Best Practice Guide - Part 1

Regular Cropping of Apples: including Flowering, Fruit Set, Thinning and Fruit Growth

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[Summarised Version for Fruit Growers]

Objective of the Guide:

The aim of this summarised version of the full **Best Practice Guide** is to provide apple growers and the extension and advisory organisations serving them with an up to date, albeit brief, resumé of the information currently available from throughout the world on flowering, pollination, fruit set and fruitlet growth of apples. Tentative recommendations are made in the form of highlighted bullet points

The aim is to encourage all UK apple growers to adopt the Best Practices currently available for producing this crop.

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This Guide is one of three, all produced by staff of:

Horticulture Research International – East Malling
Farm Advisory Services Team (FAST)
ADAS
Qualytech

The authors have made their best efforts to ensure that the suggested practices noted within the Guide are safe and approved. Where there is no current UK approval for the use of a spray product or other technique, this is clearly stated

Neither the authors nor MAFF can accept any liability associated with any loss incurred as a result of adopting recommendations made within the guide.

Introduction:

World supplies of apples, from both the Northern and Southern Hemisphere have increased significantly over the last 20 years. This has resulted in an over supply to the European and UK markets in most seasons. This oversupply causes a depression in the prices realised for UK-produced apples and a fall in the profitability of apple growing enterprises.

If apple production in the UK is to remain profitable, it will be essential for growers to maximise production per unit cost (land, labour, materials and capital costs) of large-sized, high quality fruits. This must be achieved regularly in each season, commencing soon after the establishment of the orchard.

Regular Cropping of Apple is dependent upon having:

- **Sufficient flower numbers to set an optimum crop**
- **Adequate flower 'quality' to enable adequate fruit set**
- **Good conditions for flower pollination and fertilisation**
- **The correct numbers of fruits set and retained per tree, so as to optimise final fruit size and quality**
- **The best conditions and management post fruit set to ensure optimum fruitlet growth**

Each one of these factors will be influenced by:

- **Temperatures, light levels and other climatic conditions in the orchard**
- **The growth characteristics of the scion and the influence of the rootstock**
- **The system of tree management**
- **Soil water and nutrient supplies**
- **Hormonal and other internal tree factors**

This Guide aims to consider and discuss each of these essentials and some of the factors influencing them.

Organisation of the Guide and how to use it

This summarised version of the full guide is divided into 3 main sections covering:

- **Initiation and development of Sufficient High Quality Flowers by the Apple Tree**
- **Pollination and Fruit Set and Preventing Excessive Fruitlet Drop**
- **Flower and fruitlet thinning (abscission) and alternative methods of improving fruitlet growth**

In this brief version of the full guide Summaries of the Best practices are presented in a bullet point format. This is based on the current available knowledge from the UK and around the world.

In the full guide, there are sub sections covering in more detail the possible **Strategies for Optimising** the various components of flowering, pollination, fruit set, thinning and fruit size/quality.

For those wishing to explore flowering, fruit set and growth slightly more deeply, the full guide also includes sections on the **Physiology** of Flower Initiation, Pollination, Fruit Set, Fruit Growth and Retention or Fruit Drop. Finally the full guide gives a list of key **References** that are cited in the text.

The full Best Practice Guide is intended for advisors or others seeking a more in depth study of the various facets of flowering, fruit set and growth.

Initiation and development of sufficient high quality flowers by the apple tree

Introduction:

It is essential that apple trees produce sufficient flowers to set an optimum crop of fruits in relation to the size of the trees. It is also vital that these flowers are of sufficient quality to set fruits reliably and to produce large fruits of good texture and storage potential.

On young newly planted trees the objective is to induce quality flowers on the trees in the second and third years after planting. This is known as improving their floral precocity. If orchards are to break even rapidly and move towards profitability on the investment, cropping early in the orchard's life is essential.

On mature trees lack of abundance of flowering is a relatively rare problem and usually only occurs with varieties that are prone to biennial bearing. Fortunately, most of the traditional varieties suffering from this problem (e.g. Miller's Seedling, Laxton's Superb) are no longer grown commercially, but Elstar the popular Dutch variety can become strongly biennial in its cropping. Even the variety Cox is considered partially biennial in some countries.

Occasionally, excessive flowering and inadequate new extension growth may be a problem with some varieties grown on dwarfing rootstocks such as M.27. Here the grower's objective must be to reduce the abundance of floral spurs and increase shoot growth, so as to bring the trees back into a more optimal balance of fruit production with shoot growth.

Summary of Best Practices for Improving the Initiation and Development of High Quality Flowers by the Apple Tree

If abundant yields of large, high quality fruits are to be achieved on UK apple orchards, growers must ensure that adequate numbers of flowers are produced on the trees. It is also essential that the flowers produced are of high quality. High quality flowers are essential if fruit set is to be achieved in the often less than ideal weather conditions at flowering time in UK orchards. Flower quality also influences whether fruits are retained on the trees throughout the season and their size and quality at harvest.

Adequate floral abundance and good flower quality are essential considerations on both mature and young, immature trees. Flowering and fruiting on young apple trees (older than 3 years) is particularly vital if the investment in the orchard is to be

economically viable. Floral abundance is usually only a limiting factor on mature apple trees, if the varieties have a tendency towards biennial cropping. However, flower quality is often a limiting factor in fruit set and retention on mature trees. The Best Practices are listed in three sections:

- **The Importance of Flower Quality**
- **Improving Flowering on Young, Newly-Planted Trees**
- **Improving Flowering on Mature or Semi-Mature Apple trees**

The Importance of Good Flower Quality

Flower quality is the ability of a flower to set and carry (retain) a fruit

Types of flower buds

There are two main types of flower buds formed on apple trees:

Spur Buds – formed on spurs and short terminal shoots. These begin their initiation shortly after fruit set in the preceding season

Axillary buds – Formed in the lower (basal) leaf axils on extension shoots later in the season than spur buds, usually as shoot growth slows down in mid to late summer

♦ The aim of the apple grower must be to encourage the rapid production of high quality flowers on the spurs and short terminal shoots of young trees.

♦ Only with a few varieties, such as Gala and its sports, can axillary flowers be relied upon to contribute significantly to cropping on young trees. Even with Gala, axillary flowers are only useful if they are produced on strong wood of approximately 10mm diameter

Factors Influencing Flower Quality

Anything that reduces the production of resources (sugars and carbohydrates formed by photosynthesis) by the tree or diverts them away from the developing flower buds will reduce their quality. An imbalance of hormone levels in the tree will also affect flower bud development. The main factors influencing flower quality are listed below:

- Too many fruits on the tree – this will reduce flower bud numbers in the following year especially in varieties with a tendency to biennial cropping. Thin as early as possible to the correct crop load.
- Too much vigour (length of shoots and numbers of shoots) will create an imbalance in the tree and reduce the quality of flower buds.
    - Adopt practices to reduce vigour.

- Lack of light – shading will significantly reduce flower bud quality.

- Leaf quality – poor nutrition and disease (especially mildew) will impact directly on flower bud quality. Mildew should be controlled all the way through the season to prevent infection in developing buds which will carry over to the next season.
- Nutrient levels should be checked by visual and analytical techniques. It is particularly important to avoid excess nitrogen levels and maintain adequate phosphorus and trace elements to ensure good flower bud development.

Improving Flowering on Young Newly-Planted Apple Trees

When planting young trees the following should be considered:

♦ Plant well-feathered trees with healthy, non- desiccated roots. Tree 'quality' at the time of planting has a significant influence on how well the young trees establish and how quickly they begin to flower and fruit.
- The onset of flowering is advanced and the abundance and quality of flowers improved if well-feathered trees are planted in good fertile soils.
- Trees with 6 to 8 strong well-spaced feathers with wide branch angles should be chosen.
- It is also important that these relatively large trees receive good management to minimise the transplanting check to growth. Excessive transplanting check to growth will cause tree stunting and may lead to the production of branches with bare wood.

♦ Where available choose trees guaranteed virus-free and true-to-type
- Healthy trees establish more quickly and crop more abundantly

♦ Choose the most appropriate rootstock for the site/soil conditions the chosen scion variety and the planned system of management:
- Irrespective of the vigour of tree desired by the apple grower, he or she should always chose the rootstock or rootstock/interstock combination, which is likely to induce precocious cropping.
- Most dwarfing rootstocks (M.9 and its clones e.g. Pajam 1 and Pajam 2, M.27, P.22 etc) improve precocity of cropping. Unless soil conditions are excellent avoid use of very dwarfing rootstocks such as M.27 and P.22.
- Amongst the more vigorous rootstocks MM.106 and M.116 both induce good floral precocity in scions and are well suited to use in cider orchards.
- Use of dwarfing rootstocks as interstocks also improves floral precocity of scions.

♦ Improve flower quality (i.e. ability to set fruits) on young trees. By being aware of the limitations on fruit set, associated with poor flower quality on very young trees, growers can improve the situation by:
- applying only balanced fertilisers
- bending branches down or brutting branches, so as to improve flower quality

♦ Ensure good tree establishment and avoid bare wood developing by:-

- Planting in good conditions – preferably before Christmas.
- Providing adequate water and nutrients (both to the roots and by foliar feeding)

♦ Growers should obtain analyses of the soil mineral and organic matter contents prior to tree planting. Based on these analyses and the current recommendations concerning optimum levels (e.g. ADAS recommendations in M.A.A.F, 2000) any necessary base dressings should be applied.

♦ Supplementary nutrition of trees in their first or second years following planting are only warranted on shallow and relatively infertile soils.

♦ Supplementary irrigation should be applied, preferably using trickle systems, only when soil moisture deficits reach 50mm.

♦ Prevent stress to the trees (e.g. by wind desiccation)

♦ Prune and train trees so as to establish ideal balance of growth and flowering:

- Tip the leader following planting. Avoid pruning that will stimulate excessive growth in the laterals i.e. tipping or heading back. Only tip laterals on varieties, which have a tendency to produce, bare wood immediately following planting (e.g. Meridian).

- Remove excess feathers, especially those with strong upright growth and poor branch angles; this will help produce better leaf and flower quality on the remainder. Aim for 6-8 good feathers. Remove low and unwanted feathers

- Tie down lateral growth towards the horizontal or below this angle on very strongly growing varieties.

- Use low doses of chemical growth regulators, where necessary to achieve reduced shoot growth and improved balance of growth.

  - Low concentration treatments with Cultar may aid flower production on young trees that are growing too vigorously.

Improving Flowering on Mature Apple Trees

Before attempting any adjustment or manipulation of flowering it is vital to :

Assess the correct numbers of fruit buds needed for an optimum crop

Take into account the variety, the growth habit of the trees and the cropping history.

- Assume 1 to 2 flower buds will be required to produce one harvested fruit. This is, however, dependent upon scion variety, tree vigour and site conditions

    - Cox, Bramley, Discovery

    In well managed regularly cropping Cox orchards the average fruit set will be between 15% and 20%. Each fruit bud produces a cluster of 5 or 6 flowers therefore assume one fruit will set from each flower cluster. If 100 fruits per tree are required leave between 100 and 120 fruit buds. The fruit set in vigorous shaded trees can be much lower and 2 fruit buds will be required to ensure one fruit at harvest.

    - Gala, Jonagold, Egremont Russet, Braeburn

    These varieties set more readily and also crop well on 1-year wood. A setting level of approximately 20-250% can be achieved; therefore 80 buds should produce 100 fruits.

Increasing Flower Numbers on Mature Trees

Where insufficient flowers are present it will be due to one or more of the following factors:

- Too much vegetative growth
- Lack of light in the tree canopy
- Too heavy a crop in the previous year

Poor Flowering due to excessive vegetative growth
Growers experiencing problems of excessive shoot growth and poor flowering on mature or semi-mature apple trees should:

- Adapt pruning techniques in the light of the amount of fruit bud

Where insufficient fruit buds is the result of excessive vegetative growth growers should change their pruning/tree management practices

- Prune only lightly in the winter months
- Make fewer cuts
- Concentrate on branch removal to achieve correct tree shape
- Delay leader pruning until the early spring
- Bend shoots to the horizontal (Gala , Braeburn) or below (Cox, Discovery, Bramley and Jonagold)

- Increase use of plant growth regulators (such as Cultar). Aim to stop growth before it becomes too strong, using winter and spring treatments> However, sprays between pink bud and early fruitlet can affect fruit set and GA_{4+7} sprays should be added to reduce this effect.

- Only summer prune to remove strong upright shoots and those shading fruits within the canopy.
  - When summer pruning, remove whole shoots back to their base. Do not head back shoots.

If the above adjustments to management practices prove inadequate and flowering is still insufficient growers can:

- Consider girdling (bark ringing) of the trunk as a means of improving floral abundance and reducing excessive shoot growth.
  - Care must be taken, however, when bark ringing varieties that are sensitive to diseases such as apple canker (*Nectria galligena).*

- Consider root pruning However, this should only be resorted to when other measures have failed to bring over vigorous apple trees into a balance of shoot growth and fruiting.
  - Root pruning on one side of the tree should be tried initially and the effects observed.

  - To be effective the treatment should be applied close to the tree trunk (50cm) using some sort of adapted chisel plough.

  - Tree anchorage may be a problem following severe root pruning

Poor flowering due to lack of light into the tree canopy

A lack of light within the tree will reduce flower bud numbers and their quality. As shoots tend to grow strongly towards the light, further shading can be induced.

Light levels within the tree canopy can be improved by:

- Changing pruning techniques to reduce shading. This is particularly important in the top of the tree to reduce the height and width of the upper tree canopy.

- In spindle trees create a well defined A shaped tree

- If lower branches remain shaded, remove them

- Remove strong upright shoots or bend them into a space

- Reduce the height of windbreaks surrounding the orchard
- Use of light reflecting material on the orchard floor

Poor flowering due to excessive cropping in the previous season
The number of seeds in the fruit produced in the previous season will have a major effect on the numbers of flowers formed. To reduce this effect growers should:

- Thin as early as possible, to reduce the fruit numbers and hence the seed numbers causing the flowering inhibition
- Do not delay harvesting more than two weeks after the optimum date as this can reduce flower numbers, especially if other risk factors (e.g. vigour and shading) are also a problem.

Overcoming Biennial Bearing

With varieties that have developed a biennial pattern of cropping growers should**:**

- Prune away excessive spurs in the winter prior to an 'on' year
- Thin blossoms on biennial varieties in the 'on' year
- Thin, preferably at flowering time, using ATS
- No chemical treatments, other than thinning treatments are approved for use against biennial bearing

Flower Quality on Mature Trees and its Improvement

Growers should strive to produce flowers of high quality with Effective Pollination Periods (EPPs) of 3 days or more.

For optimum flower bud quality:

- Trees should be thinned early in the previous season to optimum crop loads
- Fruit harvesting should not be delayed too long, as late picking may reduce flower quality on varieties such as Bramley
- Maintain good tree health status by judicious use of pest and disease control measures.

- Use nitrogenous fertilisers sparingly in the spring and summer prior to harvesting so as to reduce shoot growth which competes with developing flower buds

- Consider urea sprays in the autumn, following harvesting but before leaf fall to improve the quality of flowers in the subsequent spring

- Aid flower quality by light, rather than severe winter pruning

- Summer prune to allow adequate light into the centres of the trees

- Bend shoots towards the horizontal or below, but this should not be carried out to excess or the optimal balance of new renewal shoot growth and flower bud production will be lost.

- Growers should take note of the average maximum temperatures in February, March and April in their Cox orchards, as these have a significant bearing on flower quality

    - . Where temperatures are higher than desired average maxima (i.e.10^0C or higher), they are advised to intensify their efforts to secure good pollination and flower fertilisation. This can be achieved by supplementing bee populations, providing increased shelter and boosting supplies of compatible pollinating varieties.

    - Where temperatures are of the desired average maximum, or lower, growers will need to consider implementing appropriate

Delaying Flowering in the Spring using Plant Growth Regulators and Other Spray Treatments

In many seasons some means of delaying the time of flowering, so as to reduce the risk of frost damage would be very desirable

- Although sprays of various chemicals can influence the time of spring flowering in the previous autumn or winter, none of these treatments are approved for use in UK apple orchards.
- Further research may be warranted, examining misting techniques to delay flowering times of apple varieties.

POLLINATION AND FRUIT SET AND PREVENTING EXCESSIVE DROP OF FRUITLETS

Introduction

If apple production is to be successful it is essential that abundant crops of large high quality fruits are set on trees, in every year. If the break even point on capital invested in the orchard is to be achieved rapidly and the orchard is to move towards being a profitable investment, it is also essential that the trees begin cropping in the first two or three years following planting.

If the above objectives are to be achieved, it is vital to ensure adequate pollination and fruit set.

Summary of Best Practices for Pollination, Fruit Set and Preventing Excessive Fruitlet Drop

The pollination and fruit set of apple trees can be influenced by many factors, including the choice of site, climatic conditions (and the provision of frost protection), the planting of suitable pollinating varieties, the provision of bees in the orchard and various management factors.

Choice of orchard site and its optimisation

Growers are advised to take account of the following when choosing a site for an apple orchard:

Site altitude, aspect and slope

- Choose a site, which is preferably between sea level and 125 metres above sea level
- Study the cropping history of previous orchards planted on the proposed site, or of neighbouring orchards
- If available, study meteorological records taken on the site in previous years.

- Avoid sites prone to spring frosts or sites exposed to cold east or north winds

♦ Sites with a slight slope to allow the escape of cold air flows are to be preferred

- Ensure that there are no barriers (buildings or windbreaks), which impede the movement of cold air off the site and create ‘frost pockets’

- Apples can crop on north and east facing slopes but fruit size is likely to be maximised on warmer south facing slopes

♦ Sites close to large bodies of water tend to be slightly warmer and less sensitive to frost damage

♦ Choose a site which is sheltered from strong winds

Provision of adequate shelter in the orchard

♦ Plant windbreaks at regular intervals (every 100m) around sites, so as to provide adequate shelter for pollination, but not impede the escape of cold air flows during nights of radiation frosts.

♦ Choose species such as Alders, which are less competitive for water and nutrients than Willows or Poplars

♦ Plant at spacings of 1.0m-1.75m apart in single or, if very good shelter needed, in double rows.

♦ Trim windbreaks regularly and cut to approximately 7m in height

♦ Plant windbreaks several years in advance of planting the orchard trees to ensure adequate shelter when the young apple trees begin to flower

♦ Where living windbreaks are not available use artificial windbreaks

Planting of suitable pollinating varieties in sufficient numbers

Most apple varieties are self-sterile and require pollen from another variety to achieve effective fruit set. Pollinating varieties, either other dessert or culinary varieties or ornamental crab apple varieties are planted in the orchard to provide this pollination. Growers are advised to take account of the following when making decisions on choice and abundance of pollinators required:

Summary of Pollination Requirements of the Principal Commercial varieties

Varieties differ in their pollination requirements as noted below:

Cox and **Queen Cox**	weak self fertile but only at at temperatures of 20-25ºC
Q Cox clone 18	fully self fertile
Braeburn, Fiesta, James Grieve and **Gala**	Partially self fertile will set crops with its own pollen but a pollinator is recommended
Jonagold	Has the ability to set fruits without pollination (therefore, seedless) given suitable weather.
Other varieties	Require a pollinator

What constitutes an adequate supply of pollen therefore varies with the variety. It is also influenced by the season and the vigour of the orchard.

The number of trees of the pollinating variety planted in relation to the numbers of the main variety

- Generally the number of pollinators should be 1 in 8 to 1 in 10, but in extremes ie

  poor setting, cool sites with excess vigour 1 in 4 to 1 in 6 will be necessary
  weak trees of a partially self fertile variety on a good site 1 in 12 to 1 in 15 would be adequate.

- Take advice from your local advisor before choosing a ratio of pollinator to main variety for planting in a new orchard. This ratio will be influenced by:
  - How favourable the orchard location is, in terms of temperatures and shelter from winds
  - The populations of bees, either wild or introduced in the orchard
  - The pollen producing abilities of the pollinating varieties chosen
  - The propensity of the main commercial scion variety to set abundantly or lightly

- The compatibility (full or partial) of the chosen pollinating varieties with the main variety

Avoid varieties exhibiting a degree of incompatibility (see notes below) as these will give poor results in marginal site/weather conditions.

The Importance of Pollen Compatibility with the main commercial variety

It is wrong to assume that any two varieties of apple flowering at the same time will always be compatible with each other and capable of setting fruits when pollen is exchanged. Although, given favourable weather conditions during flowering this is mainly true, there are exceptions to this rule:

♦ Consider choice of pollinators carefully, avoiding unsuitable pollinators, especially on sites where conditions for pollination are less than ideal

- Do not use triploid varieties, such as Bramley's Seedling, Jonagold or Boskoop as pollinators for other varieties. They produce only small amounts of pollen most of which is sterile.

- Do not use Red Pippin as a pollinator for Elstar; unless climatic conditions are very favourable the varieties may prove incompatible

- Do not use Falstaff or Greensleeves as pollinators for Gala, unless climatic conditions are very favourable the varieties may prove incompatible

- Do not use Gala or Greensleeves as pollinators for Falstaff, unless climatic conditions are very favourable the varieties may prove incompatible

- Partial compatibility, where only 50% of the pollen is capable of growth down the style may be experienced when using the following varieties as pollinators for Cox: Alkmene, Elstar, Red Pippin, Gala, James grieve and Falstaff

- Partial compatibility, where only 50% of the pollen is capable of growth down the style may be experienced when using the following varieties as pollinators for Gala: Golden delicious, Summered, Alkmene, Arlet, James Grieve, Cox, Elstar, Red Pippin and Worcester Pearmain.

Partial incompatibility is not a problem where ratios of pollinators is relatively high, blossom abundance on the pollinators and pollen supply is high and conditions for pollination are good.

Climatic influences on compatibility/incompatibility relationships

When weather conditions are very favourable during flowering some of the full and partial incompatibility mentioned above is overcome. Temperatures of more than 20 or 25^{0}C will often be sufficient.

- Pollen germination and growth down the style is greatly aided at temperatures of >20^{0}C
- At higher temperatures (e.g. 25C) pollination efficiency is improved with variety combinations, which are normally incompatible or show only partial compatibility
- Winds cause pollen desiccation and often death.
- Frost causes death of pollen and the female parts of the flowers. The damage is not always visible.

Pollination using ornamental crab apples or other Malus species

Ornamental crab apples were, some years ago, recommended as potential pollinators for commercial varieties of apples grown in the UK. Their main advantages over the use of more conventional fruiting varieties as pollinators is that they take up less space in the orchard and often require no picking. These are no longer popular with fruit growers.

- Several species of ornamental Malus can prove effective pollinators for commercial varieties of dessert and culinary apples
- They have the advantage of taking up less space in the orchard than normal pollinating varieties.
- The tried and tested species/varieties are M. hillierii, M. aldenhamensis, M. Golden Hornet, M. Winter Gold and M. Evereste.
- Always plant several of these ornamental crab pollinators in an apple orchard, not just one. Their winter chilling and spring forcing temperature requirements are different from those of the commercial apple varieties and this often leads to lack of synchrony in flowering times.
- Do not neglect the pruning and, where necessary, the thinning of ornamental crabs, or they may go biennial and fail to produce the required flowers in sufficient abundance

Synchrony of flowering times

For effective pollination it is essential that the main and pollinating varieties flower at approximately the same time period in the spring.

- Choose pollinating varieties which, according to local records, have flowering periods that overlap by a minimum of 6 days with the main apple variety in the orchard

- This overlap should be consistent and judged from records collected over a number of years at sites close to the intended site for the new orchard

Production of adequate quantities of viable pollen by the pollinators

Pollinating varieties for use in orchards of self-sterile varieties of apple must produce adequate quantities of viable pollen. The quantities produced are influenced by the scion variety chosen, the rootstock used, the crop loading (on the fruiting crabs), the orchard climatic conditions, the density of pollinating varieties planted and their management.

Scion Varieties and their production of viable pollen

- Take account of the pollen producing potentials of the varieties chosen as pollinators. Varieties such as Golden Delicious produce copious quantities, whilst Cox and its clones produce much less.

- Triploid varieties, such as Bramley and Jonagold produce almost no viable pollen and should not be used as pollinators.

- Do not choose the self-fertile clones of Queen Cox or Cox as pollinators for self-sterile varieties; they produce too little viable pollen.

Rootstock influence on the production of viable pollen by scions

- Pollinating varieties grown on dwarfing rootstocks, such as M.9 produce more flowers per unit tree size than the same variety on a more invigorating rootstock

- Trees on dwarfing rootstocks also take up much less valuable space in the orchard

Crop loading and its influence on pollen production by scion varieties

- Manage the crop loads on the pollinating varieties so as to avoid overset and the establishment of a biennial pattern of cropping
- Only if thinned well will the fruiting pollinating varieties produce abundant supplies of flowers and pollen on a consistent seasonal basis

The orchard environment and its influence on pollen quality

- Avoid frost damage to pollinators by good site selection and, where possible, use of frost protection measures

- In the event of frosts after green cluster, check the pollen viability using simple pollen germination tests

The management of the pollinating variety in the orchard

- Prune and train pollinating varieties so as to stimulate renewal growth and adequate production of quality flowers

- Apply water and nutrients to pollinating varieties so as to sustain their growth and flowering

Provide ideal conditions for pollen transfer

Transfer is by insects and to a small extent by wind.

Best practice is to achieve an orchard environment which:

- Encourages a wide range of natural insect vectors especially bumble bees by leaving (or creating) grassy sheltered banks and alternative food sources

- By creating adequate shelter, reduces wind speeds to encourage insect flight. Does not reduce wind speed too low, creating stagnant air and no wind transfer of pollen

Introduce bees where needed

- Where these natural levels of insect activity are low, or where pollinator numbers are low and tree vigour is high, pollination can be supplemented by importing hives of honey bees. Honey bees will forage more successfully on clear days and when temperatures are above 12^0C. Best Practice – rent healthy well stocked (>15000 bees) hives and shelter the hives from cool winds.

- Introduce hive or bumble bees to orchards only when 20% of the flowers are open. Introduction earlier may lead to the bees seeking food supplies on other crops growing nearby. Once habituated to another crop it is often very difficult to attract the bees back into the apple orchard

- Remove (by mowing or use of herbicides) weeds or other species that are flowering in the orchard at the same time as the apples. These may prove more attractive to the bees than the apple flowers

- Avoid broad-spectrum insecticides during blossom.

Improve conditions for Pollen Germination and pollen tube growth.

Germination of Pollen

The fertilization process begins with the pollen falling on the stigma and germinating. Germination requires adequate moisture but not excessive as the pollen grains need to take in water in order to germinate, drying winds will reduce viability. Pollen grains lose viability rapidly once wetted so rain will significantly reduce pollination. Germination is temperature dependent with optimum temperatures being between 15ºC and 25ºC.

Some laboratory tests have indicated that certain sprays can reduce pollen germination. The relationship between these tests and the effect in the orchard is not known at today's spray volumes. Dinocap was the most damaging with Captan and sulphur also having some reduction on pollen germination.

Laboratory tests have shown that Boron and Calcium can aid pollen germination but field experiments have given very variable results.

Best practice to increase pollen germination

- Aim to create a sheltered orchard environment in order to lift average temperatures, reduce desiccation from drying winds.

- Avoid any sprays especially on those warm days when germination is the most likely to proceed

- Avoid spray volumes, which thoroughly wet the flowers.

- Provide plenty of pollen as there is evidence that increasing the number of grains on the stigma seems to stimulate germination.

- Ensure that trees are not deficient in Boron or Calcium.

Growth of the pollen tube

Pollen tube growth is almost entirely dependent on temperature. Where temperatures are low and the tube does not grow down the style within 2-4 days fertilization may not occur.

Some varieties notably Falstaff and Redsleeves have pollen that is able to germinate and grow at much lower temperatures.

Best practice for encouraging growth of pollen tubes is:

- Create a sheltered warm environment in the orchard.
- Consider using Falstaff or Redsleeves as pollinators, especially in sites which have marginal spring temperatures.

Successful fertilization of the ovule

The Effective Pollination Period is the number of days after the flower opens during which time it can receive pollen and still set a fruit. Some varieties have shorter periods than others. Measurements of Cox showed it to be both shorter than other varieties and more variable from year to year. The EPP combines the time taken for the pollen to germinate, the pollen tube to grow and the time during which the ovule remains viable. How the EPP is influenced is not understood but aiming for best practice in all the above areas will induce stronger flowers, more viable pollen better pollination conditions and a higher success rate at fertilization.

Self fertility

A few varieties of apple show either full or partial self-fertility. This means that they can, given favourable climatic conditions during flowering, set fruits with their own pollen.

Self-fertile clones

Two varieties, **Queen Cox Self-fertile Clone 18** and **Cox Self-fertile Clone 8,** both produced in the last 20 years, are fully self-fertile and can be planted without pollinators.

- Self-fertile Queen Cox clone 18, which is available from UK nurseries, gives more reliable cropping than the traditional self-sterile clones, in years unfavourable for pollen transfer between varieties by bees
- This self fertile Queen Cox clone should not be used to pollinate other varieties, as it produces insufficient viable pollen

- Growers considering purchasing Self-Fertile Queen Cox clone 18 are recommended to obtain this only from a verified source.

Planting Partially Self-fertile Varieties without Pollinators

A few varieties show partial self-fertility, especially when temperatures at the time of flowering are high.

- Although several popular apple varieties, such as Red Pippin and Braeburn show a level of self fertility if climatic conditions at flowering time are favourable, this cannot be relied upon to ensure consistent and high yields of fruits on most UK sites

- Although Braeburn planted without pollinators will set good yields of fruits, these will contain few seeds and will have low levels of calcium. The seeds are essential in the uptake of calcium into the fruits and the reduction in bitter pit incidence.

- Varieties such as Gala and Golden Delicious also often set fruits with their own pollen when weather conditions are particularly favourable. However, most of the selfed fruits usually drop off at the time of June Drop.

Protecting the flowers and young fruitlets from damaging climatic conditions

In some seasons considerable damage to flowers and young fruitlets is caused by frost. Desiccating winds at the time of flowering also serve to kill pollen and inhibit the activity of pollinating insects.

Orchard Management aids to reducing frost damage

Management of the soil beneath trees can help alleviate frost damage

- Most heat loss during radiation frosts (50%-80%) is from the soil surface.

- To help in avoiding damage from radiation frosts, keep soil surface free of weeds and grass, keep soil compact and moist.

- Although covering the surface during the day with materials aimed at increasing heat absorption and then removing these in the evening is beneficial, it is also much too labour intensive.

Installation of a frost protection system

Several methods of providing protection to the trees from frosts have been studied. All of these are used with varying degrees of success in different parts

of the world. Only systems based on water sprinkling are currently recommended in the UK. Two types of sprinkler irrigation have been used; under tree systems with micro jets or over tree systems using impact spray nozzles.

Under tree sprinklers

- Low level, under tree micro sprinklers can reduce frost damage.
- In calm (no wind) conditions applications of 2mm water /hour to compact and previously moist soils can raise orchard temperatures by 1 or 2 degrees 2 metres above the soil surface.
- Micro sprinklers cause no limb breakage, which is common following extended use of overtree sprinkler systems.

Overtree sprinklers

- Over tree sprinkler systems, using impact type nozzles applying 2-3mm of water per hour during frosts, can provide useful protection to the flowers.
- The advantages of the systems are that they have low running costs and can be used for irrigation purposes as well as frost protection
- The disadvantages are the high installation costs, the potential for limb breakage due to ice loads on the tree and damage to the soil structure by the large amounts of water applied
- Water volumes applied can be reduced by use of a ‘pulsed’ system or by better targeting of the sprays, such that using mini sprinkler nozzles they hit only tree canopies and not the space between.

Protecting the trees within canopy structures

Some suggestions have been made in recent years that apple trees could be protected from unfavourable weather conditions at blossom time by enclosing the trees within protective structures.

- Protecting apple trees from frost or other poor weather conditions at the time of flowering, by enclosing them within plastic or other structures, is not considered to be economic in the UK.
- The costs of applying and removing covers is prohibitively high

- Leaving trees under covers for extended periods causes problems of low light levels, atypical growth, poor fruit quality and reduced flower production.

- Polythene covers provide almost no protection from frost, as they are permeable to long wave radiation. They may prevent damage from wind desiccation, however.

Use of chemical sprays designed to provide some protection from frost and winds

For many years, scientists have sought to identify products that, when applied to trees, improved the resistance of their flowers to frost damage. These are sometimes known as cryoprotectants.

Sprays of plant growth regulators, antitranspirants and other compounds

- Sprays of 'AntiStress' to stone fruit varieties have given inconsistent effects in terms of protection of flowers from frost in UK orchards. Evidence for their effects on apple blossoms is still very limited.

Supplementing pollen supply in the orchard using floral bouquets

In situations where the orchard has insufficient pollinators or these trees have become biennial in cropping it may be necessary to supplement the supplies of flowers/pollen in the orchard.

- Where pollen supply in the orchard is inadequate, due to biennial flowering of the pollinators, growers should consider placing floral bouquets in the orchard during the flowering period to supplement pollination.

- Where inadequate pollination is a more consistent problem (i.e. in every year), growers should either interplant the trees with additional pollinators or graft branches of these pollinating varieties into some of the existing trees of the main commercial variety.

FLOWER AND FRUITLET THINNING (ABSCISSION) AND ALTERNATIVE METHODS , OF IMPROVING FRUITLET GROWTH

Introduction:

Apple trees frequently set and retain excessive numbers of fruits in relation to tree size and leaf area. The result of this is the production of fruits at harvest, which are smaller than required by the markets and which often show poor storage potential. Fruit growers need to reduce the fruit numbers on the trees so as to retain through to harvest only those that can be sized adequately.

Remember, it is better to have 80 apples on a small tree which average 68mm in diameter than 120 apples averaging 60mm.

The larger fruits are

- **Twice the value**
- **Easier and cheaper to pick**
- **Cheaper to grade**

This essential crop load adjustment can be achieved using several strategies, which are discussed below.

This part of the Best Practice Guide, which focuses on flower and fruitlet thinning (abscission) and alternative methods of improving final fruit size and quality, is subdivided into three main parts:

Part 1: **Summary of Best Practices for determining/achieving optimum fruit numbers**

Part 2: **Summary of the methods of reducing crop load, including flower and fruitlet thinning**

Part 3: **Summary of the Alternative methods of improving fruitlet growth and quality**

Optimum Levels of Fruit Set for UK Apple Varieties

Introduction

Most early attempts to estimate optimum crop loadings focused on final fruit set per 100 blossom clusters. Long Ashton Research Station conducted studies in the 1960s and estimated that Cox trees on MM106 should carry 60-120 fruits /100 blossom clusters to set a full crop. The author estimated that the Cox trees needed to initially set 150 to 210 fruits/cluster to achieve the ideal values for final set after 'June Drop'. The precise values were influenced by blossom abundance, tree size and management factors (Williams, 1970b). In the same study, the author estimated that optimum fruit set values for Bramley's Seedling were 18 fruits/100blossom clusters. With Bramley's Seedling, intitial set values of 24 fruits / 100 clusters were considered ideal. Whilst these values may still be of value to Cox and Bramley producers using MM106 rootstocks, new work is needed to estimate optimum values for trees grown on M.9 in high density systems.

Estimating optimum crop load on the basis of final set per 100 flower clusters is a far from ideal method, as the abundance (density) of blossom clusters on a tree varies from season to season. Ideal methods would be ones based on fruit numbers per leaf area or fruit numbers per amount of light intercepted by the tree canopy. Unfortunately, as both of these are impossible to measure quickly, growers are usually encouraged to adopt simpler methods of estimation. These may be

- **Thinning to specified numbers of fruits per tree**
- **Thinning to specified numbers of fruits per flower cluster**

Best Practice Guide to Achieving Optimum Fruit numbers

Researchers and others have on many occasions attempted to estimate the optimum cropping levels for UK grown apple varieties. Unfortunately, this is extremely difficult to achieve, as the optima depend upon tree age, rootstocks, site conditions (soils and climate) and systems of tree management. Nevertheless, it is essential that some estimate is made so that thinning decisions can be appropriate

Thinning decisions should be based on

- Accurate assessment of optimum fruit numbers per tree for each orchard.
- The current seasons weather
- The current health of the tree and balance of shoot growth to flower numbers.
- Historical records of under or over cropping.

Optimum Fruit Numbers needed per tree

Use the table below developed by FAST as a guide to fruit numbers per tree, or better still using accurate grading records calculate the actual numbers per tree over the last three seasons and relate these to optimum yield and fruit size expectations.

Trials and observations conducted by FAST in the UK have demonstrated the value of using thinning guidelines based on target numbers of fruits per tree at harvest. These target fruit numbers are adjusted to take account of the tree spacings within the rows or between rows in multi-row beds. The recommended values for the principal apple varieties are shown in the Table below:

Table: Target numbers of fruits/tree at harvest to obtain optimum grade out

Tree spacing	**Target number of fruits / tree**				
	Cox & Discovery	**Gala**	**Jonagored**	**Katy**	**Bramley**
4 feet	80	96	95	70	40
5 feet	95	115	120	80	50
6 feet	110	125	130	100	60
8 feet	215	230	240	200	100
12 feet	420	460	475	400	200

The above numbers of fruits are those required at the time of harvest and, if thinning is carried out prior to 'June Drop', extra fruit numbers will need to be left on the trees to compensate for this. For early thinning, approximately 10% to 20% more fruitlets should be left on the trees than shown in the above Table.

Modern weight/size grading equipment will provide accurate weights of fruits and therefore fruits per kg for each size band. Where these are not available use the figures below as a guide.

Dessert Fruit		***Bramley***	
Size	**Kg**	**Size**	**Kg**
<55mm	0.06	<70mm	0.13
55-60mm	0.07	70-80mm	0.16
60-65mm	0.08	80-90mm	0.22
65-70mm	0.10	90-100mm	0.27
70-75mm	0.13	100-110mm	0.37
75-80mm	0.16	110-120mm	0.45
>80mm	0.20	>120mm	0.50

The Current Season's Weather

The best assessment of current weather is to use Accumulated Day Degree calculations as these most closely reflect the effect of temperature on

plant growth and development, and avoid perceived effects of odd hot or cold days. Also take into account the effect of a mild winter on flower quality.

Current health of tree

Experience shows that trees which show little vigour will set more readily and consistently than vigorous trees. M27 will set better than M9 which is better than MM106.

In orchards with consistently high flower bud numbers and regular heavy setting:

- Reduce flower cluster numbers at pruning time (see section on pruning)/

Trials evidence and observations show that where fruit numbers are optimised early (ie before full bloom) by mechanical removal or frost damage significant improvements in fruit firmness can be achieved.

Summary of the Best Practices for Reducing and Optimising Crop Load (including thinning)

Growers must first decide whether there is a need to thin the apple orchard and then determine which method of thinning is the most appropriate.

Growers wishing to optimise the crop loads on their apple trees have recourse to several possible strategies. They can reduce the potential numbers of flowers by:

- Removal of sites of floral bud development in winter pruning
- Flower (blossom) thinning
- Fruitlet thinning

Do I need to thin and which method should I use

Flower (Blossom) Thinning

If current guidelines on rates and timings are observed, over thinning with blossom thinners is unlikely. The aim is to reduce the cost of hand thinning. Before deciding on blossom thinning it is important to ask:

- Does historical data show consistently that thing is necessary?
- Are the flower cluster numbers twice as high (or more) than necessary for a good set? (see earlier section on Best Practice Guide to Achieving Optimum Fruit numbers)
- Has there been little or no frost damage and none forecast?

If the answer is yes to the above it is very appropriate to consider blossom thinning.

Fruitlet thinning

When contemplating the need for thinning of fruitlets it is vital to ask:

- Are trees compact in growth?
- Are leaves small and dark?
- Are fruitlet numbers double or more than required?
- Are fruitlets clearly visible above foliage?

If the answer is yes to the above it is very appropriate to consider a fruitlet thinning treatment.

Hand thinning

When contemplating the need for hand thinning of fruitlets it is vital to follow the following guidelines:

- Check fruit numbers on at least 10 representative trees in each orchard.
- Estimate whether fruit numbers more than 120% of those required at harvest?
- If thinning is warranted, hand thin to optimum fruitlet numbers (before fruitlets reach 25mm in diameter)
- Remove small and shaded fruitlets and those on weak wood.
- Where fruitlet numbers are between 100% and 120% of optimum, wait and reassess 2-3 weeks later. If necessary, thin at this stage removing poor quality fruit.

Removal of sites of floral bud development in winter pruning

Winter pruning can reduce the need for flower or fruitlet thinning on trees that regularly set too many fruits

- On trees which are making excessive numbers of flowers, too many of which set, resulting in poor fruit size, spur reduction should be carried out as part of winter pruning

- On trees where excessive flowering is accompanied by minimal new shoot growth, some renewal pruning of branches should be carried out to restore a better balance between shoot growth and flowering. This usually entails heading back some of the branches quite severely.

Flower (Blossom) Thinning

Flower thinning involves the removal of a proportion of the flowers (hand or mechanical methods of flower thinning) or alternatively treating flowers in some way to prevent them setting fruits (chemical methods of flower thinning). Mechanical methods of flower thinning are at an early development stage and cannot be recommended, currently.

Hand Thinning of Apple Flowers

- Hand thinning of flowers has the advantages that it is environmentally sensitive (uses no chemicals) and allows competition between developing fruitlets to be reduced at the earliest opportunity.
- However, hand thinning of flower clusters is rarely if ever carried out in mature commercial orchards. It is too labour intensive and hence too expensive.

- Hand removal of flower clusters on newly planted trees may be appropriate in the first one or two seasons

Chemical Methods of Thinning Apple Flowers

Most chemicals that have been tested and found effective in preventing apple flowers setting fruits work by desiccating the flower organs and preventing pollination and/or fertilisation (fruit set). There are a number of chemicals that work in this way but the only one currently available to UK growers is the nutrient ammonium thiosulphate (ATS):

Ammonium thiosulphate (ATS)

The foliar nutrient ATS has a very useful side effect as a blossom thinner on apples and other crops. If applied at flowering time, ATS works by desiccating and, therefore, damaging the stigmas and styles of apple flowers, so preventing them setting fruits.

When using ATS as a blossom thinner on apples it is important to consider the best timings for the sprays, the ideal weather conditions, the optimum spray concentrations and any variations in treatment associated with different apple scion varieties.

Spray timings when using ATS

- Thinning using ATS is most efficient if the sprays are applied between 20% and 50% full bloom.
- Flowers which are at balloon stage through to those that have been open for 2 days are the most sensitive to the sprays.
- Although the petals of flowers at the pink bud stage are damaged by ATS sprays, the flowers still remain capable of setting fruits.
- Flowers that have been open for more than two days and have been pollinated by bees will often still set fruits, although damaged by the ATS sprays.
- In seasons when flowering is concentrated over just a few days, then a single treatment with ATS will often be sufficient to thin the trees effectively.
- In years when the blossoming period is extended two sprays may be required; the first when 25% of the blossoms have opened and a second when most of the spur flowers have opened.
- With varieties that are prone to set large numbers of fruits on one-year-old wood (axillary blossoms) growers often endeavour to selectively prevent this fruit set using sprays of ATS applied after full bloom. Axillary blossoms, which often give rise to smaller than

average fruits at harvest, flower several days after spur blossoms and to thin them ATS sprays must be delayed until early petal fall on spur blossoms. Care must be taken with this late treatment, however.

- Thinning trees with ATS usually stimulates abundant flower production the following year. Higher concentrations of product or multiple sprays may be needed in this second year to compensate for the increased abundance of flowers

The ideal weather conditions

- As temperature increase above 15^0C, the efficiency of thinning when using ATS is increased

- Slow drying conditions (high humidities) improve thinning slightly, but may also cause phytotoxicity on the spur leaves.

- Spraying high concentrations of ATS in slow drying conditions is not recommended on account of the potential problems of phytotoxicity to the spur leaves. Spur leaves are essential to the early growth of the persisting fruitlets.

Spray concentrations and volumes

- The most effective spray concentrations of ATS range from 0.5% to 2.0% active ingredient

- The required concentration and also spray volume for effective flower thinning is influenced by both the temperature and the relative humidity.

- Research in Canada has indicated that when sprays of ATS are applied at low volumes the spray concentration needs to be increased, in comparison with sprays applied at high volumes

- Research in Poland indicates that sprays of ATS applied at low volumes (at appropriate concentrations) are more effective than sprays applied at high volumes

The Table below, developed by FAST, gives some guidance on concentrations and spray volumes as influenced by the temperatures and humidities at the time of spraying:

Slow Drying

Relative Humidity (%)	Temperature ^{0}C 10-15		15-20		20+	
	ATS %	Litres/ha	ATS %	Litres/ha	ATS %	Litres/ha
>95	1.0	200-400	1.0	300-500	1.0	300-500
85	1.0	300-500	1.5	400-600	1.5	400-600
<80	1.0	400-600	1.5	600-800	1.5	800-1000

Quick Drying

- It may be necessary to increase the concentrations of ATS by 0.5 % on very heavy setting varieties or alternatively, apply a second spray.

- Trials at HRI-East Malling have shown that two of the ATS brands available in the UK, Thiosul and F.3000, are approximately similar in their thinning efficacy and differ very little in the small amount of phytotoxicity induced on spur leaves. The brand 'Blossom Plus' is similar in its efficacy.

The tables below, prepared by FAST show amounts of 'Blossom Plus' required to achieve different ATS concentrations in different volumes of water:

Water vol. GPA	Pints of 'Blossom Plus' ATS concentration %			
	0.5	1.0	1.5	2.0
20	0.8	1.6	2.4	3.2
40	1.6	3.2	4.8	6.4
60	2.4	4.8	7.2	9.6
80	3.2	6.4	9.6	12.8
100	4.0	8.0	12.0	16.0

Water Vol. L/ha	Litres of 'Blossom Plus' ATS concentration %			
	0.5	1.0	1.5	2.0
200	1.1	2.2	3.3	4.4
400	2.2	4.4	6.6	8.8
600	3.3	6.6	9.9	13.3
800	4.4	8.8	13.2	17.6
1000	5.5	11.1	16.6	22.2

Use of adjuvants

- In most cases it is recommended that no additional adjuvant is added to the proprietary ATS products. Where a wetter is added, the limited information available suggests that no more than 2 fluid oz of Agral per 100 gallons (60mls/500litres) should be used.

Do not tank mix ATS with any other spray material or apply within 2 days of applying other sprays, or excess leaf damage may occur.

Variations associated with specific varieties

Varieties differ slightly in terms of their thinning requirements and hence in the ideal ATS treatment required for optimum thinning; Brief recommendations, mainly based on the experience of advisors in the FAST organisation, are presented below:

Alkmene (Early Windsor/Ceeval) One application of ATS at 1.0-1.5% at full bloom is sufficient and no adjuvant is usually necessary.

Braeburn

No thinning trials have yet been undertaken on Braeburn in UK conditions. However, preliminary trials conducted in New Zealand show that sprays of ATS may have promise for thinning this variety (Irving, *et al.,* 1989).

Bramley:

Two applications of 1.5-2.0% ATS, the first at full bloom on 2-year-old wood and the second approximately 7 days later.

Cox

One application of ATS at 1.0-1.5% just after bloom on 2-year-old wood. Do not include any adjuvant unless blossoming is very profuse.

Discovery

One application of ATS at 1.0-1.5% just after bloom on 2-year-old wood. Do not include any adjuvant unless blossoming is very profuse.

Egremont Russet

Two applications of 1.5% ATS are usually necessary. The first is applied at 80%-90% full bloom on 2-year-old wood and the second approximately 7 days later. Only include adjuvant if profuse amounts of bloom are present and fruit size is a known problem associated with the orchard.

Gala

Two applications of ATS at 1.0-1/5%; the first timed at 80% full bloom on the 2-year-old wood and the second approximately 7 days later. The second spray is aimed to target axillary blossoms on 1-year-old wood.

Golden Delicious

Trials in Europe have shown that sprays of 1% to 2% (depending upon blossom abundance and season) are effective in thinning this variety.

Jonagored

One application of ATS at 1.0-1.5% at full bloom is sufficient and no adjuvant is usually necessary. **Only apply to Jonagored if the orchard has a history of oversetting with small fruit and poor tree growth.**

Spartan

Two applications of ATS at 1.0-1.5% with the first timed at full bloom on 2-year-old wood and the second approximately 7 days later. The second

application should be omitted if weather conditions during bloom are not favourable for good fruit set.

Summered
Recent evidence from Norway, indicates that sprays of 1% ATS are effective in thinning this variety

Worcester Pearmain
Two applications of ATS at 1.0-1.5% with the first timed at full bloom on 2-year-old wood and the second approximately 7 days later. The second application should be omitted if weather conditions during bloom are not favourable for good fruit set.

Other Chemicals Tested as Flower Thinners for Apples

Lime sulphur
Lime sulphur was used many years ago as a thinner for Victoria plum. More recently, organic growers in parts of continental Europe have begun to show renewed interest in the product as a thinner for apples.

Recent trials conducted in the Netherlands indicate that lime sulphur at 4% applied at full bloom can provide useful thinning of the variety **Elstar.**

Lime sulphur is not currently approved for use as a flower thinner in the UK.

Urea
Sprays of 3-4% urea have occasionally produced good results when applied at full bloom in German and Danish trials. However, the product appears to thin only when it also causes significant damage to the spur leaves. Such damage will probably have negative effects on fruit development and calcium uptake into the persisting fruitlets. Urea is not approved for use as a flower thinner on apples in the UK.

Fruitlet Thinning

Apple fruitlets are best thinned by hand as this allows the largest and best shaped fruits to be retained and permits the establishment of even distribution of fruitlets along the tree's branches. However, hand thinning demands much costly labour and alternative strategies, based on use of chemical sprays have been sought. To date, there has been little effort to produce mechanical methods of thinning apple fruitlets.

Hand Thinning
Hand thinning is the best way to achieve the correct crop load. It also allows the best fruitlet distribution on the tree to be established by allowing fruits in poor positions on the branches or spurs to be removed.

Even when hand chemical thinning has been carried out, growers should double check the fruit number and hand thin down to the correct crop load per tree.

Procedures for Hand thinning:

1 Check the fruit numbers on a small sample of trees and compare with target numbers

2 Calculate how many fruits per cluster or per foot of branch length need to remain.

3 Decide on a simple set of rules for the fruit thinners:

- Remove all fruits under branches
- Remove all fruits on one-year-old wood
- Leave one (or occasionally 2) fruit per cluster
- Leave fruits to be spaced 4 inches apart
- On short-stalked varieties (Cox, Discovery, Egremont Russet and Bramley) remove the 'king' fruit as this may be misshapen. Leave the next largest lateral fruit in the cluster
- On long-stalked varieties (Gala and Jonagored) the king fruit is retained as it is the largest and is not misshapen

4 Check the crop load by counting or by using special binoculars provided by extension specialists, such as FAST. This aid to assessing crop load has proved quick and very reliable

5 Begin thinning as soon as possible as this maximises the benefits to fruit size and texture.

Timing of Hand Thinning

In a research trial conducted at HRI-East Malling in 1997, semi-mature trees of **Royal Gala** on M.9 rootstock were thinned to single fruits per cluster at different timings and the effects on yields and grade outs recorded. The Table below shows some of the results:

Effects of different timings of hand thinning Royal Gala trees in 1997

Treatment Timing of hand thinning	No. fruits/tree	Weight of fruit harvested/tree (kg)			
		Total	>65mm diameter	>70mm diameter	% of total .65mm diameter
None (control)	235	18.6	1.4	0.1	8
Full bloom	52	7.8	6.1	2.6	78
Late Initial set	80	10.9	8.0	4.4	73
12mm diam	100	12.6	5.9	2.7	43
18mm diam	84	9.5	2.8	0.2	29
24mm diam.	83	9.1	3.3	0.8	36

- Trial results show that thinning at or before the 12mm fruitlet diameter stage is essential

- Thinning Gala at the time of initial set is particularly beneficial

- Very early thinning of Cox may, however result in some problems in storage

Chemical Thinning of Fruitlets

Carbaryl (Sevin-Thinsec)

Carbaryl (Sevin or Thinsec) is a chemical originally developed as an insecticide but which was shown in the late 1950s to have additional activity as a fruitlet thinner. Unfortunately, the carbamate group of insecticides, to which it belongs, are now considered environmentally unacceptable and have been withdrawn from use in most apple producing countries of the world. Carbaryl has continued to be used as a fruitlet thinner in most countries until the last decade, when several countries banned its use. Carbaryl has harmful effects on beneficial insects, such as bees and also on water organisms, although in recent years the formulations sold have been improved in this respect. Carbaryl (Thinsec) will be withdrawn from use in the UK within the next 2 years.

- When planning to use carbaryl (Thinsec) it is important to consider the timings of the sprays, the spray concentrations and water volumes required.

Spray Timings

Thinsec may be applied at one of three timings:

- Petal Fall:

This timing is only recommended when flowering is abundant, weather conditions have been ideal for fruit set and the orchard has a history of poor fruit size. Care must be taken to avoid spraying trees when bees are still working in the orchard, as some carbaryl formulations are extremely toxic to bees. In trials abroad, early carbaryl sprays (at flowering) have been shown to increase fruit russeting in some situations.
This spray may need to be followed up with a second spray at the 12mm stage.

- 2-3 weeks after petal fall

This timing is generally less effective than other timings and is only used where limited thinning is required.

- Fruitlet diameter approximately 12mm

This is the most commonly used timing for Thinsec and the one recommended on the label. **Bramley** is best sprayed a little earlier, when fruitlet diameters are 10-12mm.

Thinning with carbaryl is increased under shade or low light conditions.

Spray Concentrations and Water Volumes Required

Thinsec is generally used at 2 litres/ha (1.5 pints/ac) in a minimum water volume of 270 litres/ha (25 gall/ac). The surfactant Agral is added at 125ml/1000litres (2fl oz/100gals).

Varieties differ in their ease of thinning using Thinsec and the following rates and spray volumes are recommended:

Scion Variety	Thinsec rate in litres /ha	Minimum vol. of water (litres/ha)	Thinsec rate in fluid oz/acre	Minimum vol. of water (galls/acre)
Discovery	1.9	270	27	25
George Cave	1.9	270	27	25
Golden Delicious	1.9	270	27	25
Worcester Pearmain	1.9	270	27	25
Cox	2.4	350	34	33
Spartan	2.4	350	34	33
Gala	4.8	650	68	60
Bramley	4.8	650	68	60

- If Thinsec is to be applied alone (i.e. not in a tank mix with other pesticides), add the surfactant Agral at 125ml/1000litres (2fl.oz/100gals).

- Adding Codacide at 1% of the spray volume (up to a maximum of 1.4 l/ha or 1 pint/ac) will enhance thinning. However, caution should be exercised when using this additive to thinning sprays applied to Gala, as may induce fruit russeting.

- Mixtures of Cultar (paclobutrazol at 150ml/ha or 2fl oz/ac)) with Thinsec (3 litres/ha or 2.5 pints/ac) have given good thinning results with the variety Bramley, especially when applied at petal fall with the addition of Agral. However, there are currently no label recommendation for use of this mixture for thinning. This has implications to growers who use Cultar for growth control, as applications within 5 days of a Thinsec application may cause overthinning on varieties such as Cox.

Other Fruitlet Thinning Chemicals

- No other chemical fruitlet thinners are currently approved for use in the UK
- Trials with benzyladenine (BA) appear promising
-

Combined flower and fruitlet thinning treatments

- Growers should consider supplementing any blossom thinning, achieved using ATS, with supplementary hand thinning at the 12mm fruitlet diameter stage.
- Recently promising results have been achieved using combinations of ATS for blossom thinning and BA for fruitlet thinning. However, BA is not, currently, approved for use as a fruitlet thinner in the UK.