100 flower clusters, only the highest concentration produced an effect similar to that achieved with hand-thinning. Final fruit set/100 flower clusters was also reduced significantly by the TD sprays, and these reductions appeared to be positively related to the concentrations sprayed. The 2000 ppm sprays most closely simulated the effects of hand-thinning. The apparent anomaly of set increasing between initial and final set on the hand-thinned controls was attributable to the setting of late-flowering blossoms not included in the first initial set counts.

Counts of initial and final fruit set per tree were more variable and no statistically significant differences were recorded when these set measurements were adjusted to take account of tree size, using trunk cross sectional area.

None of the treatments reduced total harvested yields significantly, although the mean reductions attributable to the 2000 ppm TD treatments were approximately 25% (Table 13). Only the hand-thinning treatment increased mean individual fruit weight. No statistically significant differences were recorded in the weights or percentages of fruits harvested in the Class 1 > 70 mm diameter category, although the hand-thinned trees did appear superior in this respect.

Table 13. Effects of sprays of endothallic acid (TD) on the yield and fruit size of Royal Gala in 1996

Treatment	kg/tree	Mean fruit wt (g)	% Class 1 > 70 mm	% Class 1 > 65 mm	kg/tree Class 1 > 70 mm	kg/tree Class 1 > 65 mm
Control	20.2	91.9	2.8	16.4	0.3	2.3
Hand-thinned	17.7	111.8	9.5	49.8	1.5	8.5
TD 500 ppm	17.6	89.1	1.4	13.9	0.2	1.6
TD 1000 ppm	17.7	91.0	0.9	12.8	0.1	2.1
TD 2000 ppm	15.2	96.9	3.7	26.6	0.4	3.4
LSD 5%	5.64	15.29	7.36	20.35	0.98	2.79

3.2.2.1: *Conclusions concerning the use of endothallic acid as a thinner for Gala clones*

- Sprays of endothallic acid (TD) (500, 1000 or 2000 ppm) applied to Royal Gala in 1995 reduced initial and final fruit set.
- The severity of thinning was increased by higher concentrations of the product.
- Sprays of endothallic acid (TD) at 1000 or 2000 ppm in 1995 increased mean fruit size and the percentage of fruits graded in Class 1 > 65 mm.
- In 1995 none of the endothallic acid treatments were as effective as hand-thinning.
- Trees treated with 500 or 1000 ppm endothallic acid in 1995 developed flowers (41% to 112% more) in spring 1996 than the unthinned controls.
- All three concentrations of endothallic acid sprayed in 1996 reduced initial and final levels of fruit set but only the highest concentration matched the hand-thinning in achieving the desired crop loading.
- Only hand-thinning increased mean fruit weight in 1996.
- None of the treatments reduced yields.
- The poor response to endothallic acid sprays in 1996, in terms of effects on fruit size, was attributable to the much higher numbers of flowers on the trees compared to unthinned controls following their effective thinning in 1995. Although the sprays did reduce fruit set in 1996, this was insufficient to increase fruit size on trees with over abundant blossoms.

3.2.3 Armothin as a flower thinner for Royal Gala

The chemical 'Armothin' (Azco Nobel Chem. Co. Ltd.), a 98% fatty amine polymer, has been tested successfully as a blossom thinner for peach trees in Italy. In 1998, it was tested as a blossom thinner on 8-year-old Royal Gala trees on M.9 rootstock. The product was applied at 0.5% (at high volume 1000 l/ha) at three timings, balloon blossom (28 April), 5 days after full bloom on spurs (8 May) and 10 days after full bloom on spurs (13 May).

The manufacturers expressed concerns that Armothin may cause some russeting of fruits. To counteract this, a further three treatments were tested in which sprays at the three timings were combined with a programme of GA_{4+7} sprays. GA_{4+7} (Novagib) 10 ppm was applied four times (13, 22 and 27 May and 1 June) at the beginning of petal fall.

The thinning results were disappointing in that, although the Armothin sprays appeared to damage and brown the blossoms, they had only small and statistically non-significant effects on final fruit yields, mean fruit weights and the percentages of fruits in Class 1 > 65 mm diameter (Table 14).

Table 14. Influence of sprays of Armothin on the fruit set, yield and fruit size of Royal Gala in 1998

Treatment	Final set/100 fruit buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 65 mm
Control unthinned	146	24.5	94	12
Hand-thinned	52	12.8	125	59
Armothin 0.5% - 10 days AFB	124	21.1	112	36
LSD 5%	36.6	6.9	12.5	15.6

However, in a second trial on another set of Royal Gala trees of similar age, a spray of Armothin applied 10 days after full bloom on spur wood did have beneficial effects (data not shown). The final set level, adjusted for tree size, was reduced by the Armothin spray and mean fruit weight and the percentage of fruits in the > 65 mm Class 1 category increased. This inconsistency of results is not understood.

3.2.3.1: Conclusions concerning the use of Armothin as a thinner for Gala clones

- Armothin gave inconsistent results as a blossom thinner when applied to Royal Gala trees in 1998.
- No fruit russeting was caused by the Armothin sprays

3.2.4 Pelargonic acid and sulfcarbamide as flower thinners for Royal Gala

Trials in the USA have shown that pelargonic acid (Thinex) and sulfcarbamide (Wilthin) may be effective thinners for some cultivars of apples.

A preliminary trial conducted in 1994 on self-fertile clones of Cox, showed these two products to have some activity as blossom thinners on self-fertile clones of Cox's orange Pippin. A further trial comparing these two products was conducted in 1995 on 5-year-old Royal Gala trees on M.9 rootstock. High volume sprays of pelargonic acid (750, 1500 and 4000 ppm) were compared with unthinned trees or trees hand-thinned to 2 fruits/cluster at the 12 mm diameter stage.

None of the pelargonic acid sprays had any thinning effect but the highest concentration spray of sulfcarbamide (4000 ppm) reduced final set and increased slightly mean fruit size (Table 15). However, none of the pelargonic acid or sulfcarbamide spray treatments were as effective as thinners as sprays of ATS or endothallic acid compared in the same trial (see above)

Table 15. Effects of sprays of pelargonic acid or sulfcarbamide on the fruit set, yield and fruit size of Royal Gala in 1995

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% fruits > 65 mm diameter
Control – unthinned	370	22.2	68	2
Hand-thinned	243	20.8	95	26
Pelargonic acid 750 ppm	336	20.0	66	3
Pelargonic acid 1500 ppm	372	23.4	71	0
Pelargonic acid 3000 ppm	333	19.3	69	0
Sulfcarbamide 1000 ppm	343	22.3	76	3
Sulfcarbamide 2000 ppm	331	21.6	72	5
Sulfcarbamide 4000 ppm	261	18.8	81	7
LSD 5%	47.5	3.8	12.7	11.0

3.2.4.1: Conclusions concerning the use of pelargonic acid or sulfcarbamide as thinners for Gala clones.

- Pelargonic acid showed no promise as a flower thinner for Royal Gala when sprayed at 750 – 3000 ppm in high volume at the time of full bloom.
- Sulfcarbamide (Wilthin) showed adequate thinning activity when applied at 4000 ppm, but this concentration was above the recommended dose approved in the USA

3.2.5 Benzyl adenine as a fruitlet thinner for Royal Gala

1995 Trial:

In 1995, sprays of benzyl adenine ('Paturyl'formulation) were applied to five-year-old Royal Gala trees planted on M.9 rootstock at HRI-EM. Three concentrations were applied, 50, 100 and 200 ppm and all were sprayed at high volume (1000 l/ha) when the average fruit diameter was 12 mm (26 May). The treated trees were compared with unsprayed controls, with trees hand-thinned to two fruits/cluster at the 12 mm stage and trees sprayed with carbaryl (750 ppm) also at the same 12 mm stage. The trial was designed in six randomised blocks of single tree plots.

Table 16. Effects of benzyl adenine (BA-Paturyl) and carbaryl (Thinsec) sprays on the fruit set and abscission of Royal Gala in 1996

	Fruit set/100 flower clusters		% abscission
Treatment	Initial	Final	Initial – Final set
Control-unthinned	584	370	36
Hand-thinned	232	243	-5
Paturyl 50 ppm	411	280	32
Paturyl 100 ppm	461	269	40
Paturyl 200 ppm	501	285	41
Carbaryl 750 ppm	402	218	46
LSD 5%	78.8	47.2	10.6

For reasons not understood, the fruitlet thinners appeared to reduce initial set, even though this was measured only a short time after the application of the treatments (Table 16). They were not expected to stimulate such a rapid effect. Their main effect was on abscission noted between initial and final set when > 40% of fruitlets abscinded from the treated trees. Nevertheless, these percentages of abscission were not significantly higher than those recorded on the unthinned controls in 1995. Final set/100 floral buds was, however, significantly less than on the unthinned controls for all the Paturyl-sprayed trees and similar to percentages recorded on hand-thinned trees.

Only carbaryl reduced total yields significantly (Table 17). None of the benzyl adenine treatments improved mean fruit size or fruit grades significantly. In contrast, mean fruit size and Class 1 grade-outs following the carbaryl treatment was much improved and similar to those achieved by hand-thinning.

Table 17. Effects of benzyl adenine (BA-Paturyl) and carbaryl (Thinsec) sprays on the yields, fruit sizes and grades of Royal Gala in 1995

	Total yield/tree	Mean fruit wt.	% Class 1 fruits
Treatment	(kg)	(g)	> 65 mm diameter
Control-unthinned	22.2	67.8	1.7
Hand-thinned	23220.8	94.6	25.6
Paturyl 50 ppm	41120.5	76.5	5.4
Paturyl 100 ppm	46118.2	77.2	8.8
Paturyl 200 ppm	50118.9	76.6	6.9
Carbaryl 750 ppm	40218.0	93.9	20.5
LSD 5%	3.7	12.3	10.7

1996 Trial:

In 1996, the same trees used in 1995 were again treated. BA (Paturyl) was sprayed at high volumes at 0.047%, 0.094% or 0.188%, with the addition of Tween 20 (0.1%) surfactant, when the fruitlets on the old wood were an average diameter of 12 mm (10 June). The spray treatments were compared with unsprayed trees and with trees hand-thinned to one fruit/spur cluster at the same time (10 June).

Although all the trees sprayed with Paturyl in 1995 appeared to produce more flower clusters than the controls in spring 1996, this effect was only statistically significant for the 50 ppm treatment, which developed similar flower cluster numbers to the hand-thinned trees (Table 18). However, after adjustments to take account of tree size (using trunk cross sectional area) the positive effects on flower bud number of both the 50 ppm and 200 ppm treatments were statistically significant.

In contrast to 1995, no treatment effects on initial fruit set/100 flower clusters were observed. All three Paturyl concentrations reduced final fruit set/100 flower clusters to a similar degree, but these effects were small and final fruit set percentages on the hand-thinned trees were less than half those on the unsprayed trees. Initial fruit set numbers/tree (adjusted for tree size) were higher than on the controls for the 50 ppm and 200 ppm Paturyl treatments. Similar increases were noted in final set numbers/tree, although this was only statistically significant for the 50 ppm Paturyl treatment.

Table 18. Effects of benzyladenine (BA-Paturyl) sprays on the fruit set of Royal Gala in 1996

	Fruits/100 clusters		Fruits per cm^2+	
Treatment	Initial	Final	Initial	Final
Control	328.4	312.9	18.1	17.3
Hand-thinned	96.5	114.6	9.4	11.2
Paturyl 50 ppm	321.0	245.3	35.3	25.6
Paturyl 100 ppm	307.2	241.5	26.8	20.7
Paturyl 200 ppm	345.9	241.3	36.1	22.7
LSD 5%	43.58	44.60	11.54	6.42

+ per cm^2 trunk cross sectional area

None of the Paturyl treatments affected total yields/tree (Table 19). Mean individual fruit weight was increased by hand-thinning but reduced on the trees sprayed with 50 ppm Paturyl.

Table 19. Effects of benzyl adenine (BA-Paturyl) sprays on the yield and fruit size of Royal Gala in 1996

			% Class 1		kg/tree Class 1	
Treatment	kg/tree	Mean fruit wt. (g)	> 70 mm	> 65 mm	> 70 mm	> 65 mm
Control	20.2	91.9	2.8	16.4	0.30	2.3
Hand-thinned	17.7	111.8	9.5	49.8	1.47	8.5
Paturyl 50 ppm	23.3	75.9	0.0	2.0	0.00	0.5
Paturyl 100 ppm	19.9	86.4	0.2	4.2	0.03	0.8
Paturyl 200 ppm	21.9	81.4	1.0	10.3	0.14	1.8
LSD 5%	5.64	15.29	7.36	20.35	0.98	2.79

Only hand-thinning increased the weight of fruits harvested in the Class 1 > 70 mm diameter category.

No trials were conducted with BA (Paturyl) in 1997. The severe frost damage to plots in April rendered the fruitlet thinning treatments inappropriate.

In 1998, three products containing BA, Paturyl, Accel (Abbott Labs. Inc.) and Perlan (Fine Agro Chemicals Ltd.) were compared as fruitlet thinners for Royal Gala. Eight-year-old trees on M.9 rootstock were sprayed at high volume (1000 l/ha) with 100 ppm active ingredient of each of the three products. The sprays were all applied at the 12 mm fruitlet diameter stage and the treated trees were compared with unsprayed controls and trees hand-thinned to 1 fruit/cluster at the 12 mm stage.

None of the treatments reduced significantly the final fruit set/100 floral buds, nor the total yields (Table 20). However, all three treatments improved the percentage grade-out of fruits Class 1 > 65 mm in diameter and also had a small effect on mean fruit size.

A similar effect was observed in another trial where BA (Perlan – 100 ppm) was sprayed on Royal Gala at the 12 mm stage (data not shown).

Table 20. Effects of sprays of benzyl adenine (Paturyl, Accel or Perlan) on the fruit set, yield and fruit size of Royal Gala in 1998

Treatment	Final set/100 floral buds	Yield/tree (kg)	% Class 1 > 65 mm	Mean fruit wt. (g)
Control-unthinned	146	24.5	11.5	94
Hand-thinned	52	12.8	59.4	125
Paturyl	140	25.2	39.7	111
Accel	132	26.5	30.8	101
Perlan	126	26.1	29.7	109
LSD 5%	36.6	6.9	15.6	12.5

3.2.5.1 Conclusions concerning the use of benzyl adenine as a thinner for Gala clones

- Sprays of Paturyl (BA) applied in 1995 at the 12 mm stage reduced final fruit set/100 floral buds to levels similar to those achieved with hand-thinning.
- None of the Paturyl treatments improved fruit size significantly in 1995. In contrast, carbaryl, which induced more thinning and reduced yields, did increase fruit size and grade-out.
- Paturyl treatments in 1995 increased flower numbers formed on trees in 1996.
- Treatments in 1996 reduced final fruit set/100 floral buds but much less than achieved by hand-thinning.
- Thinning achieved with Paturyl in 1996 was insufficient to improve fruit size and grade-out. This was caused, partly by the increased flower abundance on the treated trees, as a result of the sprays applied in 1995.
- Comparisons of three formulations of benzyl adenine (Paturyl, Perlan and Accel) in 1998 showed that sprays (100 ppm) applied at the 12 mm fruitlet diameter stage improved the fruit grade-out without reducing total yields.
- It is concluded that sprays of benzyl adenine are inconsistent in their efficacy in thinning Gala clones. More research is needed to alleviate these inconsistencies.

3.2.6 Combinations of the chemical spray treatments for thinning Royal Gala

Successful thinning treatments that were used in North America for many years comprised sprays of a blossom thinner such as DONOC (Elgetol) followed later by sprays of carbaryl at the 10-12 mm diameter stage. Such combinations of blossom thinning followed by fruitlet thinning are thought to provide the best strategy for fruit growers.

In 1998, combinations of a blossom thinner followed by a fruitlet thinner were tested on eight-year-old Royal Gala trees. The blossom thinner used was ATS (Thiosul) at either 0.5% or 1.0% applied at full bloom on the spur wood (May 1). The fruitlet thinner used was benzyl adenine (Perlan) at 100 ppm applied at the 12mm fruitlet diameter stage (20 May). All sprays were applied at high volume (1000 l/ha) and the ATS sprays included the surfactant (wetter) Tween 20. The spray treatments were compared with unthinned trees and with trees hand-thinned to 1 fruit/cluster at the 12mm diameter stage. Both of the treatments combining ATS and BA reduced final set/100 floral buds, and the treatment including 1.0% ATS also reduce total yields (by 23%) (Table 21).

Table 21. Effects of combinations of ATS and BA on the fruit set, yield, and fruit size of Royal Gala in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	kg/tree Class 1 > 70 mm	> 65 mm
ATS + BA 0.5%	131	23.7	122	12.5	52
ATS + BA 1.0%	105	21.2	130	13.0	62
Unthinned	183	27.7	101	6.8	25
Hand-thinned	66	142	138	10.9	78
LSD 5%	38.7	5.8	14.9	3.6	15.8

The hand-thinning treatment reduced total yields much more (49%). The weight of fruit harvested/tree in the Class 1 > 65 mm grade was more than doubled by the two combination treatments and in this respect they were more beneficial than hand-thinning.

3.2.6.1 Conclusions concerning the use of combined chemical treatments for thinning Gala clones

- Combination treatments, comprising sprays of ATS applied at full bloom followed by BA sprays applied at the 12mm fruitlet diameter stage, have shown promise for thinning Gala clones. Such combinations need further testing.

3.3 Results of Thinning Trials on the Variety Queen Cox

3.3.1 ATS as a flower thinner for Queen Cox

1995 Trial:

In 1995, ATS was sprayed at high volume (100 l/ha) to five-year-old Queen Cox trees planted on M.9 rootstock at HRI-EM. Concentrations of 5000, 10000 and 15000 ppm (0.5%, 1.0% or 1.5%) were compared. The surfactant polyoxyethylene sorbiton (Tween 20) was added to the sprays at 0.1%. The sprays were applied at 80% open flower (full bloom) on 3 May and treated trees were compared with untreated controls and with trees hand-thinned to 2 fruits/flower cluster on 26 May, when the average fruitlet diameter was 12 mm. The trial was designed in six randomised blocks of single tree plots.

All three ATS treatments reduced initial fruit set slightly more severely than the hand-thinning (Table 22). Fruit abscission thereafter was similar on hand-thinned and trees sprayed with 0.5% ATS but slightly increased on trees treated with 1.0% or 1.5% ATS

Table 22. Effects of ATS sprays on the fruit set and abscission of Queen Cox trees in 1995

Treatment	Fruit set/100 floral buds Initial	Fruit set/100 floral buds Final	% abscission Initial to Final set
Control unthinned	232	105	55
Hand-thinned	160	109	30
ATS 0.5%	130	80	33
ATS 1.0%	131	64	44
ATS 1.5%	136	54	59
LSD 5%	48.0	39.5	19.5

Final set/100 floral buds was lowest on trees treated with 1.0% or 1.5% ATS.

At harvest, total yields/tree were reduced significantly by the ATS 1.5% but only slightly by the two lower concentration treatments (Table 23). The average individual weights of fruits were increased significantly by the 1.0% and 1.5% spray treatments. All three ATS treatments increased the percentages of fruits harvested in the > 65 mm diameter size categories.

Table 23. Effects of ATS sprays on the yields, fruit size and grades of Queen Cox in 1995

Treatment	Total yield/tree (kg)	Mean fruit wt (g)	% Class 1 fruits > 70 mm	% Class 1 fruits > 65 mm
Control unthinned	13.0	84.3	9.6	12.5
Hand-thinned	13.9	82.0	2.3	9.8
ATS 0.5%	12.6	100.8	10.1	32.2
ATS 1.0%	10.7	108.8	12.4	37.5
ATS 1.5%	9.4	119.0	19.4	39.4
LSD 5%	3.3	22.0	17.3	16.4

1996 Trial:

In 1996, ATS treatments were applied to the same trees used in 1995. Sprays were again applied at high volumes and at concentrations of 0.5%, 1.0% and 1.5% to trees at 80% open flower (15 May). The surfactant Tween 20 (0.1%) was again added to the sprays. Comparisons were made with unthinned trees and also with trees hand-thinned to 2 fruit/flower cluster. Hand thinning was carried out when fruitlets were approximately 12 mm in diameter (10 June). The trial was designed in six randomised blocks of single tree plots.

Table 24. Effects of sprays of ATS on the fruit set of Queen Cox in 1996

Treatment	Flower clusters /tree	Flower clusters /cm^2	Fruits/100 clusters Initial	Fruits/100 clusters Final	Fruits/cm^2+ Initial	Fruits/cm^2+ Final
Control	90.3	5.5	144.1	164.6	7.3	7.2
Hand-thinned	93.2	6.0	115.5	121.0	6.4	6.7
ATS 0.5%	165.8	10.0	100.1	107.7	9.6	10.1
ATS 1.0%	252.8	15.0	73.3	62.1	10.9	9.3
ATS 1.5%	211.7	12.1	77.7	63.4	9.3	7.6
LSD 5%	86.19	4.51	40.95	46.77	4.80	4.10

+ per cm^2 trunk cross sectional area

ATS treatments applied in 1995 increased significantly the flower cluster numbers developing in spring 1996; this effect was greatest following the 1.0% sprays in 1995 (Table 24). Hand-thinning in 1995 had no effect on flower cluster numbers in 1996.

Initial set/100 flower clusters was reduced by all three spray concentrations of ATS, although the largest effects were noted following either the 1.0% or 1.5% sprays, which reduced set numbers much more than hand-thinning. Few fruits abscinded between initial and final set and the treatment differences noted early in the season persisted until just prior to harvest. The slight increase in set noted on the hand-thinned trees was attributable to the setting of late-flowering blossoms.

None of the treatments had any statistically significant effect on initial or final fruit set per tree (adjusted for tree size). Total yields per tree similarly were unaffected by any of the treatments, although trees treated with ATS all bore slightly (but not statistically significant) more fruits (Table 25). Mean fruit size was reduced on the trees treated with either 0.5% or 1.0% ATS and the percentages of fruits graded in the Class 1 > 70 mm diameter category were also less following these treatments. None of the treatments, including hand-thinning, increased yields of fruits in this highest size grade in 1996.

Table 25. Effects of sprays of ATS on the yield and fruit grades of Queen Cox in 1996

Treatment	kg/tree	Mean fruit wt (g)	% kg Class 1 > 70 mm	% kg Class 1 > 65 mm	kg/tree Class 1 > 70 mm	kg/tree Class 1 > 65 mm
Control	11.0	122.7	24.4	43.7	2.0	4.5
Hand-thinned	11.6	125.3	39.0	63.5	3.7	6.7
ATS 0.5%	14.0	94.5	13.3	30.5	1.9	4.5
ATS 1.0%	13.8	91.8	7.0	28.2	0.8	3.6
ATS 1.5%	12.7	106.3	17.9	39.6	2.3	5.0
LSD 5%	4.58	26.52	21.33	25.01	2.19	3.13

1997 Trial:

In 1997, sprays of ATS (Thiosul) were applied to 8-year-old Queen Cox trees at full bloom (18th April). The sprays were applied at high volume (1000 l/ha) at either 1.0% or 1.5% active ingredient together with the wetter Tween 20 (0.1%). Two further treatments compared the same two concentrations of ATS in combination with hand-thinning (2 fruits/cluster) carried out at the 12 mm fruitlet diameter stage. Another treatment examined the thinning efficacy of ATS (1.0%) applied at both 40% and 80% open flower stages (15th April). All the treatments were compared with unthinned trees and trees hand-thinned to 2 fruits/cluster at the 12 mm stage.

Severe frost occurred at blossom time in 1997 just after the ATS sprays were applied. The damage was significant, even though the experimental orchard had some protection using overhead irrigation. All of the ATS treatments reduced final fruit set/100 floral buds (Table 26).

Table 26. Effects of ATS and hand-thinning treatments on the fruit set, yield and fruit size of Queen Cox in 1997

Treatment	Fruit set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)
Control unthinned	58	13.3	128
Hand-thinned (HT)	47	11.5	128
ATS 1.0%	47	11.4	146
ATS 1.5%	38	7.8	142
ATS 1.0% + HT	43	11.5	144
ATS 1.5% + HT	37	9.1	149
ATS 1.0% at 40% and 80% full bloom	32	8.9	134
LSD 5%	21.5	4.5	18.9

The trees treated with two sprays of ATS (40% and 80% full bloom) showed a significant reduction in final set. Although other treatments reduced the final set averages, these effects were not statistically significant. Total yields were reduced on the trees sprayed with 1.5% ATS more than on trees sprayed with 1%. Mean fruit size was largest on the trees treated with 1.5% ATS that were also hand thinned. Good fruit size and minimal reductions in yields were achieved by the sprays of 1.0% ATS.

1998 Trial:

In 1998, a trial on 8-year-old Queen Cox compared three formulations of ATS as blossom thinners. Sprays of Thiosul (Hydratek), F3000 (Phosyn) and CMF (Common Market Fertilisers) were compared. All were sprayed at high volume (1000 l./ha) at 1.5% together with 0.1% Tween 20.

All the sprays reduced final set/100 floral buds; the most severe effect was initiated by the CMF formulation (Table 27). Total yields/tree were also reduced by the sprays and yields of Class 1 > 65 mm diameter fruits increased by two of the treatments, F3000 and Thiosul.

Table 27. Effects of ATS spray formulations on the fruit set and yield of Queen Cox in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Yield/tree of Class 1 > 65 mm diameter (kg)
Thiosul	52	12	8.7
F3000	51	12	8.8
CMF	36	9	6.2
Unthinned	97	16	6.5
LSD 5%	24.2	3.0	2.33

3.3.1.1. Studies on the sensitivity of Queen Cox blossoms to ATS in relation to their time of opening

In 1998, a study was made using one eight-year-old tree of Queen Cox to determine if flowers sprayed at different stages of development differed in their sensitivity to ATS.

At full bloom (May 1st) whole trees of Queen Cox were treated with high volume sprays of ATS (1.5% a.i. Thiosul). Just prior to spraying, each flower bud on the tree was labelled according to its type (spur, terminal, axillary) and stage of development. Four categories of blossoms were apparent at the time of spraying: 1) spur or terminal clusters fully open; 2) spur or terminal clusters king blossom only open; 3) spur or terminal clusters all flowers at balloon stage and 4) axillary clusters at late pink bud.

The effects of the sprays on fruit set were recorded in late June and the results are shown in Table 28. This shows that sprays to clusters on which all the flowers were open completely ihibited fruit set. Sprays to clusters with only the king blooms open also reduced fruit set severely (to 11%) on Queen Cox. However, where clusters were either at balloon (spur and terminal) or the late pink bud (axillary) stages, fruit set was much higher (46-60%). This is despite the apparent severe petal necrosis observed on all flowers two days after spraying. More than half of the persisting fruitlets remained as the desired singles (i.e. on fruit/floral bud).

Table 28. Sensitivity of Queen Cox flowers to sprays of ATS

	Full open	King only open	Balloon	Pink bud
<u>Queen Cox</u>				
% of clusters setting fruits	0	11.1	60.5	55.3
% of fruits/flower bud:				
singles	-	4	37	39
doubles	-	7	14	13
> doubles	-	-	9	3

The flower cluster size and their times of opening in 1998 were also monitored. Each flower bud developed between 1-8 flowers. On each recorded branch there was an average ranging from 4.5-5.8 flowers/bud on spurs (two-year or older wood) and from 5.5-6.8 flowers/bud on the terminals. Axillary flowers formed on only one of the 8 sampled branches of Queen Cox.

The detailed records made of the numbers of flowers produced showed slight branch to branch variations, as did the proportions of each floral bud type. Of the total numbers of flowers on each branch:
13.0%-18.5% were king flowers on spur and terminal buds.
66%-83% were lateral flowers (i..e. all flowers other than king flowers) on spur and terminal buds.
20% were axillary flowers.

The cumulative percentages of each blossom type opening on each day are shown in Figure 3. King flowers on spur or terminal buds began opening on April 22nd and finished on 9th May. The lateral flowers on spurs and terminals began opening only 1 day later, on April 23rd and their opening was also completed by the 9th May. Axillary blossoms opened much later, beginning on May 7th and 9th (king and lateral respectively) and finishing on May 12th and 15th (king and lateral respectively). This extended flowering season resulting in quite small percentages of the total blossoms on the trees opening on any one day.

It can be seen that, at the time of spraying ATS, on May 1st, 50% of the king flowers and 30% of the lateral flowers on spur and terminal clusters had opened. In contrast, none of the axillary blossoms had opened by May 1st. From the sensitivity tests conducted using ATS (see above section of report), clusters with at least one flower open seemed to be the most sensitive and few fruits set on such clusters when sprayed with ATS. The flowering records on Queen Cox show that at the time of spraying on May 1st, just under half of the spur and terminal clusters on the trees were at this vulnerable stage, whereas none of the axillary clusters was.

The information on flower-opening times was also used, in combination with climate data, to assess the potential for successful pollen transfer, germination and growth down the style. It can be seen from Figure 4 that, during the period when most spur and terminal blossoms were opening (26 April - 6 May), mean daily temperatures were less than 10^{o}C, much lower than desirable. Only later, when the axillary blossoms comprised the majority of blossoms opening, did temperatures climb to higher and more desirable levels.

Figure 3

Figure 4

3.3.1.2: Conclusions concerning the use of ATS as a thinner for Queen Cox

- ATS sprays at 1/0% and 1.5% a.i. increased the mean fruit size and improved the grade out of Queen Cox fruits in 1995.
- ATS sprays at 1.5% reduced total yields in 1995
- Trees treated with ATS in 1995 bore significantly more blossoms in 1996
- Although repeating the treatments on the same trees in 1996 reduced initial and final set / 100 floral buds (as in the previous year) this thinning was insufficient on account of the increased blossom density.
- It is concluded that, if treatments result in increased blossom density, spray concentrations or frequency may need to be increased in order to achieve adequate thinning with ATS.
- In the severe frost year of 1997 spraying trees with ATS (1.0%) at blossom time did not increase the severe yield reduction caused by the frost. Sprays at 1.5% did increase the yield reduction.
- In 1998, trials showed that several formulations of ATS were equally effective in thinning Queen Cox, although one formulation did cause slightly more phytotoxicity.

3.3.2 Endothallic acid as a flower thinner for Queen Cox

1995 Trial:

In 1995, endothallic acid (TD2337-2) was sprayed at high volume (100 l/ha) to five-year-old Queen Cox trees planted on M.9 rootstock at HRI-EM. Concentrations of 500, 1000 and 2000 ppm were compared and all were applied at the 80% flower open (full bloom) stage on 3 May. The treated trees were compared with unthinned trees and with trees hand-thinned to two fruits/cluster at the 12mm diameter fruitlet stage (26 May). The trial was designed in six randomised blocks of single tree plots.

All of the TD treatments reduced initial set and the severity of the effect was associated with spray concentrations (Table 29).

Table 29. Effects of endothallic acid (TD) sprays on the fruit set and % abscission on Queen Cox trees in 1995

	Fruit set/100 floral buds		% abscission
Treatment	Initial	Final	Initial to Final set
Control unthinned	232	105	55
Hand-thinned	160	109	30
TD 500 ppm	175	91	47
TD 1000 ppm	99	67	33
TD 2000 ppm	78	48	38
LSD 5%	48.0	39.5	19.5

Final fruit set was significantly reduced by the highest concentration treatment and slightly, albeit not statistically significantly, by the 1000 ppm treatment.

Total yields were reduced by the highest concentration sprays of TD (2000 ppm), but not significantly by the other TD treatments Table 30). Mean individual fruit weight was also increased by the TD sprays at 1000 and 2000 ppm. However, the increases in the percentages of fruits harvested in the larger size categories, that were recorded on the TD sprayed trees, were not statistically significant.

Table 30 Effects of endothallic acid (TD) sprays on the total yields, mean fruit size and grades of Queen Cox in 1995

	Total yield/tree	Mean fruit wt	Class I fruits (%)	
Treatment	(kg)	(g)	>70mm diameter	65-70mm diameter
Control	13.0	84.3	9.6	12.5
Hand-thinned	13.9	82.0	2.3	9.8
TD 500 ppm	12.4	94.9	10.6	17.7
TD 1000 ppm	10.1	104.6	10.7	35.8
TD 2000 ppm	8.4	111.3	19.3	25.0
LSD 5%	3.4	22.0	17.5	17.0

1996 Trial:

In 1996, endothallic acid (TD2337-2) was sprayed again at high volume (1000 l/ha) to the same trees used for the trial in 1995. Sprays of 500, 1000 or 2000 ppm (0.05%, 0.10% or 0.20%) were applied at the 80% open flower (15 May) stage. No additional wetter was included. Comparisons were made with unthinned trees and trees thinned to 2 fruits/cluster at the 12 mm stage (10 June). The trial was designed in six randomised blocks of single tree plots.

Table 31. Effects of sprays of endothallic acid (TD) on the fruit set of Queen Cox in 1996

Treatment	Flower clusters /tree	Fruits/100 clusters Initial	Fruits/100 clusters Final	Fruits/cm^2+ Initial	Fruits/cm^2+ Final
Control	90.3	144.1	164.6	7.3	7.2
Hand-thinned	93.2	115.5	121.0	6.4	6.7
TD 500 ppm	157.0	130.8	122.7	12.3	11.3
TD 1000 ppm	202.8	90.4	81.1	11.2	10.0
TD 2000 ppm	293.4	37.0	39.9	5.7	5.7
LSD 5%	86.2	40.95	46.77	4.80	4.10

+ per cm^2 trunk cross sectional area

Two of the TD sprays applied in 1995 (1000 and 2000 ppm) increased significantly the numbers of flowers produced on the trees in 1996 (Table 31). This effect was similar to the effect noted on Royal Gala (see above). These same treatments, when repeated in 1996, again reduced initial and final fruit set/100 flower clusters. The effects of the lowest concentration spray (25 ppm) were not statistically significant. None of the treatments affected total yields although a small, though non-significant, increase was recorded on trees treated with the lowest and intermediate TD concentrations (Table 32).

Mean individual fruit weight was reduced on the trees sprayed with the two lower TD concentrations. No statistically significant differences in the weights or percentages of yields in the Class 1 > 70 mm diameter category were recorded, although the means from the two lower spray concentration treatments indicated some reductions.

Table 32. Effects of sprays of endothallic acid (TD) on the yields and grades of Queen Cox in 1996

Treatment	kg/tree	Mean fruit wt (g)	% Class 1 > 70 mm	% Class 1 > 65 mm	kg/tree Class 1 > 70 mm	kg/tree Class 1 > 65 mm
Control	11.0	122.7	24.4	43.7	2.0	4.5
Hand-thinned	11.6	125.3	39.0	63.5	3.7	6.7
TD 500 ppm	13.9	85.2	5.6	30.5	1.0	2.8
TD 1000 ppm	13.5	98.0	13.4	28.2	1.7	3.9
TD 2000 ppm	11.5	117.8	28.2	39.6	3.2	5.8
LSD %%	4.58	26.52	21.33	25.01	2.19	3.13

3.3.2.1 Conclusions concerning the use of endothallic acid as a thinner for Queen Cox

- Endothallic acid (TD) sprayed at 1000 or 2000 ppm significantly reduced the initial and final fruit set on Queen Cox trees in 1995
- Yields were reduced by sprays of endothallic acid at 2000 ppm but not by sprays at lower concentrations in 1995
- Fruit size and grade out were increased significantly by the 2000 ppm sprays in 1995. The percentage of fruits in the >65mm grade was increased by sprays of endothallic acid at 1000 ppm in 1995
- In 1996, flower bud numbers / tree were increased significantly on the trees sprayed with TD in 1995
- Although the TD sprays, which were repeated in 1996 on the same trees, again reduced both initial and final fruit set/100 floral buds, mean fruit size and grade outs were not improved. The sprays thinned insufficiently to compensate for the increased flower densities on the sprayed trees.

3.3.3 Pelargonic acid and sulfcarbamide as blossom thinners for Queen Cox

Pelargonic acid (Thinex) and sulfcarbamide (Wilthin), with proven efficacy as blossom thinners in the USA, were tested on Queen Cox in 1995. They had previously shown some promise in 1994 as blossom thinners in branch unit tests on self-fertile clones of Cox. The trial in 1995 was conducted on 5-year-old trees of Queen Cox on M.9 rootstock. Sprays, which were applied at full bloom, were at high volume (1000 l/ha) and included 0.1% Tween 20 wetter. Three spray concentrations of pelargonic acid (750, 1500 or 3000 ppm) were compared with three concentrations of sulfcarbamide (1000, 2000 or 4000 ppm) with unsprayed controls and with trees hand-thinned to 2 fruits/cluster at the stage when fruitlets were 10-12 mm in diameter (26th May). The trial was designed in six randomised blocks of single tree plots.

The pelargonic acid sprays had no effect on the final set/100 floral buds or final fruit numbers/tree (Table 33). Only the highest concentration spray of Wilthin (4000 ppm) reduced final set slightly.

Table 33. Effects of full bloom sprays of pelargonic acid or sulfcarbamide on the fruit set, yield and fruit size of Queen Cox in 1995

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt.	Class 1 fruits % > 70 mm	Class 1 fruits % > 65-70 mm
Unthinned control	105	13.0	84.3	9.6	12.5
Hand-thinned	109	13.9	82.0	2.3	9.8
Pelargonic acid					
750	114	14.7	87.8	0.8	15.0
1500	109	14.6	88.0	1.3	18.6
3000	96	11.9	84.6	4.0	13.9
Sulfcarbamide					
1000	106	13.8	90.8	0.4	16.1
2000	92	12.5	89.2	1.9	23.6
4000	67	11.2	130.8	34.6	17.0
LSD 5%	28.5	3.76	23.72	18.88	19.25

Only one treatment, sulfcarbamide at 4000 ppm increased mean fruit size and the percentages of fruits in the larger size grades.

3.3.3.1 Conclusions concerning the use of pelargonic acid and sulfcarbamide as blossom thinners for Queen Cox

- Pelargonic acid proved to be a poor blossom thinner for Queen Cox at the concentrations tested, even though it caused significant petal and primary leaf necrosis
- Sulfcarbamide was only effective as a blossom thinner for Queen Cox at a concentration of 4000 ppm, which is higher than the rates recommended in the USA.

3.3.4 Benzyl adenine as a fruitlet thinner for Queen Cox

1995 Trial:

In 1995, sprays of benzyl adenine, (Paturyl 10 WSC, a 10% ai proprietary formulation manufactured and sold in Hungary as a branching agent for nursery trees), was compared at three concentrations: 50, 100 and 150 ppm, with carbaryl (Thinsec at 750 ppm) as fruitlet thinners for Queen Cox. The trial was conducted on 5-year-old trees on M.9 rootstock and the sprays were applied at high volume (1000 l/ha) at the 10-12 mm fruitlet diameter stage. Tween 20, a wetter, (surfactant) was included at 0.1% in all the sprays. The sprayed trees were compared with unthinned controls and with trees hand-thinned to 2 fruits/cluster at the 12 mm stage.

All the spray treatments reduced final fruit set (Table 34) but this effect was just short of statistical significance for the BA treatments. None of the treatments reduced total yields significantly but the reduction was almost significant for the carbaryl treatment. All of the treatments increased mean fruit weight, although the effect of 50 ppm BA was just short of significance. The treatment using 150 ppm BA had the most beneficial effect on increasing the percentage of fruit > 70 mm in diameter. This treatment, the BA 200ppm and the carbaryl treatments increased the percentages of fruits in the 65-70 mm in diameter.

Table 34 Effects of benzyladenine (BA-Paturyl) sprays on the fruit set and yields of Queen Cox in 1995

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit weight (g)	Class 1 (%)	
				>70mm diameter	65-70mm diameter
Control – unthinned	105	13.0	84.3	9.6	12.5
Hand-thinned	109	13.9	82.0	2.3	9.8
BA 50ppm	75	11.8	105.0	17.0	25.3
BA 100ppm	66	11.0	107.6	13.6	37.1
BA 200ppm	68	11.4	116.2	38.3	29.9
Carbaryl 750 ppm	54	9.8	117.9	20.1	52.9
LSD (5%)	39.5	3.3	22.0	17.3	16.4

1996 Trial:

In 1996, BA (Paturyl) was sprayed to the same trees used in 1995, at high volumes at 50, 100 or 200 ppm with the addition of Tween 20 (0.1%) surfactant, when the fruitlets on the old wood were an average diameter of 12 mm (10 June). The spray treatments were compared with unsprayed trees and with trees hand-thinned to 2 fruits/spur cluster at the same time (10 June). All trees treated with Paturyl in 1995 developed more flower clusters than the control trees in 1996, although this effect was only statistically significant for the trees treated with 200 ppm (Table 35).

After adjustments to take account of tree size, the 100 ppm treatment also showed statistically significant increases in flower cluster density. Initial set/100 flower clusters was reduced on the trees treated with 50 ppm Paturyl and increased on those treated with 200 ppm. This cannot be attributable to the sprays in 1996, which had not been applied at the time of initial set counts, and must be a direct or indirect effect of the treatments in the previous season. All Paturyl treatments reduced final set/100 clusters to similar levels. Initial fruit set/tree (adjusted for tree size) was more than doubled on the trees treated with the two higher concentrations of Paturyl and, although slightly diminished by subsequent fruitlet abscission, this increase persisted through to final set.

Table 35 Effects of sprays of benzyl adenine (BA-Paturyl) on the fruit set of Queen Cox in 1996

	Fruits/100 clusters		Fruits cm^2+	
Treatment	Initial	Final	Initial	Final
Control	144.1	164.6	7.3	7.2
Hand-thinned	115.5	121.0	6.4	6.7
Paturyl 50 ppm	95.5	96.4	7.7	8.2
Paturyl 100 ppm	153.1	118.0	15.4	11.3
Paturyl 200 ppm	194.0	105.9	22.6	11.8
LSD 5%	40.95	46.77	4.80	4.10

+ per cm^2 trunk cross sectional area

Total yields/tree were highest on the trees treated with 200 ppm Paturyl and these trees, not unexpectedly, produced the smallest mean individual fruit weights (Table 36). No significant treatment differences were recorded in the weights or percentages of yields in the Class 1 > 70 mm diameter category, although the hand-thinned trees performed best in this respect.

Table 36 Effects of benzyl adenine (BA-Paturyl) sprays on the yield and grades of Queen Cox in 1996

			% Class 1		kg/tree Class 1	
Treatment	kg/tree	Mean fruit wt. (g)	> 70 mm	> 65 mm	> 70 mm	> 65 mm
Control	11.0	122.7	24.4	43.7	2.0	4.5
Hand-thinned	11.6	125.3	39.0	63.5	3.7	6.7
Paturyl 50 ppm	11.1	105.6	23.7	43.2	1.8	3.7
Paturyl 100 ppm	12.6	95.8	18.8	35.9	1.9	3.8
Paturyl 200 ppm	16.5	85.4	3.7	24.0	0.7	4.2
LSD 5%	4.58	26.52	21.33	25.01	2.19	3.13

1997 Trial:

In 1997, plans to test benzyl adenine were abandoned following severe frost damage to the experimental trees at blossom time. No trials using BA were conducted on Queen Cox in 1998.

3.3.4.1 Conclusions concerning the use of benzyl adenine as a fruitlet thinner for Queen Cox

- Sprays of BA applied at the 12mm fruitlet diameter stage to Queen Cox trees in 1995 reduced final fruit set/100 floral buds and increased mean fruit size and grade out of the larger sized fruits
- The most effective spray concentration was 100ppm applied at high water volumes.
- No significant reductions in total yield were caused by the sprays in 1995
- Trees treated in 1995 bore many more flowers in the spring of 1996
- Repeating the treatments in 1996 again reduced final fruit set / 100 floral buds
- The thinning stimulated on the trees in 1996 was insufficient to compensate for the increased flowering and fruit size was not increased by the treatments in this second year

3.4 Results of thinning trials on Jonagold

3.4.1 ATS as a flower thinner for Jonagold

1997 Trial:

The first trial on Jonagold (Crowngold) was carried out in 1997 on 7-year-old trees on M.9 rootstock planted at 4.0 x 2.0 m and trained as slender spindles. Three concentrations of ATS (Thiosul), 0.5, 1.0 and 1.5% were compared in high volume sprays (1500 l/ha) applied at full bloom on 21 April.

Frost damage was severe in 1997 and the results of this trial should be interpreted with caution. Following the severe frost damage no hand-thinning was carried out. Yields were very low, such that even on the unthinned control trees, 90% of harvested fruit were Class 1 > 70 mm.

Table 37 Effects of ATS sprays on the fruit set, yield and fruit size of Jonagold in 1997

				Class 1 > 70 mm	
Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	kg/tree	%
Control	44.1	12.2	268	11.1	90
Hand-thinned*	54.5	14.5	294	13.0	89
ATS 0.5%	43.4	10.8	273	10.2	94
ATS 1.0%	33.3	9.7	286	9.0	93
ATS 1.5%	25.4	8.0	300	7.1	90
LSD 5%	15.9	3.7	NS	3.4	NS

*no hand-thinning was necessary

The ATS treatments reduced final set and yields but had no beneficial effect on fruit size or grades (Table 37). The main observation of interest from this trial was that even when frost damage to flowers was severe, the ATS had an additive effect and reduced yields further. On other varieties (e.g. Cox) trees compensated for the effect of frost and the ATS effect was not additive as here.

1998 Trials:

In 1998, ATS sprays were tested as blossom thinners on Jonagold trees as part of three separate trials. In one trial on 8-year-old trees on M.9, ATS (1% ai) was sprayed (high volume) at full bloom on spur wood; 0.1% Tween 20 wetter was added to the sprays. Sprayed trees were compared with unthinned controls and trees hand-thinned to 1 fruit/cluster at the 12 mm diameter stage. The trial was designed in six randomised blocks of single tree plots.

In this trial the ATS sprays had no significant effect on the final fruit set, yield or fruit size of Jonagold (Table 38).

Table 38. Effects of ATS sprays on the fruit set, yield and grades of Jonagold in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	Class 1 > 90 mm kg/tree	Class 1 > 90 mm %
Control	62.1	39.2	186	0.2	0.1
Hand-thinned*	34.2	29.2	262	7.8	27.8
ATS 1.0%	61.9	39.3	201	2.1	6.1
LSD 5%	8.0	6.8	18.2	2.8	8.8

In a second trial conducted in 1998, three different formulations of ATS were compared. Sprays at full bloom of Thiosul (Hydratek), F3000 (Phosyn) and CMF (Common Market Fertilisers Co.), all 1% at high volume (1500 l/ha) and with 0.1% Tween 20 wetter were compared. The trial was designed in six randomised blocks of single tree plots on 8-year-old trees on M.9 rootstock. Unsprayed trees were used as controls.

Table 39. Effects of ATS (1.5% ai) formulations on the fruit set and yield of Jonagold in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Yield/tree of Class 1 > 85mm diameter (kg)
Control unthinned	52	28	1.6
Thiosul 1.5%	49	26	1.0
F3000 1.5%	49	27	1.6
CMF 1.5%	40	24	2.8
LSD 5%	2.1	5.9	1.11

The most severe thinning was induced by the CMF formulation, which also appeared to cause most phytoxicity to spur leaves. The highest yields/tree of Class 1 fruits > 85 mm diameter was induced by the CMF formulation of ATS (Table 39).

The third trial in 1998 on Jonagold examined combinations of ATS with hand-thinning or with BA, as well as evaluating two sequential sprays of ATS applied during the bloom period. Treatments of ATS (Thiosul) at 0.5% or 1.0% sprayed at full bloom on spur wood were compared, as were the same treatments combined with hand-thinning at the 12 mm fruitlet diameter stage. A further treatment comprised 0.5% ATS applied at full bloom on spur wood (30 April) and again at full bloom on axillary blossoms (11 May). The results of trials testing combinations of ATS and BA are described in a subsequent section (3.4.3). The treatments were compared with unthinned control trees and with trees hand-thinned to 1 fruit/cluster at the 12 mm fruitlet diameter stage (26 May). All sprays were applied at high volume (1500 l/ha) and contained 0.1% Tween 20 wetter. The trial was designed in six randomised blocks of single tree plots.

Table 40 Effects of ATS sprays and hand-thinning on the fruit set, yield and fruit size of Jonagold in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 90 mm
Control	56.7	43.6	179	0.5
Hand-thinned (HT)	26.0	29.1	260	32.4
ATS 0.5%	53.0	40.0	176	3.3
ATS 1.0%	48.4	39.4	190	3.1
ATS 0.5% + HT	13.3	15.1	264	40.3
ATS 1.0% + HT	10.0	11.2	265	43.0
ATS 0.5% x 2	47.5	39.0	194	6.2
LSD 5%	8.0	7.8	18.8	9.9

ATS sprays at 1.0% or two sprays at 0.5% had only a small effect on final set and a single spray at 0.5% had no effect (Table 40). None of these treatments reduced set as much as hand-thinning, although, when combined with hand-thinning, the effects were additive. Total yields were reduced and mean fruit size increased only by treatments including hand-thinning. The highest percentages of Class 1 fruits > 90 mm were harvested from trees sprayed with 1.0% ATS and later hand-thinned.

3.4.2 BA as a fruitlet thinner for Jonagold

In 1997, plans to evaluate BA on Jonagold had to be abandoned following severe frost damage to the trees.

In 1998, three formulations of BA were compared as fruitlet thinners for the variety. High volume sprays (1500 l/ha) of Paturyl, Accel (Abbott Labs. Inc.) and Perlan (Fine Agrochemicals Co. Ltd.) were compared when applied at 100 ppm active ingredient to 8-year-old trees on M.9 rootstock. The sprays were applied at the 10-12 mm fruitlet diameter stage (19 May) and the sprayed trees were compared with unthinned trees and trees hand-thinned to 1 fruit/cluster at the 12 mm fruitlet diametre stage (26 May). The trial was designed in six randomised blocks of single tree plots.

None of the BA treatments reduced final set as much as hand-thinning (Table 41). The most effective thinning was using Accel and fruit size at harvest was slightly better using this treatment, which also reduced yields slightly more than sprays of Perlan or Paturyl.

Table 41 Effects of BA sprays on the fruit set, yield and fruit size of Jonagold in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 90 mm
Control	62.1	39.2	186	0.1
Hand-thinned (HT)	34.2	29.2	262	27.8
BA Paturyl	50.5	37.4	223	15.5
BA Accel	42.7	31.8	238	24.1
BA Perlan	52.2	37.2	219	11.3
LSD 5%	8.0	6.8	18.2	8.8

3.4.3 Thinning Jonagold with combinations of ATS and BA

In 1998, a trial was designed to evaluate the effectiveness of combining blossom thinning sprays of ATS (Thiosul) with later fruitlet thinning sprays of BA (Perlan). The trial was conducted on 8-year-old Jonagold trees on M.9 rootstock. The treatments compared ATS sprays at 0.5% or 1.0% combined with BA sprays at 100 ppm and with unthinned trees and trees hand-thinned to 1 fruit/cluster at the 12 mm stage (26 May). The ATS sprays were applied at full bloom on spur wood (30 April) and the BA sprays at the 10mm stage (19 May). All sprays were applied at high volume (1500 l/ha) and contained 0.1% Tween 20 wetter. The trial was designed in six randomised blocks of single tree plots.

The most severe reduction in final set and yield was achieved with hand-thinning and this treatment gave the largest mean fruit size and the highest percentage of Class 1 fruits > 90 mm (Table 42). However, combinations of ATS and BA also reduced final set, albeit less severely. The combination of 0.5% ATS and BA caused no significant loss of total yield but increased mean fruit size and also the percentage of Class 1 fruits > 90 mm in diameter.

Table 42. Effects of ATS and BA spray treatments on the thinning of Jonagold in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 90 mm
Control	56.7	43.6	179	0.5
Hand-thinned (HT)	26.0	29.1	260	32.4
ATS 0.5% + BA	46.8	41.6	208	13.4
ATS 1.0% + BA	36.1	34.0	219	15.4
BA	50.0	41.5	190	4.9
LSD 5%	8.0	7.8	18.8	9.9

3.4.4 Armothin as a flower thinner for Jonagold

In 1998, high volume sprays of 0.5% Armothin were applied to 8-year-old Jonagold trees on M.9 rootstock, 5-10 days after full bloom (8 May).

The treatment had no effect on final fruit set and total yield/tree, but did increase mean fruit size slightly.

3.4.5 Conclusions of the thinning trials on Jonagold

- Although sprays of ATS (0.5% - 1.5%) in some seasons reduced final set/100 floral buds on Jonagold, the results were inconsistent.
- In all of the trials the ATS treatments had no beneficial effects on fruit size or grade out of Jonagold.
- In 1997 the thinning effect of ATS was additive with the severe effect of frost on fruit set
- On the evidence of these trials, ATS seems to no siginificant promise if used on its own as a blossom thinner for the variety Jonagold.
- Armothin also seemed to have no significant promise as a blossom thinner for Jonagold
- Sprays of BA, applied at the 10-12mm fruitlet diameter stage in 1998, improved fruit size and grade out, although this effect was less beneficial than hand-thinning.
- Combined treatments of 0.5% ATS, applied at full bloom, together with 100ppm BA, applied at the 10-12mm fruitlet diameter stage, gave very promising results on this variety

3.5 Results of thinning trials on Bramley's Seedling

3.5.1 ATS as a flower thinner for Bramley's Seedling

1996 Trial:

In 1996, six-year-old Bramley's Seedling on M.9 rootstocks, were sprayed (high volume) at 80% open flower with either 2.0% or 3.0% ATS (Thiosul). The treated trees were compared with unthinned trees and trees hand-thinned to singles at the 12 mm stage.

Yields on the trees were only moderate in 1996 and the unsprayed controls thinned naturally to ideal levels of crop load. ATS (Thiosul) sprays applied at 3.0% reduced significantly final fruit number and total yield/tree and also increased mean fruit weight (Table 43). The 2.0% ATS treatment had no significant effect on any of these parameters.

Table 43. Effects of ATS (Thiosul) sprays on the fruit set, yield and fruit size of Bramley's Seedling in 1996

				Wt. Class 1 fruit in size grades (kg)		
Treatment	Final fruit no./tree	Yield/tree (kg)	Mean fruit wt. (g)	> 100 mm	90-100 mm	80-90 mm
Control	112	22	198	0.6	4.6	8.2
Hand-thinned	113	23	203	1.1	5.5	8.6
ATS 2.0%	106	21	200	0.7	4.8	6.7
ATS 3.0%	59	14	240	1.8	4.1	3.6
LSD 5%	20.3	3.2	22.0	0.87	1.35	1.81

1997 trials:

Frost damage in 1997 caused trials planned for that year to be abandoned.

1998 Trials:

In 1998, three different ATS formulations were compared as blossom thinners for Bramley's Seedling/M.9 trees. Sprays (1.5% ai) of Thiosul (Hydratek), F3000 (Phosyn) and CMF (Common Market Fertilisers Co.) formulations of ATS were sprayed at high volume at full bloom. All three formulations of ATS reduced final set levels and increased the yields/tree of Class 1 > 80 mm fruits (Table 44).

Table 44. Effects of three ATS formulations on the thinning of Bramley's Seedling in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Yield/tree of Class 1 > 80mm diameter (kg)
Control unthinned	104	29	10.2
Thiosul	84	28	12.2
F3000	85	26	11.0
CMF	77	25	12.0
LSD 5%	12.6	4.5	2.7

3.5.2 BA as a fruitlet thinner for Bramley's Seedling

1996 Trial:

One trial was conducted in 1996 with the objective of testing BA (Paturyl) as a fruitlet thinner on Bramley'' Seedling M.9 trees. High volume sprays (1500 l/ha) at either 100 ppm or 200 ppm (active ingredient) were sprayed at approximately the 12 mm fruitlet diameter stage. The sprayed trees were compared with unthinned and tree thinned to 1 fruitlet/cluster at the 12 mm fruitlet diameter stage.

Yields were naturally light on these trees in 1996 and large effects of the treatments were not to be expected.

Table 45. Effects of BA (Paturyl) sprays on the fruit set, yield and fruit size of Bramley's Seedling in 1996

				Wt. Class 1 fruit in size grades (kg)		
Treatment	Final fruit no./tree	Yield/tree (kg)	Mean fruit wt. (g)	> 100 mm	90-100 mm	80-90 mm
Control	112	22	198	0.6	4.6	8.2
Hand-thinned	113	23	203	1.1	5.5	8.6
BA 100 ppm	106	23	221	1.6	7.5	6.7
BA 200 ppm	80	19	244	3.1	5.8	3.9
LSD 5%	20.6	3.5	19.5	1.25	0.73	1.76

Nevertheless, the BA sprays reduced final set and the higher concentration treatment reduced total yields slightly (Table 45). Mean fruit weight and grade-out of large fruits was increased by both of the BA treatments.

3.5.3. Conclusions of the thinning trials on Bramley's Seedling

- In 1996, sprays of 3.0% ATS at full bloom thinned Bramley, increased fruit size but reduced total yields. Sprays at 2.0% had only a small effect.
- In 1998, sprays of three different formulations of ATS, (1.5%) at full bloom, all increased the yields of large fruits
- Sprays of BA (100ppm) in 1998 increased mean fruit size and improved fruit grade out whilst having a negligible effect on total yields/tree.

4. THINNING TRIALS ON PEARS

4.1 Methods used

Almost all of the trials were conducted on semi-mature Conference trees planted on Quince C rootstocks in orchards situated at HRI-East Malling. No trials were conducted on the farms of commercial fruit growers; the legal requirement to destroy all fruits from trees treated with an unapproved chemical over a period of five years after spraying was unacceptable.

The trials focused on testing several new chemicals as flower thinners and one new fruitlet thinning chemical. In all trials the spray-treated trees were compared with unthinned trees and with trees hand-thinned. A few of the trials were carried out in collaboration with other research teams working on thinning in mainland Europe.

All sprays were applied using a knapsack sprayer at volumes equivalent to 100 gallons/ha (1000 litres/ha). Where appropriate, the surfactant polyoxethylene sorbiton monolaurate (Tween 20) was added to the thinning chemicals at a rate of 0.1%.

Numbers of floral buds were counted on each tree in the spring and both initial and final fruit set recorded post petal fall and pre-harvest, respectively. Visual assessments were made of spray phytotoxicity to leaves and fruits. At harvest, fruits were weighed and graded.

4.1.1 Chemicals tested

Most of the trials on pear trees have focused on testing the blossom thinners ATS and endothallic acid (TD), and the fruitlet thinner benzyl adenine (BA). In 1998, a further chemical with activity as a blossom thinner on stone fruits, Armothin, was also tested.

4.2 Results of Thinning Trials on Conference Pear

4.2.1 ATS as a flower thinner for Conference

1995 Trial:

In 1995, a trial to test three concentrations of ATS (laboratory grade formulation at 0.5%, 1.0% and 1.5%) was undertaken on 16 year old Conference trees on Quince C rootstock. The trees were sprayed at full bloom using high volumes (1000l/ha) and the wetter Tween 20 was included in all the sprays at 0.1%. The spray treatments were compared with unthinned trees.

The ATS spray at 1.5% had a small and statistically insignificant effect on the initial fruit set/100 floral buds but the two highest spray concentrations reduced final fruit set/100 floral buds (Table 46). Total yields/tree were also reduced by the sprays of ATS at 1.0% and 1.5%. Although mean fruit sizes appeared to be increased by the ATS treatments, these differences were not statistically significant.

Table 46 Effects of sprays of ATS on the fruit set, yield and fruit size of Conference pears in 1995.

Treatment	Initial set/100 floral buds	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit weight (g)
Control – unthinned	123	46	10.6	126
ATS 0.5%	112	34	9.2	147
ATS 1.0%	117	25	7.0	145
ATS 1.5%	81	20	5.5	150
LSD 5%	52.2	15.7	4.05	25.5

1996 Trial:

In 1996, the laboratory grade formulation of ATS was compared with a commercial proprietary formulation Thiosul. High volume sprays at 2% or 3% were compared with unthinned trees or trees hand-thinned to single fruits/cluster. All sprays were applied at high volume 1500 l/ha and all included 0.1% Tween 20.

Table 47. Effects of sprays of ATS on the flowering, fruit set, yield and fruit grades of Conference in 1996

Treatment	Flower clusters/tree	Fruits/100 clusters Final	kg/tree	Mean fruit wt (g)	kg/tree Class 1 > 65 mm	> 55 mm
Control	271.4	69.0	17.7	96.1	0.27	10.1
Hand-thinned	285.6	63.4	18.7	106.3	0.28	11.2
ATS 2.5%	264.9	65.0	17.4	104.8	0.36	10.3
ATS 3.0%	277.6	46.3	16.2	131.5	2.16	12.7
Thio-Sul 2.0%	293.0	45.5	16.3	130.3	2.05	12.4
Thio-Sul 3.0%	289.3	45.7	16.1	132.2	2.37	12.6
LSD 5%	53.88	13.28	3.56	16.09	0.46	3.02

The sprays using the laboratory grade formulation at 3.0% and Thiosul sprays at either 2.0% or 3.0% reduced levels of final fruit set (Table 47). Yields /tree were reduced slightly but not significantly by the treatments but mean fruit size was increased by both of the Thiosul treatments and by the laboratory grade ATS applied at 3.0%. These same three treatments also improved the grade outs of large fruits.

1997 Trial:

A trial in 1997 again compared two concentrations of ATS 2.0% and 3.0% and two formulations of ATS, laboratory grade and Thiosul from Hydratek. Unfortunately, severe frost after fruit set caused great damage and the thinning results were not meaningful.

1998 Trial:

In 1998, sprays of 2.0% ATS at full bloom (7 April) were compared with unthinned trees and trees thinned to three fruits/cluster on 21 June. All sprays were applied at high volume (1500 l/ha) and included 0.1% Tween 20 surfactant. The trial was designed in 8 randomised blocks of single tree plots.

Final set and total yields/tree were reduced and mean fruit weight increased by the ATS treatment in 1998 (Table 48). However effects on the grade out of large fruits were not statistically significant.

Table 48. Effects of ATS blossom thinning sprays to Conference pear in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 65 mm
Control	59.5	15.1	110.5	1.7
Hand-thinned (HT)	51.5	13.7	110.5	2.6
ATS 2.0%	27.9	9.2	136.0	9.1
LSD 5%	14.6	3.4	20.6	8.3

4.2.2 Endothallic acid as a flower thinner for Conference

1995 Trial:

In 1995, 16-year-old Conference trees on Quince C rootstock were treated at full bloom with high volume sprays of endothallic acid (TD). Three spray concentrations, 500, 1000 and 2000 ppm, all applied at high volume were compared. Treated trees were compared with unthinned controls.

The two highest concentration sprays of TD (1000 and 2000 ppm) both reduced initial set/ 100 floral buds and all three spray concentrations reduced final fruit set / 100 floral buds (Table 49). Total yields were reduced significantly by the two highest TD concentrations but no significant improvements in fruit size were achieved.

Table 49 Effects of sprays of endothallic acid (TD) on the fruit set, yield and fruit size of Conference pears in 1995.

Treatment	Initial set/100 floral buds	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit weight (g)
Control – unthinned	123	46	10.6	126
TD 500 ppm	72	30	7.5	134
TD 1000 ppm	33	18	4.7	129
TD 2000 ppm	33	16	4.3	141
LSD 5%	52.2	15.7	4.05	25.5

1996 Trial:

In 1996, sprays of 1000 ppm and 2000 ppm of endothallic acid (TD) at full bloom.were compared with unthinned controls and hand-thinned trees. The wetter Tween 20 was added to the sprays, which were applied at high volume.

Table 50 Effects of sprays of endothallic acid (TD) on the fruit set, yield and fruit size of Conference pears in 1996.

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	Class 1 (kg/tree)	
				>65mm	>55mm
Unthinned	69	17.7	96	0.27	10.1
Hand-thinned	63	18.7	106	0.28	11.2
TD 1000 ppm	41	14.9	129	1.68	11.0
TD 2000 ppm	32	15.0	161	6.06	12.3
LSD 5%	13.3	3.6	16.1	0.46	3.02

Both of the TD treatments reduced levels of final set, increased mean fruit weight and improved the grade out of large sized fruits (Table 50). The small reductions in total yields were not statistically significant.

4.2.3 Armothin as a flower thinner for Conference

In 1998, the blossom thinner Armothin (0.5% ai.) was applied at full bloom and compared with NAA (Pommit Ekstra- 0.04%) applied 3 days after bloom (13 April) and with the plant growth regulator, paclobutrazol (Cultar – 300 ppm), applied at full bloom. All the sprays were applied at high volume and the treated trees were compared with unthinned and hand-thinned controls.

Table 51 Effects of sprays of Armothin and NAA on the fruit set, yield and fruit size of Conference pears in 1998

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 65 mm
Control	59.5	15.1	110.5	1.7
Hand-thinned (HT)	51.5	13.7	110.5	2.6
Armothin 0.5%	21.4	7.8	155.2	27.4
NAA 0.04%	54.1	12.9	99.0	1.1
Cultar 300 ppm	39.3	8.8	121.2	13.4
LSD 5%	14.6	3.4	20.6	8.3

The Armothin spray reduced final set/100 floral buds and total yield, by almost 50% (Table 51). However the treatment did increase mean fruit size and the percentages of fruits in the Class 1 >65mm category. The NAA treatment had no influence on final set total yield or fruit size. The Cultar spray also reduced final fruit set and total yields. Although the Cultar treatment increased mean fruit size and improved grade out slightly, these effects were not statistically significant.

4.2.4 Benzyl adenine as a fruitlet thinner for Conference

1996 Trial:

In 1996, 16-year-old Conference trees on Quince C rootstock were sprayed with 200 ppm BA (Paturyl) at the 12mm fruitlet diameter stage. The sprayed trees were compared with unsprayed and hand-thinned controls. All the sprays, which were applied at high volumes, included the wetter Tween 20.

Table 52 Effects of sprays of BA (Paturyl) on the fruit set, yield and fruit size of Conference pears in 1996.

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	Class 1 (kg/tree) >65mm	Class 1 (kg/tree) >55mm
Unthinned	69	17.7	96	0.27	10.1
Hand-thinned	63	18.7	106	0.28	11.2
BA 200 ppm	44	17.0	135	2.31	14.6
LSD 5%	13.3	3.56	16.1	0.46	3.03

The BA treatment reduced final set/100 floral buds but had no significant effect on total yields (Table 52). The spray treatment also increased mean fruit weight and improved the grade out of large fruits significantly.

1997 Trial:

Ttrials planned for 1997 had to be abandoned following severe frost damage in the spring to the Conference trees.

1998 Trial:

In 1998, mature Conference trees on Quince C rootstock were treated with sprays of BA (Paturyl or Perlan at 200 ppm) and were compared with unthinned and hand-thinned control trees. All the sprays were applied at high volume at the 12mm fruitlet diameter stage and all included the wetter Tween 20 (0.1%).

Table 53 The effects of BA sprays in 1998 on the set, yield and fruit size of Conference pears

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 65 mm
Control	59.5	15.1	110.5	1.7
Hand-thinned (HT)	51.5	13.7	110.5	2.6
BA-Paturyl 200 ppm	47.6	12.2	112.3	5.4
BA-Perlan 200 ppm	49.2	13.8	119.4	4.6
LSD 5%	14.6	3.4	20.6	8.3

The BA sprays had no significant effect on levels of final fruit set or on total yields/tree in 1998 (Table 53). Although small increases in mean fruit size and grade outs were noted, these effects were not statistically significant.

4.2.5 <u>Conclusions of the thinning trials on pears</u>

- ATS sprays applied to Conference pear trees in 1995, 1996 and 1998 gave inconsistent results. In 1995, sprays of 1.5% reduced final set but had no beneficial effects on fruit size. In 1996, sprays of 2.0% or 3.0% reduced final set and increased fruit size and improved grade outs. In 1998, 2.0% sprays reduced final set, increased mean fruit size but had only a small and insignificant effect on the grade out of large fruit sizes.

- Sprays of endothallic acid, applied at full bloom also reduced final set levels. Effects on fruit size were poor in 1995 but good in 1996.
- Armothin sprays reduced final set in 1998 but had no significant effects on fruit size or grades
- Cultar sprays at full bloom reduced final set and improved fruit size and grade out slightly.
- Sprays of NAA had no wothwhile thinning effect and gave no benefits in fruit size in 1998.
- Sprays of BA had inconsistent effects on Conference pear. In 1996 the sprays (200 ppm) improved fruit sizes and grades, but in 1998 the effects were much smaller and not statistically significant.

5. FRUIT SETTING TRIAL

5.1 Effects of AVG (Retain) on fruit set of Queen Cox

Following severe frost damage to flowers of Queen Cox in spring 1997, the planned sprays of fruitlet thinning chemicals were considered inappropriate. Instead, sprays of aminoxyvinylglycine (AVG Retain) with or without sprays of GA_{4+7} (Regulex) were applied in an attempt to increase fruit set. The sprays of AVG (250 mg l^{-1} or 500 ppm) and GA_{4+7} were applied at high volume (1000 l/ha) shortly after the frost damage.

The AVG treatments increased final fruit set slightly on the trees (Table 54). Fruit size was, however reduced by the AVG treatments

Table 54. Effects of AVG and GA_{4+7} sprays on the fruit set, yield and fruit size of Queen Cox in 1997

Treatment	Final set/100 floral buds	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 > 65 mm
Control (unsprayed)	58	13.3	129	74
AVG 250	76	14.8	111	47
AVG 250 + GA_{4+7}	62	12.1	100	35
AVG 500	77	12.5	83	16
AVG 500 + GA_{4+7}	73	11.0	73	8
LSD 5%	21.8	2.79	17.1	15.8

SP105 Project Conclusions

Use of ammonium thiosulphate (ATS) to thin Gala clones

- Full bloom sprays of ATS at 1.5% in 1995
    - Reduced initial and final fruit set on Royal Gala trees
    - Caused slight phytotoxicity to the primary spur leaves
    - Reduced total yields by 25%
    - Increased the % grade out of Class 1 >65mm diameter fruits in 1995 similar to the effects of hand thinning
    - Increased the abundance of flowering in spring 1996

- Full bloom sprays of ATS at 1.0% in 1995
    - Reduced initial and final fruit set on Royal Gala trees
    - Increased mean fruit size at harvest, albeit less than sprays at 1.5%
    - Had no statistically significant effect on total yields
    - Increased the abundance of flowering in the spring of 1996

- Full bloom sprays of ATS at 0.5% in 1995
    - Reduced initial and final fruit set slightly on Royal Gala trees
    - Had no significant effect on total yields
    - Had no significant effect on mean fruit size or grade out
    - Had no significant effect on flowering abundance in the spring of 1996

- Repeat sprays of ATS at full bloom in 1996 to the same Royal Gala trees used in 1995
    - Reduced initial and final fruit set (all concentrations i.e. 0.5%, 1.0% or 1.5%)
    - Thinned fruits to similar levels to that achieved with hand thinning (1.5% ATS only)
    - Had no effect on total yields/tree (all concentrations i.e. 0.5%, 1.0% or 1.5%)
    - Had no beneficial effects on mean fruit size or grade out (all concentrations i.e. 0.5%, 1.0% or 1.5%)

N.B. The poor response to the ATS sprays in 1996, in terms of their effects on fruit size, was attributable to the much higher numbers of flowers on the trees compared to unthinned controls following their effective thinning with ATS in 1995. Although the sprays did reduce fruit set in 1996, this was insufficient to increase fruit size on trees with over abundant blossoms. Where trees are sprayed in successive seasons several sprays of ATS may be needed over the flowering period to compensate for increased flowering abundance.

- Sprays of 1.0% or 1.5% ATS applied to Royal Gala in 1997 thinned trees and increased the grade-out of > 70 mm fruits on a frost protected plot.
- Rewetting trees shortly after spraying with ATS in 1997 did not increase the thinning effect or the phytotoxicity to leaves. However severe frost damage in 1997 may have influenced these results
- Trials in Holland have shown that damage to leaves may be increased following sprays of ATS applied in slow drying conditions
- Sprays of 1.0% or 1.5% ATS applied to Mondial Gala in 1997 did not exacerbate the severe thinning caused by the frost spring damage.
- In 1998, sprays of ATS at 1.0%, but not 0.5%, reduced final set and total yields but increased mean fruit size and the percentage of fruits in Class I > 65 mm

- In 1998, combining ATS sprays with hand-thinning reduced the time required for hand-thinning.

Thinning clones of Gala with endothallic acid (TD)

- Sprays of endothallic acid (TD) (500, 1000 or 2000 ppm) applied to Royal Gala in 1995 reduced initial and final fruit set.
- The severity of thinning was increased by higher concentrations of the product.
- Sprays of endothallic acid (TD) at 1000 or 2000 ppm in 1995 increased mean fruit size and the percentage of fruits graded in Class 1 > 65 mm.
- In 1995 none of the endothallic acid treatments were as effective as hand-thinning.
- Trees treated with 500 or 1000 ppm endothallic acid in 1995 developed flowers (41% to 112% more) in spring 1996 than the unthinned controls.
- All three concentrations of endothallic acid sprayed in 1996 reduced initial and final levels of fruit set but only the highest concentration matched the hand-thinning in achieving the desired crop loading.
- Only hand-thinning increased mean fruit weight in 1996.
- None of the treatments reduced yields.
- The poor response to endothallic acid sprays in 1996, in terms of effects on fruit size, was attributable to the much higher numbers of flowers on the trees compared to unthinned controls following their effective thinning in 1995. Although the sprays did reduce fruit set in 1996, this was insufficient to increase fruit size on trees with over abundant blossoms.

Thinning clones of Gala with pelargonic acid (Thinex) sulfcarbamide (Wilthin) or Armothin

- Pelargonic acid showed no promise as a flower thinner for Royal Gala when sprayed at 750 – 3000 ppm in high volume at the time of full bloom.
- Sulfcarbamide (Wilthin) showed adequate thinning activity when applied at 4000 ppm, but this concentration was above the recommended dose approved in the USA
- Armothin (0.5%) gave inconsistent results as a blossom thinner when applied to Royal Gala trees in 1998.
- No fruit russeting was caused by the Armothin sprays

Thinning Gala clones with benzyl adenine (BA)

- Sprays of Paturyl (BA 100 or 200 ppm) applied in 1995 at the 12 mm stage reduced final fruit set/100 floral buds to levels similar to those achieved with hand-thinning.
- None of the Paturyl treatments improved fruit size significantly in 1995. In contrast, carbaryl, which induced more thinning and reduced yields, did increase fruit size and grade-out.
- Paturyl treatments in 1995 increased flower numbers formed on trees in 1996.

- Treatments in 1996 reduced final fruit set/100 floral buds but much less than achieved by hand-thinning.
- Thinning achieved with Paturyl in 1996 was insufficient to improve fruit size and grade-out. This was caused, partly by the increased flower abundance on the treated trees, as a result of the sprays applied in 1995.
- Comparisons of three formulations of benzyl adenine (Paturyl, Perlan and Accel) in 1998 showed that sprays (100 ppm) applied at the 12 mm fruitlet diameter stage improved the fruit grade-out without reducing total yields.
- It is concluded that sprays of benzyl adenine are inconsistent in their efficacy in thinning Gala clones. More research is needed to alleviate these inconsistencies.

Combinations of ATS and BA for thinning Gala clones

- Combination treatments, comprising sprays of ATS applied at full bloom followed by BA sprays applied at the 12mm fruitlet diameter stage, have shown promise for thinning Gala clones. Such combinations need further testing.

Thinning Queen Cox with ammonium thiosulphate (ATS)

- ATS sprays at 1.0% and 1.5% a.i. increased the mean fruit size and improved the grade out of Queen Cox fruits in 1995.
- ATS sprays at 1.5% reduced total yields in 1995
- Trees treated with ATS in 1995 bore significantly more blossoms in 1996
- Although repeating the treatments on the same trees in 1996 reduced initial and final set / 100 floral buds (as in the previous year) this thinning was insufficient on account of the increased blossom density.
- It is concluded that, if treatments result in increased blossom density, spray concentrations or frequency may need to be increased in order to achieve adequate thinning with ATS.
- In the severe frost year of 1997 spraying trees with ATS at blossom time did not increase the severe yield reduction effect of the frost.
- In 1998, trials showed that several formulations of ATS were equally effective in thinning Queen Cox, although one formulation did cause slightly more phytotoxicity.

Thinning Queen Cox with endothallic acid

- Endothallic acid (TD) sprayed at 1000 or 2000 ppm significantly reduced the initial and final fruit set on Queen Cox trees in 1995
- Yields were reduced by
- Fruit size and grade out were
- In 1996, flower bud numbers / tree were increased significantly on the trees sprayed with TD in 1995
- Although the TD sprays, which were repeated in 1996 on the same trees, again reduced both initial and final fruit set/100 floral buds, mean fruit size and grade outs were not

improved. The sprays thinned insufficiently to compensate for the increased flower densities on the sprayed trees.

Thinning Queen Cox with Pelargonic acid (Thinex) or sulfcarbamide (Wilthin)

- Pelargonic acid proved to be a poor blossom thinner for Queen Cox at the concentrations tested, even though it caused significant petal and primary leaf necrosis
- Sulfcarbamide was only effective as a blossom thinner for Queen Cox at a concentration of 4000 ppm, which is higher than the rates recommended in the USA.

Thinning Queen Cox with benzyl adenine (BA)

- Sprays of BA (100 – 200 ppm)applied at the 12mm fruitlet diameter stage to Queen Cox trees in 1995 reduced final fruit set/100 floral buds and increased mean fruit size and grade out of the larger sized fruits
- The most effective spray concentration was 100ppm applied at high water volumes.
- No significant reductions in total yield were caused by the sprays in 1995
- Trees treated in 1995 bore many more flowers in the spring of 1996
- Repeating the treatments in 1996 again reduced final fruit set / 100 floral buds
- The thinning stimulated on the trees in 1996 was insufficient to compensate for the increased flowering and fruit size was not increased by the treatments in this second year

Chemical thinning of the variety Jonagold

- Although sprays of ATS (0.5% - 1.5%) reduced final set/100 floral buds on Jonagold in some seasons, the results were inconsistent.
- In all of the trials the ATS treatments had no beneficial effects on fruit size or grade out of Jonagold.
- In 1997 the thinning effect of ATS was additive with the severe effect of frost on fruit set
- On the evidence of these trials, ATS seems to no siginificant promise if used on its own as a blossom thinner for the variety Jonagold.
- Armothin also seemed to have no significant promise as a blossom thinner for Jonagold
- Sprays of BA, applied at the 10-12mm fruitlet diameter stage in 1998, improved fruit size and grade out, although this effect was less beneficial than hand-thinning.
- Combined treatments of 0.5% ATS, applied at full bloom, together with 100ppm BA, applied at the 10-12mm fruitlet diameter stage, gave very promising results on this variety

Chemical thinning of the variety Bramley's Seedling

- In 1996, sprays of 3.0% ATS at full bloom thinned Bramley, increased fruit size but reduced total yields. Sprays at 2.0% had only a small effect.

- In 1998, sprays of three different formulations of ATS, (1.5%) at full bloom, all increased the yields of large fruits
- Sprays of BA (100ppm) in 1998 increased mean fruit size and improved fruit grade out whilst having a negligible effect on total yields/tree.

Chemical thinning of the pear variety Conference

- ATS sprays applied to Conference pear trees in 1995, 1996 and 1998 gave inconsistent results. In 1995, sprays of 1.5% reduced final set but had no beneficial effects on fruit size. In 1996, sprays of 2.0% or 3.0% reduced final set and increased fruit size and improved grade outs. In 1998, 2.0% sprays reduced final set, increased mean fruit size but had only a small and insignificant effect on the grade out of large fruit sizes.
- Sprays of endothallic acid, applied at full bloom also reduced final set levels. Effects on fruit size were poor in 1995 but good in 1996.
- Armothin sprays reduced final set in 1998 but had no significant effects on fruit size or grades
- Cultar sprays at full bloom reduced final set and improved fruit size and grade out slightly.
- Sprays of NAA had no worthwhile thinning effect and gave no benefits in fruit size in 1998.
- Sprays of BA had inconsistent effects on Conference pear. In 1996 the sprays (200 ppm) improved fruit sizes and grades, but in 1998 the effects were much smaller and not statistically significant.