Current Approved Thinning Strategies for Apples and Pears and Recent Thinning Research Trials in Europe

Tony Webster

Horticulture Research International, East Malling, West Malling, Kent, United Kingdom

Presented at the 45th Annual IDFTA Conference, February 16-20, 2002, Kelowna, British Columbia, Canada.

Many varieties of apple or pear naturally set excessive numbers of fruitlets in most seasons. This can result in:

- Strong competition between developing fruitlets for the trees' assimilates and nutrients.
- Fruits which are small and unmarketable at harvest time.
- Fruits which have reduced quality and perform poorly in postharvest storage.
- Branch breakage if crops are very heavy.
- Strong competition between the developing fruitlets and the flowers forming for the subsequent season leading to reduced numbers and quality of floral buds in the following year. On some varieties this leads to a pattern of biennial bearing.

The problem of excessive fruit set (crop load) and reduced fruit size at harvest is particularly severe with varieties which are intrinsically smaller than average in size. Examples of these are the apple varieties Gala, Elstar and Cox's Orange Pippin and the pear variety Conference.

There are several possible strategies for reducing crop load and improving fruit size and quality. These are 1) reduction of numbers of floral buds by winter pruning, 2) inhibition of flower bud formation, 3) preventing fruit set by flower thinning and 4) reducing crop load by fruitlet thinning.

Reduction of Numbers of Floral Buds by Winter Pruning

The benefits of this strategy are that 1) it can be achieved as part of the routine winter pruning operation, 2) it is an environmentally acceptable method of partially achieving the objective of reducing potential crop load and 3) it gives the maximum benefit in terms of reducing competition between flowers and fruits for the trees' resources (assimilates/nutrients, etc.) as early as possible.

The disadvantages are that the technique lacks precision in terms of the relative numbers of flowers removed and left on the tree unless winter pruning is left until very late in the spring. Also, it is a high risk strategy, in that it is carried out before flowering and the risk of frost damage can be assessed.

Nevertheless, winter pruning can be a valuable aid in reduction of flowering abundance and can help to reduce the subsequent cost of alternative thinning operations. Growers need to give this technique more consideration in the future.

Of the products tested recently in Europe the most effective flower thinner is ATS.

Inhibition of Flower Bud Formation

It is well known that gibberellins can suppress flower initiation or cause early floral abortion in most pome and stone fruits if present in supra-optimal amounts during the critical stages of flower development. Excessive natural gibberellins, formed from the seeds of fruits, are thought to play a significant role in triggering biennial bearing in many fruit tree varieties.

Trials on stone fruit crops in California have sought to use sprays of synthetic gibberellins to suppress excessive flowering on fruit trees. Applied in the summer months when flower buds are initiating or in the early stages of development, the number of flower buds developing on peach trees has been reduced significantly.

There is, however, almost no evidence that a similar strategy would be effective on apples and pears. Also, it is very difficult to control the degree of flower bud inhibition achieved and the quality of flower buds (i.e., their ability to set fruits) produced in the subsequent season may be reduced. Gibberellins also may have deleterious effects on the current season's crop of fruits in terms of changing their storage potential.

For these reasons, it is suggested that currently this is not a viable strategy for use with apples and pears.

Preventing Fruit Set at Flowering Time

An increasingly popular strategy for reducing potentially excessive crop loads on trees is to prevent fruit set on a proportion of the flowers. Theoretically this can be achieved by 1) removing a proportion of the flowers at or near the time of full bloom, 2) reducing the potential for pollination of flowers in the orchard and/or 3) preventing the set of a proportion of the flowers with chemical sprays.

Removing flowers from trees can be achieved manually (by hand) or using mechanical devices. Removal by hand is only feasible and economically viable on young, newly planted trees where it is often vital to ensure adequate shoot growth and canopy development. Young trees are frequently de-blossomed for 1 or 2 years immediately following planting. It is far too expensive and time consuming in most countries to hand thin flowers on older, mature trees. Removing flowers using mechanical aids has been attempted on both peach and apple trees. Prototype machines have been developed which remove flowers using flails or combing devices (Baugher et al., 1991; Kelderer et al., 1998). It has also been shown that high pressure water or even hot air can be used to remove or burn flowers from trees (Byers, 1989; Webster and Spencer, 1999). To date, none of these machines has achieved any widespread commercial acceptance. New systems of pruning and tree training will need to be integrated with machine development, if this strategy is to succeed in the future.

Prevention of fruit set by reducing the potential for successful pollination can, in theory, be achieved by 1) reducing the numbers of potential pollinizers planted within or close to the orchard, 2) reducing the activity of bees or other pollinating insects in the orchard and/or 3) removing shelter and making conditions unfavorable for pollen growth and flower fertilization. However, all of these methods of preventing fruit set are very high risk strategies and are not recommended. Growers might, nevertheless, consider removing hives of honey bees from orchards after several days of favorable weather for fruit set, especially if these conditions occur early in the flowering period.

The most popular strategy at blossom time for reducing the risk of subsequent very heavy crop loads is to treat the blossoms with chemical sprays that prevent fruit set on a proportion of them. The objective is to prevent a proportion of the flowers from setting fruits by applying chemicals which prevent pollen germination and growth on/in the stigma and style or stimulate the degeneration of the female ovules in the ovaries. Using this strategy it is important that the chemicals applied cause minimal damage to the developing spur (primary) leaves or other parts of the tree. The primary leaves are thought to be particularly important in sustaining the early cell division of the developing fruitlets and ensuring the uptake of calcium into fruits such as apples.

It is thought that many of the flower thinning chemicals bring about their effect by desiccating the vital female organs (stigma/style or ovary) of the flower. Chemicals such as ammonium thiosulphate (ATS), lime sulfur, dinitro-ortho-cresol (DNOC), endothallic acid, pelargonic acid, sulfcarbamide and dinoseb amine all function in this way.

Reducing Crop Load by Fruitlet Thinning

Reducing the numbers of fruitlets on the tree at some stage after fruit set is traditionally the most common strategy of adjusting crop loads and is usually referred to as fruitlet thinning. It can be achieved by physically removing the fruitlets, by hand or using a machine, or by stimulating their drop (abscission) by application of chemical sprays.

Fruitlet thinning by hand has the advantage of being a low risk strategy in that it can be carried out after the risk of frost damage and facilitates precise crop loading and fruitlet distribution on the tree. Timing of fruitlet removal is also controlled precisely and the technique is environmentally acceptable. The main disadvantage with hand thinning of fruitlets is that it requires much labor to achieve within the optimum time span and is, therefore, a very high cost strategy.

The timing at which thinning is carried out can have a significant effect on the final fruit sizes (Table 1).

This study showed that hand thinning after petal fall, but prior to the more usual 12 mm fruitlet diameter stage, produced the highest yield of Royal Gala fruits that were in the desired >65 mm diameter grades. Thinning later than the 12 mm stage was much less effective and very few fruits in the desired large size categories were produced under UK growing conditions.

Attempts at mechanical thinning of fruitlets have focused on trying to comb or shake a proportion of the fruitlets from trees. Unfortunately, these attempts have not proved very successful by causing much damage to the trees and often the larger fruits are removed, leaving only the smaller, less desirable fruits on the tree. Until trees are pruned and trained to have architectures more amenable to such mechanization, mechanical thinning of fruitlets cannot be recommended.

Many chemicals have been tested as fruitlet thinners and their modes of action are still not fully understood. Auxin-type chemicals, such as NAA and NAAm (NAD), are thought to cause a temporary reduction in photosynthesis and the movement of assimilates to the fruits, as well as temporarily disrupting the movement of natural auxins within the tree. Ethephon has similar effects on auxin transport and also releases ethylene, which is instrumental in stimulating fruitlet abscission. Paclobutrazol (PP333), which has also been tested as a thinner, reduces the production of natural gibberellins within the fruitlets. In contrast, the mode of action of carbaryl (Sevin), one of the most popular fruitlet thinning chemicals over the last 40 years, is still not clearly understood.

The advantage of chemical thinning of fruitlets is that it is a low risk strategy, carried out after the risk of frost damage, which requires much less labor and is much less expensive than hand thinning. The disadvantages of the technique are its poor precision in terms of when the thinning occurs, the crop loading achieved and the often poor uniformity of fruit distribution on tree. Also, the chemicals used are unpopular with environmentalists and most are not acceptable in organic systems of production.

TABLE 1

Effect of time of hand thinning on firmness and percentage soluble solids of Royal Gala fruits in March 1997.

Treatment (time of thinning)	Fruit firmness (kg)	Soluble solids (%)
None (control)	6.0	12.6
Full bloom	6.3	14.4
Initial set	6.3	13.6
12 mm diameter	6.3	14.0
18 mm diameter	6.9	13.7
24 mm diameter	7.0	14.0

TABLE 2

Spray timings and rates of application.

Product	Spray concentration	Spray volumes	Timings
Carbaryl	Variable but 250 ppm to 1000 ppm common	High volumes often perform best	10 mm to 18 mm fruitlet diameter; occasionally immediately after petal fall
NAA	5 ppm to 40 ppm depending upon timing, variety and country	Variable	Variable between king flower and fruitlet diameter of 10 to 12 mm
NAAm	35 ppm to 100 ppm	High volume preferred	Between full bloom and 14 days after
Ethephon	Very variable from 20 ppm to 2000 ppm	Variable	Full bloom to 14 days later

TABLE 3

Sensitivity of Royal Gala flowers to sprays of ATS.

	Stage of flower opening when ATS applied			
	Full open	King only	Balloon	Pink bud
% of clusters setting fruit	8.0	7.7	46.0	52.6
% of fruits/flower bud:				
Singles	8.0	7.7	38.0	52.6
Doubles	—	—	8.0	—
>Doubles	—	—	—	—

FLOWER AND FRUITLET THINNING METHODS CURRENTLY APPROVED AND/OR USED IN EUROPE

Most European producers of apples and pears use a combination of winter pruning to reduce flower numbers and fruitlet thinning, by hand or by chemical means, to achieve their desired crop loads. Recently, many growers have also begun to attempt flower thinning using chemical sprays. This has been stimulated by the withdrawal from use of popular fruitlet thinning chemicals such as carbaryl (Sevin) and the lack of suitable alternative fruitlet thinners. Also, many of the traditional fruitlet thinning chemicals are not permitted under organic fruit production methods, which are becoming increasingly popular. Increasing costs of labor for hand thinning are also pushing growers toward seeking alternative methods of reducing excessive crop loads. The current European situation concerning use of fruitlet thinning chemicals is described below.

Carbaryl (Sevin)

This carbamate insecticide is an effective fruitlet thinner on many apple varieties but works poorly or not at all on pears and stone fruits. However, it is toxic to bees and is unpopular with environmentalists. It was withdrawn from use in Austria, Denmark, Germany, Sweden and Switzerland several years ago. Within the next 2 years approval for its use will cease in almost all other countries in western Europe. It is possible, however, that some growers will stockpile the product and will continue to use it for several years to come.

NAA

This synthetic auxin has variable efficacy as a flower/fruitlet thinner. It should be applied in water which has slightly acidic pH for best effects. Fruitlets that do not drop off sprayed trees are often checked in their growth temporarily and fruit size increases at harvest are often less than anticipated. In 1999, NAA was still officially registered for thinning in Austria, Denmark, France, Hungary, Italy, Norway, Poland, Spain and Switzerland. It was not and is still not approved for use in the UK and Germany. However, somewhat strangely it is used and even approved by the IFP authorities in the latter country.

NAAm (Amidthin)

This amide of NAA in some circumstances can prove to be a more reliable fruitlet thinner than NAA itself. In 1999, it was still registered for use in Austria, Belgium, France, Hungary, Italy, The Netherlands, Sweden, Spain and Switzerland. Registration was pending in Slovenia. Although not registered for thinning in Germany, it is thought to be quite widely used there by fruit growers. It is accepted under IFP guidelines in most countries.

Ethephon (Ethrel)

Ethrel is only a reliable thinner where temperatures are 15˚C (59˚F) or more at the time of application and for 1 or 2 days afterwards. Its efficacy as a thinner increases linearly between 12˚C (54˚F) and 24˚C (75˚F). Achieving the optimum spray concentration and timing is very difficult and is influenced by variety and season. Ethrel works best if the water it is dissolved in is slightly alkaline. It is officially registered as a thinning agent in France, Italy (for peach only but tolerated on apple), The Netherlands, Norway, Poland and Switzerland.

The spray timings and rates of application for the commonly used fruitlet thinning chemicals are shown in Table 2.

Most fruit growers use a combination of chemical fruitlet thinning supplemented by later hand thinning. However, the problem with hand thinning is the very high cost. In the UK casual laborers can thin only 7 to 8 traditional medium-sized trees on M.106 rootstock each hour, but many more smaller trees on M.9. Labor costs in the UK, including a small proportion for supervision, amount to approximately £5.00 (US$7.5) per hour. At the relatively wide spacings of 270 trees/acre on MM.106 this amounts to approximately 35 worker hours per acre or a cost of £175 ($260) per acre to thin. Although smaller trees planted at closer spacings take less time per tree to thin, times (and hence costs) per acre are very similar.

The economics of apple and pear production in Europe is currently very poor. The oversupply of fruits to the European markets has depressed prices significantly. Many fruit growing enterprises have gone out of business and, without cheap family labor, many more would have failed. Businesses in some European countries survive by providing only part-time employment to their owners who have other supplementary employment.

If apple and pear production is to remain economically viable in the future, it will be essential to 1) reduce the three critical cost centers in production, those associated with harvesting, pruning and thinning and/or 2) to receive higher prices for the fruits produced.

RESULTS OF RECENT EUROPEAN THINNING TRIALS AND POSSIBLE FUTURE THINNING STRATEGIES

Approximately 10 years ago an organization called the European Fruit Research Institutes Network (EUFRIN) was set up in an attempt to coordinate some of the research conducted by the various universities and institutes within Europe. Within EUFRIN, a Working Group on Chemical Thinning was set up, which now includes scientists from Austria, Belgium, Denmark, Germany, Hungary, Italy, Netherlands, Norway, Poland, Sweden, Slovenia, Spain, Switzerland and the United Kingdom. This group meets annually in one of the participating countries and agrees upon protocols for collaborative trials with the aim of comparing results on different varieties at different locations. The group also lobbies chemical companies in attempts to enlist their help in gaining approval for new and promising thinning products. Currently, the group is also considering writing publications on its findings.

Many new chemical flower thinners have been tested by the EUFRIN Working Group participants. Following this work ammonium thiosulphate (ATS) is now used to some extent on apples and plums, although official approval is still lacking. Urea is used to a small extent in Germany, although it causes undesirable damage to spur leaves. The surfactant/spray additive Armothin shows promise as a peach thinner in France and Italy but has proved less reliable on plums, apples and pears.

Other products tested extensively but found to be unreliable and/or excessively phytotoxic were pelargonic acid (Thinex), MCDS (Wilthin) and Endothall.

ATS (ammonium thiosulphate) has proved to be the most reliable and least phytotoxic of the flower thinners tested. Rates of 0.5% to 3.0% have been compared and 1% to 1.5% rates have proved the most efficient. Using ATS, flower thinning increases as temperatures at the time of spraying increase but in slow drying conditions (high humidity) phytotoxicity to spur leaves increases. Trials have shown that low concentrations perform well if supplemented by later sprays of benzyladenine (BA).

ATS has proved an effective thinner on apple, pear, peach and plum. Although petals are severely browned, flowers sprayed at pink bud or earlier are not thinned. It is therefore essential to target the newly opening flowers. Figure 1 shows the cumulative opening of Royal Gala flowers in a typical UK season. The relative sensitivity of Royal Gala flowers to ATS in the same season is shown in Table 3.

Urea sprays have also been shown to thin apple and peach flowers quite effectively but they often cause significant damage to the spur leaves. This leaf damage may cause a reduction in the uptake of calcium on some apple varieties and increased sensitivity to the bitter pit disorder. Also, occasional problems of fruit rusetting are reported following sprays of urea for flower thinning. These problems and the often variable thinning responses make urea an unreliable product. Nevertheless, sprays of 3% to 4% urea are used in parts of Germany on varieties prone to biennial bearing. In Poland mixtures of urea and NAA have also been trialed extensively.

The new fruitlet thinner benzyladenine (BA) has been tested quite extensively by the EUFRIN Working Group. The more traditional fruitlet thinners NAA and Ethephon also have been trialed by the group, as has paclobutrazol.

In some trials on apple BA has proved as effective as carbaryl (Sevin) but the product has shown variable responses depending upon season, site and variety. The interesting response to BA is the increase in fruit size achieved in some seasons without any apparent reduction in the numbers of fruits on the trees. However, the response to the product needs to be more reliable before it can be recommended as a replacement for carbaryl. The variable effects of BA in UK trials as a fruitlet thinner for Royal Gala or Queen Cox apples are shown in Tables 4 and 5.

Paclobutrazol (Cultar/PP333), if applied at or in the 1 or 2 weeks after flowering, can stimulate fruit drop (abscission) of pear, plum and other stone fruits. The problem with using this product is that if fruits are hit with very low doses of the product (i.e., amounts too low to trigger fruit drop) the fruits persist on the trees but fail to grow to their full potential size. Also,

TABLE 4

The variable effects in UK trials of BA sprays as fruitlet thinners for Royal Gala apple (the same trees were treated in 1995 and 1996).

Treatment	1995 Total yield/tree (kg)	1995 Mean fruit wt. (g)	1995 % Class 1 >65 mm	1996 Total yield/tree (kg)	1996 Mean fruit wt. (g)	1996 % Class 1 >65 mm	1998 Total yield/tree (kg)	1998 Mean fruit wt. (g)	1998 % Class 1 >65 mm
Unthinned	22.2	67.8	1.7	20.2	91.9	19.2	24.5	94	11.5
Hand thinned	20.8	94.6	25.6	17.7	111.8	59.4	12.8	125	59.4
BA 50 ppm	20.5	76.5	5.4	23.3	75.9	2.0	—	—	—
BA 100 ppm	18.2	77.2	8.8	19.9	86.4	4.4	25.2	111	39.7
BA 200 ppm	18.9	76.6	6.9	21.9	81.4	11.3	—	—	—
Carbaryl	18.0	93.9	20.5	—	—	—	—	—	—
LSD (5%)	3.7	12.3	10.7	5.6	15.3	20.4	6.9	12.5	15.6

the sprays can cause reductions in shoot growth which may or may not be desirable.

Thinning sprays for organic orchards are urgently needed, as few of the existing products are approved under organic protocols. Unfortunately, in Danish trials none of the natural products tested were effective as thinners and most caused much phytotoxicity. More recent French trials indicate that rapeseed oil can be effective as a thinner but is also phytotoxic. The vegetable oils tested in recent years in Washington State have not yet been tried in Europe.

CONCLUSIONS

Of the products tested recently in Europe the most effective flower thinner is ATS. However, it is essential to adjust the spray concentration, volume and timing to suit the variety and the prevailing climatic conditions.

BA is the most effective new fruitlet thinner tested and could prove to be a useful replacement for carbaryl (Sevin). Approval is being sought for its trial use in several European countries.

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TABLE 5

The variable effects in UK trials of BA sprays as fruitlet thinners for Queen Cox apple (the same trees were treated in 1995 and 1996).

	1995			1996		
Treatment	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 >65 mm	Total yield/tree (kg)	Mean fruit wt. (g)	% Class 1 >65 mm
Unthinned	13.0	84.3	22.1	11.0	122.7	43.7
Hand thinned	13.9	82.0	11.1	11.6	125.3	63.5
BA 50 ppm	11.8	105.0	42.3	11.1	105.6	43.2
BA 100 ppm	11.0	107.6	50.7	12.6	95.8	35.9
BA 200 ppm	11.4	116.2	68.2	16.5	85.4	24.0
Carbaryl	9.8	117.9	73.0	—	—	—
LSD (5%)	3.3	22.0	—	4.6	26.5	25.0

FIGURE 1

Royal Gala flower opening, cumulative % of blossom numbers of each type opened on each day.