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Warning:
The details of chemicals and treatments contained in this report are provided for information only and in no way are meant as recommendations for use by UK fruit growers.

Most of the products listed in this report are currently not approved for use on apples and pears in the UK

A.D. Webster,
March 2003

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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APPLE AND PEAR RESEARCH COUNCIL

Project: SP 137: Current developments in the use of plant growth regulants in apple and pear production

Final Report: 31 March 2003

Reporter: Dr. Tony Webster

SUMMARY

The objective of the project was to locate, appraise and summarise recent information (both published and that obtained via networking) concerning the use of plant growth regulating chemicals (plant bioregulators) on apple and pear crops. The information is presented in separate sections on: i) Chemical regulation of shoot growth, ii) Chemical aids to thinning, iii) Chemical aids to fruit set and retention, iv) Chemical aids to improving fruit size, quality and ripening, v) Chemical aids to storage, vi) Miscellaneous chemical aids to fruit production and vii) The development and release of new chemical bioregulators.

Chemical regulation of shoot growth

Most of the research and development trials conducted over the last few years have focused on evaluating the effects of prohexadione-calcium (Regalis / Apogee). The product appears to have promise on both apple and pear, when used at cumulative seasonal concentrations of 250-500mg l^{-1}. Its advantage is its minimal persistence in the plant and soil, so causing no residue problems. This is in comparison with Cultar (paclobutrazol), which can be very persistent in both the tree and the soil. The product also helps reduce sensitivity of pear trees to fireblight, possibly partly by reducing secondary flowering. Its disadvantages are its lack of persistence when used on very vigorous trees; it must not be sprayed closer than 45 days to harvest and trees growing vigorously later in the season will not be adequately controlled. Its effects on flowering in the subsequent season are inconsistent and hence less beneficial than those following Cultar applications. Recent trials in Poland indicate that the thinning efficacy of benzyl adenine (BA) sprays may be enhanced when trees are pre-treated with Regalis. The product is released for grower trials in Belgium and will soon be available in several other European countries.

Chemical aids to thinning

Researchers in Europe and other parts of the world continue to evaluate chemicals for use as either flower (blossom) thinners or fruitlet thinners. A niche demand for specialised flower or fruitlet thinners is being created by the developing culture of organic fruits.

Flower thinners

In addition to ammonium thiosulphate (ATS), which has been evaluated in the UK, other pollenicides such as Wilthin (Monocarbamide dihyrogensulfate), Dormex, Endothall and lime sulphur continue to stimulate interest. Wilthin is already registered for use in the USA and it is thought likely that Endothall will also gain approval in the future. Phytotoxicity of these flower thinners to spur leaves tends to be most severe in northern climates with slow drying conditions. Wilthin performed poorly in UK trials conducted several years ago and is not considered a promising chemical for UK growers. In similar UK trials endothallic acid (Endothall, Thin Rite) gave similar results to ATS. It is questionable whether additional effort into testing these alternative blossom thinners is currently warranted in the UK.

Fruitlet thinners

Many research trials abroad have continued to explore the use of traditional thinning chemicals, such as NAA (Rhodofix), NAAM (= NAAD or Amidthin), and ethephon (Ethrel), used either alone or in combinations. Although these products have occasionally provided good thinning results, these are mainly limited to areas enjoying better climatic conditions than the UK. Warm temperatures at and following their application are usually essential for their uptake and the stimulation of fruitlet thinning. Also, although NAA and NAAD can thin fruitlets effectively, they frequently produce no benefits at harvest in terms of improved fruit size.

Only one new fruitlet-thinning chemical, benzyl adenine or BA (Expander, Exilis, Accel, Cylex) shows promise as a possible alternative to the proscribed carbaryl. The trial results with BA have, to date, proved somewhat inconsistent, depending upon variety, season and orchard. Further research is needed urgently in an attempt to explain the reasons for these inconsistencies and develop suitable remedial strategies.

Thinners for Organic orchards

The rules concerning, which chemicals are permitted for use in organic orchards is inconsistent from country to country. In some countries common salt, mixtures of calcium chloride and magnesium chlorides (sold as NC.99) and lime sulphur have all been used with some success as thinners. However, it is perhaps unlikely that such chemicals would be allowed in the UK. Various fish and vegetable oils, as well as edible films and coatings have also shown some, albeit variable, efficacy as flower thinners and their evaluation under UK conditions is warranted. Probably the chemical most worthy of test is colza oil (oil seed rape oil) which has given promising thinning results in France and Norway. Some of essential oils (e.g. clove), although expensive, may also prove to have flower thinning activity and soap formulations have also been shown to be effective in a few trials.

Chemical aids to fruit set and retention

Improved techniques for use of gibberellin sprays in improving fruit set and retention on pear trees have been developed in Holland and Belgium. These have already been adopted in some UK orchards.

A new product (possibly marketed in the future as Budshield) ~~NB what is the chemical name, how does it work?~~may warrant testing as an aid to protecting floral buds from frost damage.

Chemical aids to improving fruit size, quality and ripening

Trials in the USA have shown the potential for using sprays of Ethrel to promote improved fruit colouring, together with ReTain to prevent premature softening and pre-harvest drop. Use of ReTain (amino-ethoxyvinylglycine or AVG) in combination with the surfactant Silwet has aided ReTain uptake and reduced the negative effects of heavy rainstorms just after spray application on the treatment efficacy. Sprays of CPPU have been shown to increase fruit size in one set of experiments and sprays of methyl jasmonate have improved fruit colouring.

Chemical aids to storage

The product 1-MCP (SmartFresh) shows promise in improving storage life, by delaying softening and reducing incidence of scald. Emulsions of 10% corn oil in which the Vitamin E content has been reduced to less than 3% also show promise, with scald completely inhibited after 6 months regular storage and still significantly reduced after a further 2 months storage.

Miscellaneous chemical aids to fruit growing

Although the refined kaolin product Surround has been shown to have clear benefits to apple production in regions where summer climatic conditions are very hot, it is unlikely to have similar benefits in UK conditions. When applied in cooler climatic conditions fruit size is often reduced. Also, removing the unsightly residues from the fruits proves a difficulty.

The development of new chemical bioregulators

References are given to publications which outline the constraints, both commercial and environmental, on the future development of new bioregulators.

CHEMICAL REGULATION OF SHOOT GROWTH

Prohexadione-Ca (Pro-Ca)

This new product from BASF continues to show promise in trials conducted in the USA and in mainland Europe. It has a similar mode of action to daminozide or Alar (i.e. it inhibits gibberellin production at a late stage in the biochemical pathway) It is much less persistent in the plant and soil than Cultar (paclobutrazol), which also inhibits gibberellin biosynthesis but at a much earlier stage in the pathway. Almost immediately after application (within 5 days), the growth of extension shoots slows and within two weeks the check to growth is almost complete. However, growth resumes again after only a few weeks as the product loses its effect within the plant. On strong growing apple and pear trees, repeated applications are needed at

approximately three week intervals. Varieties differ in their response to Pro-Ca and, as expected, trees also react somewhat differently when worked on different rootstocks. Also, trees with a heavy crop load require fewer sprays. Currently, there is a 45 day spray interval between the last application and harvest.

Trials on apples in the USA have shown that sprays applied at petal fall or within 10 days of petal fall (single or split applications) significantly reduced the current season's shoot growth (Miller, 2002). The early timing was essential if suppression of initial shoot growth was to be achieved, whereas spray concentrations were more important in terms of maintaining control for an extended period in the season. The cumulative dose usually required on most well-managed trees was 250mg l^{-1}, although twice this dose or even higher was needed on very vigorous trees. When trees showed re-growth in mid season a supplementary spray of 125mg l^{-1} was sufficient to regain control, if applied not later than the end of July. The benefits of the growth control achieved were improved coverage with pesticide sprays and reductions in the time needed for dormant season pruning by 23%. In this five year study, conducted on Golden Delicious and Delicious trees, no deleterious effects on fruit size or quality were noted.

Although Pro-Ca seems to have very little effect upon the fruit size of treated apple trees, sprays applied to pear trees (Williams) at the cell division stage (May) can reduce final fruit size, according to American trials.

Although compatible with most pesticides and fungicides, Pro-Ca's effects are reduced if it is applied together with calcium sprays.

Pro-Ca has a secondary benefit on pears, in that it inhibits secondary blossoming and so reduces the tree's susceptibility to fire blight (Southwick, *et. al.*, 2002). However, attempts to use sprays of the product to reduce the severity of fireblight damage on apple trees already infected with the bacterial disease, have proved ineffective (Schupp, *et al.*, 2002).

Applications to pears usually begin when shoots are approximately 3" (7.5cm) long and rates of 125 to 250mg l^{-1} are generally used. A total seasonal application of 24 fl. oz/acre (equivalent to 500 mg l^{-1}) is applied in 2 to 4 sprays and Regulaid is used as a surfactant in USA trials. The addition of ammonium sulphate, at the same concentration as the Pro-Ca, is thought to be beneficial when the water used for spraying is high in calcium. Shoot growth following the treatments was reduced 25% to 50% (Moran, *et al.*, 2000).

Pro-Ca is thought to be taken up only by leaves and green shoot tissues and to be translocated very little within the tree. One problem experienced with pear trees grown on vigorous *Pyrus* rootstocks (as is usual in the USA) is that once applications of Pro-Ca cease (at a minimum of 45 days prior to harvest) very strong new shoots often develop and total growth on the tree at the end of the season can be similar to that on unsprayed controls (Eugene Mielke – personal communication). This is only likely to happen, however, where the rootstock offers no vigour control; on semi-dwarfing quince rootstocks vigorous re-growth should prove less of a problem, as shown by the author in limited trials of the product several years ago. Other problems noted in trials of Pro-Ca on pears conducted in Oregon, are slightly less fruit colour at

harvest and reduction in flowering on trees in the following season. Trials are continuing in attempts to reduce these problems.

In trials conducted in Poland in 2002, pre-treating trees of the apple variety Lobo with prohexadione-Ca was shown to increase the thinning efficacy of sprays of BA or NAA applied subsequently.

Prohexadione-Ca has been approved for use in grower trials on apples and pears in Belgium, and in the USA, under the brand names of Regalis and Apogee respectively.

CHEMICAL AIDS TO THINNING

European Chemical Thinning Trials:

The following notes were gleaned from reports kindly provided by colleagues participating in the European Fruit Institutes Network (EUFRIN) working group on fruit thinning. This group, which includes members from almost all fruit producing countries in Western and Central Europe, meets annually to discuss the results of thinning trials and to plan new joint trials. Since funding of thinning work ceased in the UK several seasons ago, the UK is no longer a participating member of the group. However, ex colleagues have kindly provided me with the results of their trials from which the following report is derived.

The following results reported on below are gained from personal communication with researchers and hence are subject to written verification. Such results are highlighted in colour.

The notes below are arranged by variety:

Gala and its Clones

Trials were conducted in 2001 and 2002 by researchers based at Bologna, Italy on 6-year-old Galaxy trees spaced 3.5 x 0.7m apart in single rows and trained as slender spindles. The treatments compared different rates of benzyl adenine (BA) with NAA and its amide NAAm, (NAAD) all applied at approximately the 10mm fruitlet diameter stage. Also included were blossom sprays of 2% or 4% lime sulphur.

Hand thinning reduced total yield by approximately 2kg/tree but increased mean fruit weight by 6g. However, the increase in the grade out of the largest fruits was quite small. All of the BA treatments had some thinning effect but the most thinning, the most yield reduction and the largest mean fruit size was achieved with sprays at between 150 and 400 mg l^{-1}. A combination of BA (100 mg l^{-1}) with NAA (10 mg l^{-1}) also increased the percentage of fruits in the largest size category. BA at the lowest dose (75 mg l^{-1}) seemed to increase small fruit as did lime sulphur at 4%. In 2002, the BA sprays at 200ppm gave effects similar to hand thinning. Perhaps surprisingly BA at 400ppm produced even larger fruits with no reduction in total yields.

These results would indicate that use of BA on Gala has some potential in the environmental conditions of the Po Valley in Italy. . However, the trials were conducted using knapsack sprayers at rates of 100l/ha and further work using commercial sprayers will be needed in the future

Results of Gala thinning trial conducted at Bologna in 2001

Treatment	Final fruit set/100 clusters	Tot. yield/tree (kg)	Mean fruit wt. (g)	% 70-75mm	% >75mm
Control	10.9	17.0	168	40.6	38.6
Hand	9.7	15.0	174	44.6	35.2
BA 75 mg l^{-1}	9.7	15.7	171	38	36.0
BA 100 mg l^{-1}	8.1	15.2	187	37.9	42.3
BA 150 mg l^{-1}	7.9	12.5	191	32.7	52.9
BA 200 mg l^{-1}	7.9	12.4	186	33.8	54.2
BA 400 mg l^{-1}	9.2	13.5	184	31.4	57.5
NAA 10 mg l^{-1}	10.1	15.2	171	44.7	35.2
BA 100 mg l^{-1} + NAA 10 mg l^{-1}	9.5	14.4	168	32.5	50.2
NAAm 10 mg l^{-1}	9.0	15.7	167	41.7	37.5
NAAm 10 mg l^{-1} + NAA 10 mg l^{-1}	10.0	13.9	162	38.0	39.0
Lime sulphur 2%	8.9	17.1	169	43.0	32.8
Lime sulphur 4%	8.9	15.2	160	41.0	32.8

(Results courtesy of Prof G. Costa)

Complementary Italian trials were carried out in 2001 and 2002 by researchers based in the northern Tyrol area of Italy, using Royal Gala on M.9 rootstock. The trees used were 10-years-old and planted in single rows spaced 3.0 x 0.75m apart and trained as slender spindles. These trials compared unthinned and hand thinned trees with trees sprayed with Ethrel, NAA, NAAm, BA or lime sulphur. The BA, NAA and NAAm treatments were all applied at the 13mm fruitlet diameter stage, whilst the Ethrel and lime sulphur were applied at full bloom.

Hand thinning gave almost the best results in terms of mean fruit size (159g) compared with unthinned controls (131g). However, yields were reduced from 20 to 14 kg/tree by hand thinning. Ethrel had only a moderate effect on fruit size (140g), as did one of the BA treatments. NAA was slightly better (151g) but the best treatment in terms of fruit size was achieved with a combination of NAA and BA. In 2002, the results of thinning treatments applied in this area of Northern Italy were all rather negative, with the control trees compensating by dropping more fruits than normal.

Two formulations of BA seem to be available in Italy; Expander (10% a.i.) and Exilis (2% a.i.). In this trial Expander gave the better effects. The concentrations used in this trial were a little confusing but Expander is quoted at 100g/hl + 50g/hl and the wetter Tween 20 was used as an additive. Lime sulphur at 3% thinned fruitlets and also gave some increases in final mean fruit size (144g).

Trials conducted in Provence, France on the Gala clone Mondial compared lime sulphur at 3% at one day before and 5 days after full bloom. Both treatments were successful in reducing fruit set. Colza (oil seed rape) oil, applied at a concentration of 2% at one day before and three days after full bloom more than halved final set (338 to 164 fruits/100 flower clusters). When applied 1 day before and 5 days after full bloom, the Colza treatment induced even more thinning (to126 fruits/100 clusters). Lime sulphur caused almost no phytotoxicity, whereas Colza oil induced quite bad phytotoxicity in some cases. It is suggested that Colza treatments may have some potential for organic orchards, if the phytotoxicity effects can be alleviated.

In further French trials ethephon (Ethrel) applied at full bloom proved the best thinner of Gala.

***Gala Preliminary Conclusions of Trials Conducted in 2001*:**

- BA sprays at the 10-15mm fruitlet diameter stage have some potential as thinners for Gala.
- Combinations of BA with NAA are worthy of further tests.
- Lime sulphur gives inconsistent results as a blossom thinner but may warrant further testing.
- Colza (oil seed rape) oil may be worth testing in organic orchards.
- Ethephon (Ethrel) is likely only to be successful as a blossom thinner, in areas where temperatures at blossom time are 15^0C or higher.

Jonagold and its Clones

Trials were conducted at Bavendorf on Jonagold/M.9 spaced 3.7 x 1.7 m apart and trained as slender spindles. An experimental 'curtain sprayer' was used. In one trial, ATS was compared with lime sulphur as blossom thinners. ATS (local product used 58% a.i.) was compared at different doses, spray volumes and timings, either 3 days before or 3 days after full bloom. The largest mean fruit size was achieved using 20litres of the ATS product in 500 litres of water per hectare and applied before full bloom. The later spray at the same rate was less effective.

The best lime sulphur treatment, in terms of final fruit size, was 30 litres of product applied in 1000litres of water per hectare (3%) three days before full bloom.

The very largest fruits in this trial (possibly undesirable at 197g average weight) were achieved using a combination of ATS (15l. of product in 1000l of water three days before full bloom) followed by Ethephon (300ml) + NAAm (800g) in 1000l of water at petal fall.

In a second trial on Jonagold, BA at 100ppm active ingredient was compared at different spray volumes and timings with NAA at 10 mg l^{-1}. BA applied on the 25th May thinned more than when applied four days earlier. Both sprays were applied in 1000litres of water/ha. At reduced spray volumes (500l or 250l per hectare) thinning efficacy was much reduced.

NAA (10 mg l^{-1}) also thinned very effectively when applied in 1000litres volume on 21st May. The most thinning was achieved with a mixture of BA (100 mg l^{-1}) and NAA (10 mg l^{-1}) applied at the same spray volume and date.

In Belgium trials conducted on young (4 y-old) trees of Jonogored, sprays of BA (using Accel, which is 1.8% BA and 0.18% $GA_{4+7,}$ or VBC3001 which is a pure BA formulation available in Belgium) applied at 100 mg l^{-1} BA active ingredient at the stage of 10mm fruitlet diameter in 2-yr-old wood, had no positive effect on thinning. In this trial, other treatments, comparing NAAm were also unsuccessful in thinning in 2001. However, the results in this trial should be treated with caution, as the hand thinning control also had no positive effects. The same lack of response to the thinning treatments were again noted in 2002, when similar treatments were applied.

***Jonagold: Preliminary Conclusions of Trials Conducted in 2001*:**

- ATS sprays, applied just before full bloom thinned Jonagold effectively in German trials.
- ATS applied several days after full bloom was less effective in thinning.
- Lime sulphur (3%) was also an effective thinner applied at the earlier timing.
- ATS combined with sprays of ethephon (Ethrel) and NAAm (Amidthin) gave the very best thinning, but fruit size was possibly too large.
- BA at 100 mg l^{-1} applied at the 10-12mm fruitlet diameter stage also thinned Jonagold in German trials.
- High spray volumes 1000l/ha gave more efficient thinning than lower volumes (500 or 250l/ha).
- Timing and possibly associated weather conditions may be influential in determining spray efficacy of BA. Further work is need on this aspect of its use.
- Trials on young trees of Jonagored in Belgium comparing BA, and NAAm showed no significant chemical-induced thinning in 2001 or 2002.
- Although trials conducted in Poland indicate that sprays of NAA are effective thinners of Jonagold, NAA often performs poorly in trials in other countries.

Braeburn

Trials were conducted at Arhweiler in Germany using trees were on M.9 and grown as slender spindles at 3.0 x 0.75m apart in single rows with Gala pollinators. Sprays were applied at 500l/ha. The treatments compared ATS applied at different timings, all around full bloom. The addition of various additives to the sprays, such as monoammonium sulphate, citric acid, melk acid and Genapol (ethoxyluted fatty acid) was also compared. Lime sulphur (3%) was also tested, with or without the additive monoammonium sulphate, at the same range of timings. The spray timings for both products (3 sprays applied to all trees) were i) beginning of bloom on old wood, ii) full bloom on old wood and iii) full bloom on young wood. The concentrations of ATS were 3% at the first spray timing, 2.25% at the second and 1.7% at the third and final timing; lime sulphur was applied at 3% in all three sprays. The spray treatments were compared with hand thinned and unthinned controls.

The three sprays of ATS without any additive or with the additive Genapol reduced fruit set per unit tree size to a similar level to that achieved by hand thinning. The other treatments had a slightly reduced effect on fruit set. Yields were reduced most

but fruit size increased most by the hand thinning (mean fruit size 171g on hand thinned and 139g on unthinned controls). The largest mean fruit size achieved with chemical sprays followed use of the three sprays of ATS, with the addition of Genapol (161g); ATS alone gave 155g and lime sulphur on it own 157g. The unsprayed controls produced only 37% of its yield in fruit sizes greater than 70mm diameter. Hand thinning produced 82% and also the firmest fruits. However, useful increases in grade out were also achieved by most of the treatments, with ATS alone yielding 57%, ATS + Genapol 70% and lime sulphur 61% fruits in the large sizes. None of the other additives to the sprays (i.e. apart from Genapol) appeared to produce any beneficial effect on the thinning.

Trials on the variety Braeburn were also conducted in Slovenia using 5-y-old trees on M.9 planted at 3.0 x 1.0 in a V training system. The blossom treatments compared ethephon (Ethrel), at 200 mg l^{-1} when flowers were 80% open, with lime sulphur applied at 3% at full bloom. Fruitlet thinning treatments, applied at the 10mm fruitlet diameter stage, compared BA at 100 mg l^{-1}, NAA 10 mg l^{-1} and a tank mix of the two chemicals. All treatments were compared with unthinned and hand-thinned controls.

Unfortunately, the results in this trial showed large tree to tree variability and none of the treatments were statistically different from the controls. Nevertheless some of the trends may be worthy of mention.

Although treatment with ethephon (Ethrel) appeared to have no effect on final fruit set per 100 blossom clusters or per unit tree size, it did produce a useful increase in the percentages of fruits >70mm diameter (39% to 58%). It also had no deleterious effect on total yield. This may be associated with the time when the fruits were removed by the chemical compared with the later natural fruit drop. Lime sulphur appeared to reduce fruit set and total yield slightly and also increased the percentage of large fruits similar to the ethephon treatment (to 58%). Applications of BA at the 10mm fruitlet diameter stage also appeared to increase the percentage of fruits >70mm (to 52%) whilst having no deleterious effect on total yield. The largest increases in grade out percentages of >70mm fruits (to 62% or 68%) were achieved with treatments which included NAA. However, these treatments also caused the largest reductions in total yields.

In trials conducted in Provence, France, BA reduced fruit set on Braeburn in 2000 and 2001 when applied at 10 or 15mm stage respectively. Thinning was quite dose dependent. Interestingly, effects on the Hillwell clone were not so pronounced as on ordinary Braeburn (clone not mentioned). The best spray timing seemed to be approximately 30-35 days after full bloom. The French researchers have attempted to determine the best way of deciding when to spray BA, either days after full bloom or fruitlet diameter, but the results of this appeared a little inconclusive. They achieved promising results with BA sprays if they were applied sometime after 10mm fruitlet diameter. Response is dose dependent with rates of 100 to 200 mg l^{-1} probably the optimum. BA also thins very well when combined with NAA or carbaryl. Multi-site French trials conducted in 2002 again focused on use of Ethrel as a thinner for Braeburn. The results showed that post bloom applications were less variable in their thinning than sprays applied before or at full bloom. However, fruit size increments were generally poor using Ethrel.

In blossom thinning trials on Braeburn, the French researchers tried 3% lime sulphur at full bloom but the treatments had no positive effects on fruit set (i.e. thinning) Two sprays were slightly better than a single spray but the effect was still not statistically significant. They also tried sprays of common salt to trees on M.9 in their 6th leaf planted at 4.0 x 1.6. The salt, applied at 1200g/hl either in 1 or 2 sprays was compared with lime sulphur at 3000ml/hl, also either in 1 or 2 sprays. The spray volumes were 1000l/ha and the spray timing 1 or 5 days after full bloom. None of treatments significantly affected the final set, total yield or grade out. It would seem that the timing of these treatments was probably too late.

***Braeburn: Preliminary Conclusions of Trials Conducted in 2001*:**

- ATS applied in three sequential sprays over the blossom period thinned Braeburn effectively in German trials.
- Lime sulphur was also effective when applied in a three spray treatment but not effective in French trials when applied later in the blossoming period.
- BA applied at the 10mm fruitlet diameter stage may also have potential as a fruitlet thinner for Braeburn.
- The thinning response of Braeburn to BA was very dose dependent in French trials with higher concentrations resulting in increased fruit thinning.
- Braeburn can be thinned using pre or post full bloom applications of Ethrel, but fruit size increments following the later sprays were poor in 2002.

Delbard Estivale

In a trial conducted in Germany the possibilities for chemical thinning of Delbard Estivale were investigated. The trees used were planted on M.9 rootstock at 3.0 x 0.75m spacing in single rows and trained to slender spindles, with Alkmene pollinators. The spray volumes were 500 or 1000l/ha.

The blossom thinning treatments compared NAAm (Amidthin at 0.08%) + Ethrel (0.025%) applied at the end of blooming on spur wood with lime sulphur (3%) + Ethrel (0.025%) or ATS (3%) + Ethrel (0.025%) applied at full bloom. The fruitlet thinning sprays, applied at the 10mm fruitlet diameter stage, compared NAA (Rhodofix at 0.15%) + Ethrel (0.025%) or BA (Exilis at 0.2%) + Ethrel (0.025%). The controls were unthinned or hand-thinned trees.

Comparing the blossom thinners, both ATS + Ethrel and NAAm + Ethrel treatments reduced final fruit set per unit tree size and yields per tree slightly more than hand thinning. The ATS + Ethrel treatment thinned most and reduced total yields most, but gave the highest mean fruit size in comparison with unthinned controls (153g compared with 133g). The fruits from this treatment ripened slightly earlier but were of similar firmness to those from controls. The lime sulphur + Ethrel treatment had no significant thinning effect.

Although the fruitlet thinning treatment combining NAA and Ethrel thinned quite effectively and provided useful increases in fruit size (148g), the BA + Ethrel treatment gave no thinning response on this variety in this trial.

***Delbard Estivale: Preliminary Conclusions of Trials Conducted in 2001*:**

- Delbard Estivale may be thinned quite effectively at blossom time with sprays of ATS (3%) + Ethrel (250ppm).
- The poor response using lime sulphur and Ethrel suggests that it is the ATS, which is primarily responsible for the thinning action.
- BA (100ppm) + Ethrel gave poor thinning of this variety.
- NAA + Ethrel gave a good thinning response.

Conference

Trials were conducted in 2000 and 2001 in Germany on Conference pear trees on EMA rootstocks planted at 3.5 x 1.25m. No blossom thinning treatments were compared, only fruitlet thinners at the 12mm fruitlet diameter stage. BA (200 mg l^{-1}), NAA (0.15%) and Ethrel (0.04%) + BA were compared with hand-thinned and unthinned controls. The sprays were applied at volumes of 500l/ha.

In 2000, all the treatments reduced the fruit set per tree and the yields per tree. Similarly, all the treatments increased the percentages of fruits > 60mm diameter and also the mean fruit weights. The BA treatment increased grade outs from 63% to 76% and mean fruit size from 177g to 182g. The NAA treatment had a slightly better effect with values of 88% and 197 g respectively. However, the NAA treatment reduced total yields slightly more than the BA treatment, which was more similar to the results of hand thinning. Addition of Ethrel to the BA had no significant effect on this treatment.

Results in 2001 were quite different with increased final fruit set and yields on all of the treated trees. This is almost certainly the result of increased blossom density in the spring of 2001 on the trees chemically thinned in 2000. Although the percentages of fruits >60mm were all poor in 2001 (30% to 35%) the values for the sprayed trees were no less than on the controls, despite the higher yields on the former trees. Also mean fruit size was increased slightly on some of the treated trees.

In a trial conducted in southern Spain in 2000, BA (200 mg l^{-1}), NAA (10 mg l^{-1}) and a combination of both were compared with unthinned and hand thinned controls. All the treatments were applied when the fruitlets were approximately 10mm in diameter. The BA treatment thinned the Conference to similar levels of fruit set to the hand thinning treatment. This BA treatment produced the largest fruits with mean fruit weights of 173 g. compared with only 124 and 126 g on the unthinned and hand thinned controls. Interestingly, it also produced no reduction in total yield and an increase in grade outs of >60mm fruits from approximately 50% on the controls to slightly more than 80% on the BA treated trees. The NAA-treated trees were also thinned quite effectively but total yields were reduced and fruit size and grade out was not as good as on the BA treated trees. The combined BA + NAA treatment tended to over thin.

In earlier Italian trials, the thinning ability of ethephon (Ethrel), NAA and NAD was tested on two pear varieties (Conference and Rosada) in 1997 and 1998 in the north east of the country (Bonghi *et al.,* 2002). Ethephon, NAA, and NAD were applied five and ten days after full bloom (DAFB). The spray concentrations tested ranged

between 200 – 800, 5 – 40, and 7.5 - 30 mg l^{-1} for ethephon, NAA, and NAD, respectively. The results showed that the tested chemicals displayed a varying ability to thin pear fruitlets depending upon time of application, concentration and fruit load. Conference was more sensitive to the treatments than Rosada. With the variety Conference, all the chemicals showed the ability to promote fruit abscission at both spraying times, although the thinning effect varied according to chemical type and concentration, and fruit load.

Other varieties of apple and pear:

European trials on other varieties such as Elstar and Golden Delicious were also reported, but these are not presented in this report.

Thinning trials on the pear variety Clara Freis conducted in Denmark, showed disappointing results using ATS (Bertelsen, 2002). Although sprays at flowering time of 1% or 2% thinned fruitlets, damage to spur leaves was severe, no improvements in final fruit size were achieved and flowering in the subsequent season was reduced. In these Danish trials BA proved to be the most efficient thinner of this variety when used at rates of 100mg l^{-1}. Final fruit size was improved by the BA sprays and was similar to the effects of hand thinning: return bloom was also improved.

In a Polish trial conducted in 2002, pre-treatment of trees of the apple variety Lobo, with Regalis (the new growth retardant Prohexadione-Ca) enhanced the thinning efficacy of BA or NAA sprays applied subsequently.

- ❖ Pre-treatment of apple trees with the plant growth retardant Regalis, may enhance the thinning efficacy of BA or NAA thinning sprays.

Trial Results from the USA and Australia:

ATS

Although it has been used quite extensively in the USA trials as a blossom thinner for apples (as a replacement for the banned DNOC –Elgetol) for several years, ATS was still not approved officially for this use in 2001 (Warner, 2001). This is currently a source of considerable frustration to growers. The compound is registered for use as a fertiliser in the USA and several years ago the National Chelating Company of Orange, California submitted a request to the USA Environmental Protection Agency (EPA) for its registration as a flower thinner on apples. Unfortunately, the request has still not been processed. The problem is not with the products toxicity, for it is considered very safe; it is that the request does not rate as high priority on the Environmental Protection Agency's (EPA's) current agenda.

In Tasmania, trials have been conducted over a two year period to assess the potential of blossom desiccants as chemical thinning agents for the pear variety Packham's Triumph (Bound and Mitchell, 2002a). Initial trials examined four rates of the desiccant ammonium thiosulphate (Culminate™) (0.5%, 1.0%, 1.5%, 2.0% v/v) at three different timings during the flowering period (20%, 50%, 80% bloom). Higher

concentrations of Culminate resulted in greater reductions in crop load at application timings of 20% or 50% bloom. There was little thinning effect in any of the 80% bloom treatments, irrespective of concentration. There was no effect on return bloom.

Further work examined the effect of double and triple applications of Culminate during the flowering period. Two applications of 1.0% or 1.3% Culminate reduced crop load but three applications of 0.7% were required to have a thinning effect. Adding the post-bloom thinner CyLex™ (BA) to the thinning program had no additional thinning effect.

Endothall

Endothall which is now named Thin Rite and manufactured by the Cerexagir Company in the USA, is close to official registration as an apple thinner in the USA. In trials conducted over many years, it has proved reliable and effective. However, the product is likely to cost more than ATS; estimated costs per acre are £20 to £35. Endothall was also tested quite thoroughly by the author in the UK between 1995 and 1998. It proved very effective in blossom thinning, giving similar results to ATS.

Wilthin

Trials continue in the USA on the product Wilthin, which chemically is often referred to as sulfcarbamide. Trials conducted in Mississippi showed that Royal Gala, Ultra Gold and Blushing Golden could all be thinned effectively using sprays of Wilthin, if applied at the 70%-80% bloom stage. Concentrations of 5 or 15 ml l^{-1} gave the best results, increasing final fruit sizes and having no significant effect on total crop yields (Ejaz Ansari, *et al.*, 2002). However, these concentrations may be too high for its use in some regions. Trials in Idaho using 3.75 ml l^{-1} thinned effectively but caused fruit russetting in some years. Better results, in terms of reduced fruit blemishing, have been obtained using only 2.5ml l^{-1} together with the surfactant Regulaid (Byers, 1999; Fallahi, et al., 1997). Wilthin is currently cleared for use in the USA.

Dormex

Dormex (hydrogen cyanamide) is primarily used as a spray to aid dormancy breaking in countries where winter temperatures are too high to satisfy the chilling requirements of fruit trees. However, it has also been tested, quite successfully as a blossom thinning chemicals on both pome and stone fruits. Trials in the USA (Fallahi, *et al.*, 1998; Fallahi and Willemsen, 2002) showed that, if sprayed at full bloom, Dormex concentrations of 0.25% to 0.3125% (v/v) reduced fruit set on several varieties of apple, including Gala. In these trials the product was, however, usually supplemented by subsequent sprays of a fruitlet thinning chemical such as carbaryl.

Benzyladenine (BA)

Work continues in the USA and Europe in developing this product as a fruitlet thinner to replace carbaryl. Trials in Washington State have compared three formulations of BA. These are Accel (from Valent Agrochemicals and which includes a small proportion of GA_{4+7}), RiteSize (from Agtrol International of Texas) and Exilis (from Fine Agrochemicals Ltd, UK). All three products thinned apples with similar efficiency.

It will be important to check regularly with Mr. Steve Wilson of Fine Agrochemicals in the UK to ascertain the progress with Exilis and the likelihood of any release of the product in northern Europe. Such a release could then aid application for a UK SOLA.

Trials have been conducted in Australia (Bound and Mitchell, 2002b) to assess the effectiveness of benzyladenine (BA) as a post-bloom thinning agent for the pear variety Packham's Triumph. Field trials were established in two growing regions in Australia: the Goulburn Valley, Victoria and the cooler maritime climate of southern Tasmania. Trial work in both areas examined a factorial combination of concentration of BA (50, 75, 100, 125, 150, 175 or 200 mgl^{-1}) and application timings (8, 11, 14, 17, 20, 23 or 26 days after full bloom (DAFB). BA treated trees were also treated with ethephon (Ethrel) at full bloom (FB). Concentrations of 100 to 150 mgl^{-1} BA were the most effective at application timings from 11 to 26 DAFB.

In a trial conducted on Pacific Rose/MM.106 trees planted in New Zealand, sprays at 150mg l^{-1} thinned when applied (together with the surfactant Regulaid), at 6 or 12 days after full bloom (fruitlet diameters 4mm and 7mm respectively). However, delaying the sprays until 24 days after full bloom (fruitlet diameter 14mm) caused no thinning (McArtney, 2002).

Environmentally-sensitive sprays for possible use in orchards managed organically

Trials conducted in the USA have evaluated sprays of common salt (sodium chloride) as a blossom thinners for apples. Where used, it is applied at low concentrations, so as to avoid any toxic build up in orchard soils. Also, in a Norwegian trial conducted in 2002 on the apple variety Aroma, salt sprays at 1.0% applied at full bloom reduced set and increased fruit size slightly. However the trial was very minimally replicated and the results were just short of statistical significance.

Also tested in the USA as a blossom thinner on apples has been a mixture of calcium chloride and magnesium chlorides (sold as 'NC.99'). In 1999, NC.99 performed well but it was less effective in 2000. The product is marketed in the USA by the G.S. Long Company of Yakima in Washington State.

Applications of a mixture of lime sulphur and fish oil have also proved promising as blossom thinners in USA organic and conventional apple orchards. The mixture is applied at 20% to 80% full bloom. Another similar combination is lime sulphur and a highly refined petroleum oil, although it is doubtful whether this would be acceptable within UK organic protocols.

Emulsions of vegetable oils, which have proved very effective in thinning sweet cherries in China, (Ju and Duan, 2001), are now under test as apple thinning chemicals in Washington State. An emulsion of corn oil has been patented by the Chinese for this purpose and the details of its composition are not, therefore, disclosed. Sprays of this product are applied as early as white bud and through to 50% full bloom; later sprays appear to be less effective. This oil emulsion is reportedly safe to plant tissues, bees and sprayer operatives. It is also stable and very soluble in water,

leaves no greasy deposits and is easily absorbed by leaves. The validity of these claims needs investigation. In a 2002 trial conducted in Norway on the apple variety Aroma, a spray of 2% ProNature (78% Colza oil) applied at full bloom thinned very efficiently, although increases in fruit size were just short of statistical significance.

As long ago as 1944, researchers showed that paraffin wax coatings applied to the stigmas of blossoms acted as physical barriers to pollen tube penetration, but did not affect the growth of pollen trapped beneath the coatings or pollen tubes already germinated and growing down the style. With the current need for more environmentally sensitive thinning materials, researchers have begun to test some of the various edible films and coatings that have been developed (Kester and Fennema, 1986). It has also been speculated that some of these coatings may have additional pollenicidal effects (Embree and Foster, 1999). In the Canadian based work of the last mentioned scientists, conducted on the apple variety McIntosh, detailed studies were conducted on the effects of a range of coatings and other pollenicides on pollen germination and subsequent pollen tube growth.

The chemicals/products tested are shown in the table below:

Chemicals tested as coatings/pollenicides on McIntosh flowers in Nova Scotia (Embree and Foster, 1999)

Type	Common Name	Dose Rate / litre	Chemical Name	Source
Coatings	Nutri-Save	10g	N,o-carboxymenthylchitosan	Nova Chem Ltd, Halifax, N.S. Canada
	Masbrane (Gao-Zi-Mo)	20ml	Dodecyl alcohol	Aefachemi, Hong Kong, China
	PEG 1000	10-20g	$HO(-CH_2-CH_2-O-)NH$	J.T. Baker Inc. Phillipsburg, N.J. USA
	Anti-Stress	50ml	Acrylic polymers	Polymer A.G., Fresno, CA, USA
	Safer-Soap	20-40ml	Potassium salts of fatty acids	Safer Limited, Scarborough, Ontario, Canada
Pollenicides	Wilthin	4ml	Monocarbamide dihyrogensulfate	Entek Corp, Patterson CA, USA
	MAP	7.5-15ml	NH_4H2PO_4	IMC Global, Mundelein, IL, USA
	Urea	8g-16g	$CO(NH_2)_2$	Various
	Endothall	0.35-1.2 ml	7 oxabicyclo (2,2,1) heptane-2-dicarboxylic acid	Atochem North America Inc. Geneva, NY, USA
Other	Salt	4-12g	Sodium chloride	Sifto Canada Inc. Mississuaga, Ont., Canada
	Salt + Biofilm	4g + 2ml	Sodium chloride + Alkarylpolyethoxy ethanol+fatty acids+ phosphatic acids+ isopropanol	Kalo Inc. Overlandpark, KS, USA
	Basic-H	1.8-3.6 ml	Linear alcohol alkoxylates (28%)	Shaklee Corp., San Francisco, CA, USA
	ATS	17-24ml	$(NH_4)_2S_2O_3$	Oligosol, Beloeil, Quebec, Canada

The coatings PEG 1000 and Safer-Soap were shown to significantly reduce pollen tube growth down the style at all of the concentrations tested. Among the pollenicides tested, the control ATS was effective but so also were common salt and MAP, both at the higher concentrations tested. However, when used at 40ml l^{-1}, Safer–Soap did induce some leaf phytotoxicity, as did the control ATS. Some of these products possibly warrant further testing in UK conditions.

Dr. David McArthur, a researcher at the University of British Columbia, is examining the use of essential oils (clove, thyme and lemon grass) as potential thinning agents. Although expensive, he believes that it may be possible to develop thinning treatments costing approximately £200 per acre which compare favourably with the £1000 per acre costs for flower thinning by hand (Mittriam, 2000).

A very novel approach recently tested in the USA, is to endeavour to use specific diseases as a means of reducing crop loads. This was tried on citrus crops growing in California and a disease known to cause floral abscission, *Colleotrichum acuminatum*, was sprayed onto citrus flowers in attempts to reduce fruit set (Stover , *et al.*, 2002). Unfortunately, the initial results were not very promising.

Studies on the Mode of Action of Traditional Thinning Agents

Recent research, conducted in Germany (Untiedt and Blanke, 2001) has studied the effects of NAA (Rhodofix), NAAM (Amidthin) and ethephon (Ethrel) on whole tree photosynthesis. Application of 10 mg l^{-1} Rhodofix in mid May to the apple variety Elstar reduced whole tree photosynthesis by up to 30% in the three days after application. Applications of 15 mg l^{-1} (a.i.) AmidThin or 25 mg l^{-1} (a.i.) Ethrel caused similar reductions in photosynthesis. All three products are thought to reduce mesophyll conductance and decrease translocation of sorbitol and sucrose from the leaf to the fruitlet. This causes a short, but severe, stress at a time when foliage on the tree is limiting and the juvenile leaves are still expanding. All three chemicals also cause a reduction in the downward (basipetal) transport of auxin and together with the reduced photosynthesis this is thought to enhance the activity of the enzymes polygalacturonases, pectinases and cutinase in the fruitlet abscission layer, whilst at the same time the fruitlet is retarded in growth and is receiving more stress induced ethylene.

Other trials have shown NAA to have very inconsistent effects in thinning pears, depending upon the variety and the season. Like ethylene releasing chemicals, such as Ethrel, the efficacy of NAA is thought to be very temperature dependent and is generally not suited for use in cooler climatic conditions (Bertelsen, 2002). Studies conducted in the USA (Byers, 2002) suggest that natural June drop is more severe when days are dark or trees are shaded and temperatures (particularly during the night) are higher than average. Indeed, American advice is to be careful when applying thinning chemicals following several days of cloudy weather and poor light conditions; in these circumstances thinning may be too severe. (Greene, 2002). The same author believes that we also worry too much about rain showers that immediately follow applications of thinners. With almost all chemicals approximately 80% efficacy will be achieved, providing the chemical dries on the leaf prior to the rain. The notable exception is ethephon (Ethrel) which is very water-soluble.

Frost damage early in the season frequently causes fruit russet, which renders the fruits unmarketable. Trials conducted in the USA evaluated whether these fruits were 'weaker' and could be preferentially thinned using carbaryl (Hirst, 2002). The trials were, however, unsuccessful.

What is currently known about the modes of action of the various fruitlet thinning chemicals has recently been the subject of several reviews (Dennis, 2002; Wertheim, 2000). Despite much research over the past forty years it would appear that we are still some considerable way off understanding how and why the various fruitlet thinning chemicals bring about their actions. Both of these reviews call for new, focused research using the rapidly evolving new research techniques.

CHEMICAL AIDS TO FRUIT SETTING AND FRUIT RETENTION

Gibberellins

Improvement of fruit set on young pear trees variety Conference with applications of gibberellins has been studied in Belgium for several years (Deckers and Schoofs, 2002) and the treatments are also of value in spring frost years. The treatment for increasing the early productivity is applied during the full flower period, while the treatments to alleviate frost should be applied within 4 days of the frost event. Different gibberellins can be applied: GA_3, $GA_{4/7}$ or mixtures of gibberellins with a cytokinin, such as $GA_{4/7}$ + benzyl adenine (Promalin). In this research, the authors show improvements of fruit set on Conference from the second to the sixth year after planting. Every year, the same gibberellin treatments were applied to the same trees during the time of full bloom on the two-year-old wood. The results indicated that a mixture of a low dose of GA_3 and half a dose of $GA_{4/7}$ gave good results for fruit set improvement. Also, the effect of the gibberellin treatments on flower bud quality and on return bloom can be minimised. The fruit set effect following a GA_3 treatment was stronger than the effect of a gibberellin treatment with $GA_{4/7}$ applied at the same dose rate and at the same time. The GA_3 treatment was on one occasion more negative in its effects on flower bud formation than the $GA_{4/7}$ but on young trees the negative effect of the gibberellin treatments was not always observed.

Frost Protectants

Bi-products of the ethanol distillation process in the USA are showing considerable promise in reducing spring frost damage to flowers (Warner, 2001b). These products, which are still at a very early stage of testing, are classified as GRAS (Generally Regarded as Safe) by the USA Food and Drug Administration and may be acceptable within organic systems of production. Initial patents have been lodged on several of these bi-products by the G.S. Long Company Inc. of Yakima , WA, USA and if one is released to growers in a few year's time it is likely to be called Budshield. Preliminary results from Washington trials indicate that sprays of the product may give a 2^0C benefit. An original product, derived from the same process is sold as a road de-icer, under the trade name of Bareground.

CHEMICAL AIDS TO IMPROVING FRUIT SIZE, QUALITY AND RIPENING

ReTain (AVG)

Researchers at Washington State University and at the USDA centre in Washington State have been studying the use of combinations of ReTain and Ethrel to improve the eating quality of Red Delicious apples. Some strains of Red Delicious colour very early but internally are unripe and hence are very starchy ex store. Ethrel applied on its own one to two weeks before harvest at 150 to 300 mg l^{-1} improved fruit flavour. The problem is that the Ethrel treatments frequently had deleterious effects on the fruits' storage potential. The aim of the current work is to ascertain whether a programme of sprays that includes ReTain and Ethrel treatments can overcome these problems. However, the tested strategy of applying Ethrel early followed by ReTain at its normal timing is considered a very risky one by many other American researchers.

Similar work on the variety Gala in Michigan State, with the aim of enhancing fruit colour, preventing pre-harvest fruit drop and delaying maturity examined applying ReTain 4 to 6 weeks before harvest and Ethrel 2 weeks later. It was found that the treatments enhanced fruit colour without over stimulating the ripening process.

Recent research carried out in Massachusetts, USA (Greene, *et al.*, 2000) has endeavoured to assess the impact of heavy rain storms following spraying on the efficacy of ReTain applied to the apple variety McIntosh. The results show that a heavy thunder storm (simulated in the trials) one, four or eight hours after spraying significantly reduced the effect of the chemical on fruit soluble solids and red colouration at harvest, but had no effect on the chemical's influence on fruit firmness and starch rating. The simulated heavy rain also reduced ReTain's beneficial effect in preventing pre-harvest drop of McIntosh.

However, the negative effects of heavy rain on ReTain's beneficial effects were almost completely overcome when it was applied with the surfactant Silwet. This surfactant is known for its ability to improve rain fastness. Further work in the USA has emphasised the importance in only using recommended surfactants with ReTain (Greene and Krupa, 2000). 'Silwet L77' at 0.1% gives very good effects but USA growers also have a choice of other suitable surfactants, such as Silgard 309, Break-Thru and RNA Si100.

ReTain also appears to be a useful product for use on varieties of apples, which experience pre-harvest drop, such as McIntosh and Delicious. It has very similar effects to the now prohibited Alar (daminozide) in reducing pre-harvest drop and watercore in fruits (Greene, 2002b).

CPPU

The effects of the synthetic cytokinin, CPPU, on the fruit size and yield of the pear variety Spadona pears have been examined in Israel (Stern, *et al.,* 2002). CPPU caused appreciable increases in fruit size, when applied at 10-20 mg l^{-1}, two weeks after full bloom, whereas application four weeks after full bloom gave only small or no effects.

CPPU increased fruit size with no influence on fruit number, fruit shape and seed number, and it did not reduce the return bloom in the following spring. In orchard trials, applications of 10 mg l^{-1} CPPU increased fruit size by 40% in 1999 and 100% in 2000 with an increase of about 50% (1999) and 30% (2000) in the total yield.

Methyl jasmonate

Jasmonic acid and its methyl ester are compounds that modulate many physiological processes in plants, including fruit ripening. Previous studies have shown that methyl jasmonate promotes de-greening of apple peel as well as the synthesis of beta carotene. Recent studies (Rudell, *et al.,* 2002) have investigated whether treatment of fruits with methyl jasmonate could enhance apple fruit colouring. These trials showed that colouring of Fuji apples was indeed improved following treatment. Further work of a more applied nature is warranted using this chemical.

CHEMICAL AIDS TO STORAGE

1-MCP

Trials in Washington State, USA indicate that treating the apple varieties Fuji, Red Delicious, Golden Delicious and Rome and the pear variety D'Anjou with 1-methylcycloprene (1-MCP) reduced the potential for bruising in the subsequent grading of the fruits. The effects were thought to be indirect and due to the influence of the product on the ripening of the fruits (Baritelle, *et al.*, 2001).

Trials conducted in the UK during the 2000 season showed that pre-storage applications of 1-MCP improved the maintenance of pressure and delayed ethylene production in Cox's Orange Pippin and Bramley's Seedling apples (Dauney and Joyce, 2002). Concentrations of 0.1 to 10 ul l-1 maintained fruit firmness for 2-3 months but not longer in air storage. An exposure time of only 6 hours to 1-MCP seemed to be adequate and temperature at the time of exposure did not appear to effect the treatment efficacy. Beneficial effects on the incidence of scald on Bramley and storage diseases were also recorded.

Vegetable Oil Emulsions

Work is continuing in Washington State in attempts to find suitable replacements for DPA for scald control on the apple variety Granny Smith. This is particularly vital for growers wishing to produce fruits organically. Initial trials conducted with vegetable oils gave mixed results, largely due to the high levels of *alpha* tocopherol (Vitamin E) in the oils used. More recent work using emulsions of 10% corn oil in which the Vitamin E content has been reduced to less than 3% show much more promise with scald completely inhibited after 6 months regular storage and still significantly reduced after a further 2 months storage. Although not as effective as DPA after 8 months storage, the oil-treated fruits were better than the DPA treated fruits in terms of their improved crispness and acidity. Also, whilst the DPA-treated fruits developed both senescent breakdown and internal browning the oil treated fruits did not. Oil emulsions are also being tested on Delicious and Golden Delicious apples and D'Anjou pears. The oils are considered safe, inexpensive and easily adaptable to the fruit industry (Curry and JU, 2000). These results using vegetable oils, stripped of their tocopherol (Vitamin E), seem promising.

MISCELLANEOUS CHEMICAL AIDS TO FRUIT PRODUCTION

Surround

The refined kaolin clay product, sold as Surround in the USA (Engelhard Corp, Iselin, NJ, USA) continues to stimulate much research in the USA and in southern Europe. Its benefits in reducing pests and diseases and sunburn injury are well proven in American trials. However, its potential benefits in areas experiencing lower light levels (e.g. the UK) have always been questioned, as the white deposits which cover the leaves of the trees are known to reduce photosynthesis, as shown in studies conducted on individual treated leaves. This reduction could, in turn, reduce fruit size at harvest.

Interestingly, trials conducted in New Zealand and Washington State, USA, indicate that, whilst individual leaf photosynthesis is reduced that of the whole tree is not (Warner, 2001c). This may be explained by a) the beneficial effects of the reflective coverings reducing leaf temperatures in very hot climates and b) the effect of the whitened leaves reflecting light into the tree canopy and improving light absorption by the interior leaves. Details of the physiological effects of the product on apple leaves and yields can be found in Glenn, *et al*,(1999)

Trials conducted in Idaho, USA, showed that sprays of Surround reduced fruit weight, red colour and incidence of sunburn on Fuji (Schupp, *et al.,* 2002b). In New York State similar treatments to the apple variety Honeycrisp had no effect on fruit weight or colour if applied in May or June, but reduced both if applied later. The sprays resulted in undesirable residues in the neck and basal end cavities of the fruits that were not satisfactorily removed by brushing on a packing line.

Further trials (in addition to those conducted by Jerry Cross and Angela Berrie of HRI East Malling) are needed on Surround to test the effects on the tree's photosynthesis and fruit growth in UK climatic conditions.

Two new kaolin products Agreflect and Raynox are also under test in the USA (Warner, 2000).

THE DEVELOPMENT AND RELEASE OF NEW CHEMICAL BIOREGULATORS

The increasing costs to chemical manufacturers of developing new bioregulators has resulted in a reduction in the numbers of new products that have been released in recent years. The problems are particularly acute for growers of minor crops, or in countries where growth of major crops is limited and where independent national testing is obligatory. These problems stimulated a workshop to be held in Florida, USA, in 2000, entitled 'Opportunities and Challenges in the Development and Registration of Plant Growth Regulators'. The Proceedings from this Workshop were published in 2002 in HortTechnology Vol 12(1): pages 54-74. These proceedings mainly focus on how the problem is being tackled in the USA, but may provide some useful insights to interested parties in the UK. The papers published in these proceedings are as follows:

- 'Regulation of biochemical plant growth regulators at the US Environmental Protection Agency'. By Sheryl K. Reilly, Leslie K. Lake, Warren E. Schaffer and Russell S. Jones. Pages 55-63.
- 'New plant growth regulators: High risk investment?' By W. Rademacher and T. Bucci. Pages 64-67.
- 'Field research and development of plant growth regulators by the agrochemical industry' by Craig A. Campbell. Pages 68-70
- 'Development of new plant growth regulators from a university perspective.' By Duane W. Greene. Pages 71-74.

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