

**Increasing grower  
awareness of apple  
thinning technology  
and systems**

Sally Bound  
University of Tasmania

Project Number: AP02005

## **AP02005**

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# ***FINAL REPORT***

***Project AP02005***

**May 2005**

## ***A national approach to increasing grower awareness of apple thinning technology and systems***

***Sally Bound***



Tasmanian Institute  
of Agricultural Research



**Horticulture Australia**

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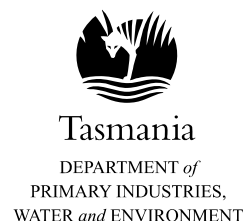
**Project title:** A national approach to increasing grower awareness of apple thinning technology and systems

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The purpose of this report is to document the outcomes of the project AP02005 – A national approach to increasing grower awareness of apple thinning technology and systems. This project has resulted in the development of a network of consultants trained in crop regulation theory and practice, and in the introduction to growers Australia wide of the computerised Apple Thinning Program developed in Tasmania. Workshops have been conducted for growers in all major apple growing areas across Australia to increase grower knowledge of crop regulation methods and best practice. In addition, the Apple Thinning Program has been transferred to a new software platform, and security features added.



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15 May 2005

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## Summary

Although crop regulation is an important component of orchard management, few orchardists or agribusiness consultants/extension personnel have an in-depth understanding of the concepts of crop regulation and there is insufficient expert support available throughout Australia on thinning in pome fruits.

This project was aimed at providing opportunities for orchardists and associated industry personnel to gain an understanding of crop regulation, and to be introduced to Australian research and the latest recommendations. It has also provided an avenue for industry to become familiar with the computerised Apple Thinning Program that was developed to assist orchardists reduce the risks associated with chemical thinning.

The methodology for this project encompassed several aspects:

- Establishment of a support network of licensed consultants
- Conduct of workshops for orchardists in all apple growing regions
- Updating of the electronic data delivery

Workshops conducted in all major apple growing regions were well attended by both orchardists and agribusiness personnel. These interactive workshops gave participants an awareness of the impact of orchard management practices on fruit load and quality, with the message that crop load management should begin in winter with pruning, not after fruit set as has commonly been the case in many regions. The main message carried away from the workshops was that an aggressive approach to thinning could ultimately reduce costs and improve returns.

Industry personnel now have ready access to best practice in crop regulation in the form of a network of accredited consultants who are also licensed to distribute the Apple Thinning Program. This software package contains the latest available information on chemical thinning practices in a user-friendly format. Orchardists can either purchase the software for their own use or access it as a bureau service through the licensed consultants.

This project has resulted in:

- the establishment of a regional support network for orchardists
- the development of a standardised approach in the provision of thinning advice
- improved access to best practice thinning methods
- increased national awareness of the Apple Thinning Program
- increased basic understanding of crop regulation and background knowledge

necessary for using the Apple Thinning Program

## **Introduction**

Crop regulation is one of the most important management tasks faced by growers in the pome fruit industry. However, the level of knowledge of crop regulation within the Australian apple industry is limited and the level of adoption of best practice thinning methods could be considerably improved. Grower groups in many regions regularly request thinning advice and workshops from Tasmanian Institute of Agricultural Research Scientist Sally Bound. However it is not always possible to conduct such workshops due to costs involved and time commitments. As there is currently no coordination in crop regulation research on a national basis, knowledge in each state is fragmented and delivery of new information to orchardists is variable. This, combined with reducing research input into crop regulation in each state has meant that access to expertise in crop regulation in Australia is limited. A network of trained consultants who would be accredited deliverers of apple thinning advice, are able to provide support to orchardists within their local area, and who are able to assist each other would alleviate this problem.

This project was aimed at providing opportunities for orchardists and associated industry personnel to gain an understanding of crop regulation, and to be introduced to the work conducted in Australia and the latest recommendations. It has also provided an avenue for orchardists to become familiar with the computerised Apple Thinning Program that was developed to assist growers reduce the risks associated with chemical thinning.

## **Background**

Although crop regulation is an important component of orchard management, few growers or agribusiness consultants/extension personnel have an in depth understanding of the concepts of crop regulation and there is insufficient expert support available throughout Australia on thinning in pome fruits.

### ***Implications of crop loading***

If the implications of crop loading are properly understood, it is often easier to decide on thinning strategies. The earlier in the growing season that thinning takes place the greater the influence on fruit size and internal quality parameters such as firmness and sugar content. While hand thinning can improve fruit size, normally by the time it is completed fruit size has already been determined and it is also too late to overcome the inhibitory effect of the young fruitlets on flower formation for the next year. Chemical thinning is designed to remove excess fruit as early as possible. As a result,



competition from unwanted fruit is eliminated early, resulting in good fruit size and good return bloom.

Crop fluctuations from year to year can also be substantially reduced by controlling cropping every year on about half the spurs in a tree. If trees are cropping annually or if it is an on-year in biennial trees, the aim is to remove over 90% of the flowers/potential fruit from the tree. This will never be without risk, but the risk can be reduced to manageable proportions. The most economical method of achieving satisfactory thinning is through chemical thinning.

### ***Crop regulation research***

Funding for crop regulation research and extension of knowledge has been limited in recent years, with governments in all states reducing inputs into research in this area. As Tasmania is currently the only Australian state with ongoing research in this area, grower groups throughout Australia make regular requests for workshops/seminars on crop regulation and new information on thinning.

In spite of limited availability of funding for crop regulation research, Australia is one of the more advanced countries in the area of chemical thinning, and many growers, particularly in Tasmania, have learnt that an aggressive approach to thinning every year means good crop loads and high quality fruit.

### ***Development of thinning tools***

In the mid 1990s, Tasmanian scientists developed a computerised expert system based on 15 years of research carried out in Tasmania by Department of Primary Industry, Water & Environment (DPIWE) and Tasmanian Institute of Agricultural Research (TIAR) staff. Also included in this expert system are the experiences of many growers who have accommodated this best practice into their operations. More recently the program has been updated using information from other Australian apple growing regions. This program, known as the Apple Thinning Program (ATP), utilises an aggressive approach with the emphasis on achieving regular crops of optimum sized fruit and avoiding under-thinning which leads to small, poor quality fruit and biennial bearing.

Funding for the research that has been the basis of this system has been provided principally by the Tasmanian government with some input from a number of chemical companies. Over 70% of the funding involved in the initial development of the program was contributed by the Tasmanian government, with less than 5% contributed by the apple industry through levy funds. The remainder of the funding has been obtained from other funding sources such as chemical companies and agribusiness.

The ATP has been used for several years by Tasmanian growers and by a small number of growers in other growing regions throughout Australia. Although the system has been demonstrated at a number of grower workshops held throughout Australia, many growers are still unfamiliar with it. There has however, been increasing feedback from those growers who are using this system, and even those who have traditionally been conservative in their approach to thinning are reporting improved results after following the program recommendations.

## **Project objectives**

This project aims to make the knowledge that is currently held within a relatively small group more widely available, thus reducing the future risk of loss of information due to loss of particular experts.

## **Achievement of objectives**

The work program, as defined in the funding application for this project has been successfully completed and project objectives have been achieved.

Outputs:

- establishment of a regional support network for growers
- national grower workshops on crop regulation and use of the ATP
- updated Apple Thinning Program

Outcomes:

- better understanding of crop regulation by growers / extension personnel
- improved access to best practice thinning methods
- improved support network through training of licensed consultants
- increased yields and fruit quality through improved thinning

## **Methodology**

The methodology for this project encompassed several aspects:

- Establishment of a support network of licensed consultants
- Conduct of grower workshops in all apple growing regions across Australia
- Updating of the electronic data delivery

The project adopted a staged implementation of:

1. Agreement between HAL and University of Tasmania on equity splits for royalties on the sale of the ATP.

2. Development of an intensive two-day training course for agricultural consultants to certify their competence to provide advice in the area of crop regulation and use of the expert system.
3. Conduct of this course. Successful course participants were able to obtain regional licences for distribution of the ATP.
4. Development of workshops for growers, including a reference manual for distribution to workshop participants. These workshops were aimed at growers and offered background information about crop regulation and introduced the ATP.
5. Conduct of workshops of 3-4 hours duration in all major apple growing regions throughout Australia. All workshops were conducted by project leader Sally Bound, in conjunction with the licensed consultants in each region.
6. Addition of security features to the ATP and updating of knowledge.
7. Transfer of the software platform to a more robust base.

## **Results and Discussion**

Although the project was approved in 2002, due to submission of an alteration of the project proposal in May 2002 following discussions between HAL and TIAR, and issues associated with intellectual property of the Apple Thinning Program, the grant agreement was not signed until September 2003. In spite of this delay, the project was commenced in July 2002 to ensure that the project did not lose a year.

### ***Establishment of support network of licensed consultants***

An intensive two day course was developed for delivery to persons interested in becoming registered consultants. To obtain accreditation and become licensed to distribute the ATP and provide related services, participants were required to undertake the two day course and successfully complete the course assessment. During the development of the course, a partnership was formed with the School of Agricultural Science (SAS) at the University of Tasmania. This partnership gave access to:

- university endorsed certificates for all participants who pass the assessment process
- additional experts in the field of horticulture
- instructional designers with knowledge of flexible delivery techniques

Following development, this course was advertised nationally. A consultants brief was drawn up (Appendix 1) and an advertisement placed in The Weekend Australian on 6<sup>th</sup> July 2002, calling for Expressions of Interest in the Commercialisation and Delivery of Spray Thinning Technology for the Australian Apple Industry.

Expressions of interest were received from Tasmania, northern Victoria, and Donnybrook in Western Australia (see Table 1). As there were no expressions of interest from regions in NSW, SA, Qld or southern Victoria, it was proposed to use 2002 as a pilot scheme, and call for further Expressions of Interest in June 2003, with the view to running another Consultants course in 2003. The advertisement for the second course was placed in *The Weekend Australian* on 28<sup>th</sup> June 2003 (Appendix 2).

The first Consultants course was conducted on 8-9 August 2002 (Appendix 3), and the second course on 7-8 August 2003. The course covered the following topics:

- flowering and fruit set
- basic principles of thinning
- methods of thinning
- bioregulators available for thinning and mode of action
- factors affecting thinning response
- spray application
- assessing potential crop load
- development of structured thinning programs
- introduction to the Apple Thinning Program
- hands-on experience with the ATP.

The course concluded with an evaluation consisting of:

- successfully working through several scenarios using the ATP
- a short written paper

All course participants successfully completed the course requirements and were accredited to distribute the ATP and provide related services (Table 1).

*Table 1: Consultant course participants.*

<b>Year</b>	<b>Company</b>	<b>Participants</b>	<b>Region</b>
2002	Roberts Limited	Peter Morrison Julian Springham	Tasmania
	Wayne Skinner Rural Supplies Pty Ltd	Sam Birrell	Northern Victoria
	Crop-Scan	Brian Shervington	Donnybrook, WA
2003	Roberts Limited	Graeme Simmonds	Tasmania

Although the network is not complete across Australia, there is now a partial network of accredited consultants with consultants registered in northern Victoria, Western Australia and Tasmania (Table 2). A South Australian company expressed interest in

becoming licensed and accredited in mid 2004. Under the licensing agreement there is only one licensee for each region, however the licensee may have more than one accredited staff member.

*Table 2: Licensees for ATP and accredited consultants.*

<b>Region</b>	<b>Licensee / Company</b>	<b>Consultant</b>	<b>Contact details</b>
Tasmania	Roberts Limited GPO Box 65 Hobart TAS 7001	Peter Morrison	Ph: 03 6264 1122 Fax: 03 6264 2003 Mobile: 0408 125 734 <a href="mailto:pemorrison@bigpond.com">pemorrison@bigpond.com</a>
		Julian Springham	Ph: 03 6337 1555 Fax: 03 6337 1597 Mobile: 0408 137 358 <a href="mailto:jspringham@robertsltd.com.au">jspringham@robertsltd.com.au</a>
		Graeme Simmonds	Ph: 03 6263 4066 Mobile: 0419 376 700 <a href="mailto:gsimmonds@robertsltd.com.au">gsimmonds@robertsltd.com.au</a>
Northern Victoria	Wayne Skinner Rural Supplies Pty Ltd 4-6 Mill Street PO Box 182 Mooroopna VIC 3629	Sam Birrell	Ph: 03 5825 2966 Fax: 03 5825 2360 Mobile: 0417 392 <a href="mailto:Croptec@mcmmedia.com.au">Croptec@mcmmedia.com.au</a>
Donnybrook area, WA	Crop-Scan PO Box 164 Donnybrook WA 6239	Brian Shervington	Ph: 08 9731 0708 Fax: 08 9731 0905 <a href="mailto:brian_shervington@bigpond.com">brian_shervington@bigpond.com</a>
Lenswood, SA	Lenswood Rural (yet to be licensed) Cold Store Road Lenswood SA 5240	Ian Daynes  (not yet accredited)	Ph: 08 8389 8233 <a href="mailto:Ian@lenswoodrural.com">Ian@lenswoodrural.com</a>

### ***Grower workshops***

A major component of the project was delivery of workshops to growers and industry personnel in the major apple growing regions throughout Australia. These workshops were open to growers, agribusiness, consultants and extension officers. Workshops aimed to give participants an understanding of the basics of crop regulation, extend the latest knowledge and developments in crop regulation and introduce participants to the Apple Thinning Program.

Material for the workshops, including a 40 page manual for growers (Appendix 4), was developed during July/August 2002. Suggestions made by participants of the Consultant course were also incorporated into the workshop content.

Workshops were organised and run from late August through to October 2002 and 2003. Advertising of the workshops and organisation of venues, equipment and refreshments were coordinated by the accredited consultants. In regions where there were no accredited consultants, other local contacts were used (Table 3). Due to time constraints there was insufficient time to run workshops in all regions in one season, hence those regions not able to be covered in 2002 were covered in September/October 2003. Workshops were conducted in the following areas:

- New South Wales - Batlow and Orange
- Victoria - Goulburn Valley and Melbourne (Knoxfield)
- South Australia – Lenswood
- Queensland – Stanthorpe
- Western Australia - Donnybrook, Manjimup and Perth Hills
- Tasmania - Huon Valley, Spreyton and Tamar Valley

*Table 3: Grower workshop coordinators.*

<b>Location</b>	<b>Coordinator</b>
Tasmania	Peter Morrison & Graeme Simmonds, Roberts Ltd
Batlow	Ron Gordon, Batlow Coop
IHD, Knoxfield	Jo Vigliatori, AgVic
Stanthorpe	Trevor Dunmall, Qld Fruit & Veg Growers Assoc
Manjimup, Perth Hills	Bruce Radys, AgWA
Donnybrook	Brian Shervington, CropScan
Goulburn Valley	Sam Birrell, Wayne Skinner Rural Supplies
Lenswood	Ian Daynes, Lenswood Rural & Paul James, PIRSA
Orange	Jeremy Bright, Agriculture NSW

Over the two seasons, a total of 12 workshops were conducted as outlined in Table 4. Workshops covered the basics of crop regulation, discussing factors affecting flowering, fruit set, thinning, fruit quality, available chemical thinning agents, and spray application and efficiency, as well as what is involved in setting up structured thinning programs. Lively discussion was an integral part of all workshops and the duration of the workshops varied from 3.5 to 4 hours, depending on the level of discussion. Participants were also introduced to the computerised Apple Thinning Program. The main message carried away from the workshops was that an aggressive approach to thinning could ultimately reduce costs and improve returns to orchardists. Workshop participants also received a reference manual.

*Table 4: Grower workshops conducted.*

<b>Date</b>	<b>Times</b>	<b>Location</b>	<b>Participants</b>
26 Aug 2002	1.00 – 5.00 pm	Grove, TAS	16
13 Sept 2002	9.30am – 1.00 pm	Tamar (Hillwood), TAS	16
13 Sept 2002	2.00 – 5.30 pm	Latrobe, TAS	11
17 Sept 2002	1.00 – 5.00 pm	Goulburn Valley, VIC	26
18 Sept 2002	1.30 – 5.00 pm	Batlow, NSW	50
20 Sept 2002	2.00 – 5.30 pm	IHD, Knoxfield, VIC	30
26 Sept 2002	6.30 – 10.00 pm	Stanthorpe, QLD	28
1 Oct 2002	7.00 – 10.30 pm	Donnybrook, WA	37
2 Oct 2002	9.00 am – 12.30 pm	Manjimup, WA	27
2 Oct 2002	7.00 – 10.30 pm	Perth Hills, WA	28
23 Sept 2003	5.30 – 9.30 pm	Lenswood, SA	38
30 Sept 2003	6.30 – 10.30 pm	Orange, NSW	17

### ***Electronic data delivery (Apple Thinning Program)***

#### *Commercialisation Path*

It was agreed that a royalty of 20% of the gross value of all sales related to the technology be shared between HAL and TIAR in the following proportions: 32% HAL and 68% TIAR. The gross sales value to be calculated against CD sales since July 2002, plus future consultants training fees. This allows ‘costs of sales’ items (CD production costs, software engineering input, help desk, cost of training, etc.) to be deducted from the gross sales value before calculating the royalty amount.

#### *Repackaging of the ATP*

The ATP was repackaged onto CD in August 2002, and made available to licensed consultants for distribution to growers in their regions. In regions where licensees were not available, growers were given the opportunity to purchase the software either directly through TIAR or from a licensed consultant outside their region.

#### *Software engineering*

Following the retirement of Dr Peter Gillard, the DPIWE Software Knowledge Engineer who undertook the programming for the ATP, a new software developer was required. Mr Peter Lowe, a systems analyst with Clockwork Electronic Systems was engaged. Following several meetings with Dr Gillard to enable him to become familiar with the ATP as developed in the expert system shell Crystal, Mr. Lowe developed a

security feature for immediate addition to the current version of the ATP. This was made available to all licensed consultants for distribution to growers in August 2003. A plan was then developed to allow for the updating of the ATP under a new software platform.

Mr Lowe has now rewritten the ATP in a new software platform. The new version of the ATP application is written in Delphi as a stand alone executable program that does not require the installation of any drivers or supporting software. This application also includes a similar security system to that retro-fitted to the previous version in 2003. Installation amounts to copying the security file and the executable into an appropriately named directory and putting a shortcut to it on the start menu or desktop.

Although written in Delphi, the application has been written in the style of an Expert System (ES) with choices at each stage affecting subsequent questions as well as the final calculation of concentration of selected chemical. The rules that are applied are held in tabular form within the application. The tables are held entirely within the executable, and are invisible and inaccessible to users. With this arrangement the values that contribute to the calculations can be easily modified if required, and a new executable compiled and distributed. Any modifications would need to be undertaken by Mr Lowe, but anything other than major changes could be completed in a few minutes.

The new application includes all current knowledge, an extended help file and a new interface. Feedback received during the Consultants courses and the grower workshops was also used to improve the application.

The application is extensible in the event that additional factors need to be included in the calculations. It is also suitable as a template for other ES style applications.

#### *The updated ATP*

The ATP now covers the following cultivars: spur-type red Delicious, non-spur red Delicious, red Fuji, Golden Delicious (Standard), Granny Smith, Gala, Pink Lady and Sundowner. Chemical thinning agents included in the program are the primary thinners NAA, ethephon and ammonium thiosulphate (ATS), and the secondary or post-bloom thinners benzyladenine (CyLex) and Carbaryl / Thiram. Options are also given for a second application of primary thinner. Information on the dormancy breaker Waiken has also been added. There is an extensive Help facility which includes notes to assist growers on a range of topics, such as *pollination, cold weather and frost at blossom time, and windspeed guidelines for spraying*. For situations where growers have already decided the rate of chemical that they wish to apply, the amount of chemical to be added to the spray tank can also be calculated by the program. All chemical rates given take into



account the type of spray machinery to be used (high volume airblast, low volume airblast, airshear, or CDA rotary atomiser). The options available within the program are given in Table 5.

*Table 5: Apple Thinning Program – chemical application options offered for each cultivar. NAA, naphthalene acetic acid; Ethrel, ethephon; FB, full bloom; ATS, ammonium thiosulphate*

	<b>Red Delicious</b>	<b>Golden Delicious</b>	<b>Fuji</b>	<b>Granny Smith</b>	<b>Gala</b>	<b>Pink Lady</b>	<b>Sun-downer</b>
NAA - primary thinner	✓	✓	✓	✓	✓	✓	-
ethephon - primary thinner	✓	-	✓	-	-	✓	✓
NAA - 3-7 d after NAA @ FB	✓	✓	✓	-	✓	✓	-
ethephon - 5-7 d after NAA @ FB	-	✓	✓	-	-	-	-
ATS - primary thinner	✓	✓	✓	✓	✓	✓	✓
Carbaryl/thiram - secondary thinner	✓	✓	✓	✓	✓	✓	✓
Benzyladenine - secondary thinner	✓	✓	✓	-	✓	-	-
Waiken - dormancy breaker	✓	✓	✓	✓	✓	✓	✓

Once the cultivar and chemical have been selected, the ATP takes the grower through a series of questions relating to the block to be sprayed before calculating the concentration of chemical to be applied. The recommended application rate is based on: cultivar, previous spray history, tree age, rootstock, previous crop load, target fruit size, growth vigour of the trees, number of flower buds present, and severity of pruning. In situations where thinning is not recommended or where responses to the questions asked indicate problems, the program issues a warning. After working through the program, the grower can then obtain a printed report for each block detailing all the input parameters and the recommended application rate, including the amount of chemical to mix per 100 litres of water.

Once the chemical rate is given it is possible to revise if uncomfortable with the advice given. The revision screen shows all the options selected and how the concentration of chemical was derived. By changing any of the inputs previously entered the program will recalculate the concentration.

The Apple Thinning Program will not eliminate all elements of risk from thinning programs - no biological system is foolproof. It is still possible to under-thin or over-thin some crops, or not completely achieve all the size or quality results desired. But the program does encapsulate the best, up to date scientifically proven ways of regulating crops for maximum economic outcomes.

The ATP is simple to use, and allows growers to:

- obtain information ahead of flowering
- process each block separately
- print a copy of the advice for their records
- print one page reports ready for the clipboard in the spray shed
- access extensive notes in the Help file

## **Industry implications and recommendations**

This project has resulted in the development of a network of consultants trained in crop regulation theory and practice. Although the network is not complete in all growing regions, there is still scope to expand through the conduct of further courses.

The accreditation of trained Consultants has enabled:

- the development of a standardised approach in the provision of thinning advice
- increased national awareness of the Apple Thinning Program
- increased basic understanding of crop regulation and background knowledge necessary for using the Apple Thinning Program
- protection against legal liability issues by fully informing users prior to commercial use of the Apple Thinning Program

Grower workshops conducted in all major apple growing regions were well attended by both growers and agribusiness personnel. These interactive workshops gave growers an awareness of the impact of orchard management practices on fruit load and quality, with the message that crop load management should begin in winter with pruning, not after fruit set as has commonly been the case in many regions. The main message carried away from the workshops was that an aggressive approach to thinning could ultimately reduce costs and improve returns.

Growers now have ready access to best practice in crop regulation in the form of the Apple Thinning program. This software package contains the latest available information on chemical thinning practices in a user-friendly format. Growers can

either purchase the software for their own use or access it as a bureau service through the licensed consultants.

***Recommendations for continuing work:***

Identification of possible consultants who are willing to undertake training and accreditation in NSW, Queensland and southern Victoria would enable better access to assistance in crop regulation by orchardists. Regular updating of accredited consultants should also be undertaken.

To ensure that Australian growers continue to have access to best practice methods in crop regulation, further research needs to be conducted with new cultivars and potential chemical thinning agents. Such research will also provide data for the continuing updating of the Apple Thinning Program. An annual review of the knowledge contained within the ATP will ensure continuing best practice in crop regulation.

***Publications:***

*Technical Manuals:*

Bound, S (2002) Principles of crop regulation – Consultants Course Manual. University of Tasmania.

Bound, S (2002) Managing Crop Load, Grower Workshop Manual. University of Tasmania.

*Popular press articles:*

Bound, S A (2004) Increase thinning success. *Tree Fruit*, August 2004. p20-22.

Bound, S A (2003) Optimising thinning results. *Tree Fruit*, August 2003. p20-23.

# Appendix 1



Horticulture Australia

## Expressions of Interest

### Commercialisation and Delivery of Spray Thinning Technology for the Australian Apple Industry

#### CONSULTANT'S BRIEF

##### OPPORTUNITY

Over the past 10 years, the Tasmanian Department of Primary Industry, Water and Environment (DPIWE) and the Tasmanian Institute of Agricultural Research (TIAR), with some funding assistance from the Australian apple industry and Horticulture Australia Ltd (HAL) have developed a computer-based "expert system" for crop thinning in apples. The system is known as the "**Apple Thinning Program**" (ATP).

Expressions of Interest are now invited from organisations, or individuals, such as consultant agronomists for the exclusive right to deliver this technology to apple growers on a region by region basis.

##### BACKGROUND

Crop regulation is one of the major tasks facing orchardists each season. Chemical management of fruit set eliminates biennial bearing and significantly lowers production costs. Chemical thinning also underpins fruit quality.

The Apple Thinning Program has combined TIAR/DPIWE research with feedback from Australian growers, resulting in a robust model for the determination and application of thinning spays for the cultivars: red Delicious, Golden Delicious, Granny Smith, Fuji, Gala, Pink Lady and Sundowner.

As part of delivering this technology to all apple growers throughout Australia, TIAR, on behalf of DPIWE, HAL and the Australian apple industry are calling expressions of interest in receiving an exclusive regional licence to deliver and sell services related to the ATP. Licences for Northern Victoria, Tasmania, and the Donnybrook region of WA were taken up in 2002

##### EXPRESSION OF INTEREST, FEES, TRAINING AND LICENCE

Companies and persons wishing to Express Interest in the technology will be expected to

- Submit an Expression of Interest detailing why they are a suitable party to deliver this technology to apple growers and specifying the region which they wish to service
- If chosen as suitable, pay a \$1000 access and training fee. The training fee for additional persons within a company is \$450.
- Participate in a short 2 day intensive course in crop regulation and the ATP technology that will be held in Hobart in early August 2003. Course costs are covered in the licensing and training fee, but participants will be expected to meet

# Appendix 1

their own travel and accommodation costs. The University of Tasmania will accredit the course. Those who pass it will receive an accredited "Certificate of Completion" from the University. Those who do not pass the course will receive an accredited "Certificate of Participation". This course can be counted as a credit towards other University courses. A Certificate of Completion in the course will be necessary to enter into the licence described below.

- Participants who successfully obtain the Certificate of Completion (or their parent organisation) will be offered an exclusive licence to sell services to growers related to the ATP technology. This licence will be exclusive for an agreed Australian apple production region and will include the exclusive right to re-sell the ATP software in that region. Consultants so licensed will be expected to pay TIAR a royalty on sales of ATP software. Any license granted to the parent organisation of a person who successfully obtains the Certificate of Completion will be conditional on that person remaining in the employ of that organisation (other staff could be trained by arrangement with TIAR). The licence will be for an initial period of 3 years. Licensees will be given options for renewal of licences following completion of an update course/workshop
- To launch the ATP technology and to train growers in its use, TIAR obtained funds from HAL to run free-of-charge growers workshops in all Australian apple production regions. Workshops were conducted in the following regions in 2002: Tasmania, Victoria (Goulburn Valley, Knoxfield), NSW (Batlow), Queensland (Stanthorpe), and WA (Donnybrook, Manjimup, Perth Hills). Grower workshops will be conducted in South Australia and the Orange/Bathurst region of NSW during August/September 2003. The licensed consultants will be expected to play a significant role in organising these workshops. Mrs Sally Bound, who has been the main technical developer of the ATP, will lead the technical aspects. There will be no fee to the licensed consultants for the workshops apart from any in-kind marketing costs that the consultants may wish to contribute.
- Licensed consultants will receive reasonable ongoing technical support from Mrs Sally Bound and TIAR. This will be on a free plus fee for service basis and will be agreed with each licensee on a case by case basis. TIAR will not take advisory calls on the ATP technology directly from the clients of licensed consultants.

## TIMETABLE

	Completion date
• Expressions of Interest received at TIAR.	18 July 2003
• Successful applicants notified	25 July 2003
• Accredited Training Workshop at TIAR, Hobart	7-8 August 2003
• Grower's workshops in regions	By agreement, commencing late August

## GENERAL CONDITIONS

TIAR expects that:

- Confidentiality will be maintained at all times.
- The consultant has the appropriate insurance cover to allow it to enter into the relationships proposed here.
- Any areas of potential conflict of interest will be identified at the time of the consultant's response to this brief and updated prior to any licence agreement being signed.
- The decision as to which, if any, Expression of Interest will be pursued further will be made by TIAR at its absolute discretion. No legal relations with regards to any proposal will arise unless and until a legal licence agreement with TIAR has been executed.

# Appendix 1

- Applications received at TIAR's office after the stipulated closing time and date will be deemed late and will be excluded from consideration unless the applicant can provide conclusive evidence of mishandling by the postage service used.

## CONTENT OF THE CONSULTANTS PROPOSAL

The consultant's Expression of Interest must address each of the following;

- Qualifications of consultants:  
The name, qualifications, experience and current role of the Consultant should be described. If a parent organisation is expressing interest, detail of the company and its role are also required. In both cases the onus is on the party expressing interest to show that it is suitable for the role.
- The region(s) for which the consultant or the parent organisation wishes to receive an exclusive licence to deliver the ATP technology and sell services related to the ATP technology.
- An indicative rate at which services related to the ATP technology would be charged to growers
- An indicative marketing plan for the ATP technology in the exclusive region.
- Indicative sales forecasts for services related to the ATP technology in each region.

All of the above **must** be addressed.

## LODGEMENT OF RESPONSE

To respond to this brief please submit your proposal addressing the above criteria and including acknowledgment that all terms and conditions stated in this brief are accepted.

**Proposals must be lodged by 5pm, Friday 18<sup>th</sup> July 2003.**

**Late proposals will NOT be considered.**

Please address all responses marked "Confidential" as follows:

**Expression of Interest: ATP Technology  
Attn: Sally Bound  
Tasmanian Institute of Agricultural Research  
13 St Johns Avenue  
New Town  
TAS 7008**

**Email:** [Sally.Bound@dpiwe.tas.gov.au](mailto:Sally.Bound@dpiwe.tas.gov.au)

**Fax:** (03) 6233 6145

# Appendix 2

*Advertisement as placed in The Weekend Australian in 2003*



Tasmanian Institute of  
Agricultural Research



Horticulture Australia

### Expressions of Interest

## **Commercialisation and Delivery of Spray Thinning Technology for the Australian Apple Industry**

The Apple Thinning Program (ATP), a computer based expert system produced by Tasmanian researchers for crop thinning in apples, is available for commercialisation throughout Australia. Grower implementation is via organisations and consulting agronomists delivering and selling services related to the ATP through an exclusive, 3 year regional licence from the Tasmanian Institute of Agricultural Research (TIAR). Licences for Northern Victoria, Tasmania, and the Donnybrook region of WA were taken up in 2002.

To obtain a 3 year Licence to Operate you will be required to:

- Pay a training and licensing fee
- Successfully participate in a 2 day course in Hobart in early August 2003.
- Run grower workshops in your designated region to launch the ATP technology
- Integrate the provision of grower advice into your consulting services with some technical support by TIAR

Expressions of Interest must address the criteria outlined in the Consultants Brief, which can be obtained by contacting Sally Bound on (03) 6233 6857 or e-mail [Sally.Bound@dpiwe.tas.gov.au](mailto:Sally.Bound@dpiwe.tas.gov.au)

**The closing date for receipt of Expressions of Interest is Friday 18th July 2003. NOTE: Late proposals will NOT be considered.**

# Appendix 3

## Principles of Crop Regulation - Course for Consultants

August 2002

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### Day 1: Thursday 8<sup>th</sup> August

Venue - Grove Research Station

- 9.30 am**            **General introduction**
- 9.45 am**            **Understanding crop loading**  
Flowering and fruit set  
Basic principles of thinning  
Methods of thinning
- 12.00 – 12.45**    **Lunch**
- 12.45 pm**           **Managing crop load**  
Bioregulators available for thinning  
Factors affecting thinning response  
Spray application  
Assessing potential crop load  
Practical component – determining fruit set and assessing crop load
- 5.00 pm**            **Depart GRS**
- 

### Day 2: Friday 9<sup>th</sup> August

Venue – New Town Research Laboratories

- 9.00 am**            **Thinning programs**  
Development of structured thinning programs  
Introduction to ATP  
Hands-on experience with ATP
- 1.00 – 1.45**        **Lunch**
- 1.45 pm**            **General Discussion**
- 3.00 pm**            **Evaluation**  
The evaluation will consist of:  
    working through two scenarios using the ATP  
    a short written paper with eight questions, six of which must be answered
- 4.00 pm**            **Summary**
- 4.15 pm**            **Close**

*Note: lunch, morning and afternoon tea will be provided on both days*



# Managing Crop Load

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**Grower Workshops**

**2002/2003**

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# Appendix 4

## Introducing the Workshops

This workshop, funded by Horticulture Australia Limited, is part of project AP02005 - *A national approach to increasing grower awareness of apple thinning technology and systems*. This project aims to optimise productivity through education of growers in crop regulation, increasing your understanding in the use of thinning regimes and familiarising industry with the Apple Thinning Program.

The Apple Thinning Program is a computerised expert system that has been developed for Australian conditions by researchers from the Tasmanian Institute of Agricultural Research and Department of Primary Industry, Water & Environment. The Apple Thinning Program combines over 20 years of research with feedback from Australian growers, resulting in a robust model for the determination and application of thinning sprays for a range of cultivars.

This workshop is designed to give you, the grower, an understanding of the basics of crop regulation, and extend the latest available information on crop regulation. During these workshops the Apple Thinning Program will be explained to ensure that you are comfortable with the use of this new technology

Sally Bound



**Horticulture Australia**



## Flowering and fruit set

In modern intensive fruit growing small, closely planted trees have replaced the large, widely spaced vase shaped trees of the past. At the same time the economic life span of an orchard has been reduced from 50 years to 10-15 years, Hence early fruit bearing is essential, especially to balance the natural habit of vigorous growth in young fruit trees and to give the early return needed on the high financial investments.

Irregularity of flowering and cropping is a major economic constraint in some pome fruit orchards and an understanding of the mechanisms involved in flowering and fruit set will assist orchardists to improve yields, fruit quality and returns.

### *1.1 Factors influencing flower initiation*

Plant bioregulators (PBRs) have a dominant role in flower initiation. Ethylene, either applied as a chemical spray or produced internally as a result of stress, may increase initiation of flower buds. The synthetic cytokinin 6-benzyladenine (BA) has also been reported to increase flowering when applied 60-100 days after bloom. Gibberellins (GA) inhibit flower bud formation. This is important, as gibberellins are produced in shoot meristems or growing points and in the seeds of the developing fruits. The time when the fruits become inhibitory to flower bud formation (4-5 weeks after full bloom (AFB)) corresponds with the time when GA levels start to increase.

During the flower initiation period, many environmental and cultural practices can also influence flower initiation. The process of initiation can be interrupted at any time if conditions become unfavourable, if floral inhibitors are used or vegetative growth is stimulated.

Improving light exposure to spurs through use of training systems and pruning techniques will also improve initiation of flowers. Inhibiting apical dominance by pulling branches to a more horizontal position may also assist.

### *1.2 Fruit set*

Fruit set is influenced by a number of factors, including:

- strength of bloom
- pollination
- weather conditions
  - temperature (bee activity, cell initiation and growth)
- light (shaded buds initiate and set poorly)
- competition between blooms (snow bloom effect - can be misleading if blossom is weak)

Several natural fruit drops may occur in pome fruits. The initial drop is of unfertilised flowers. Depending on the cultivar and seasonal temperatures, there may be two further

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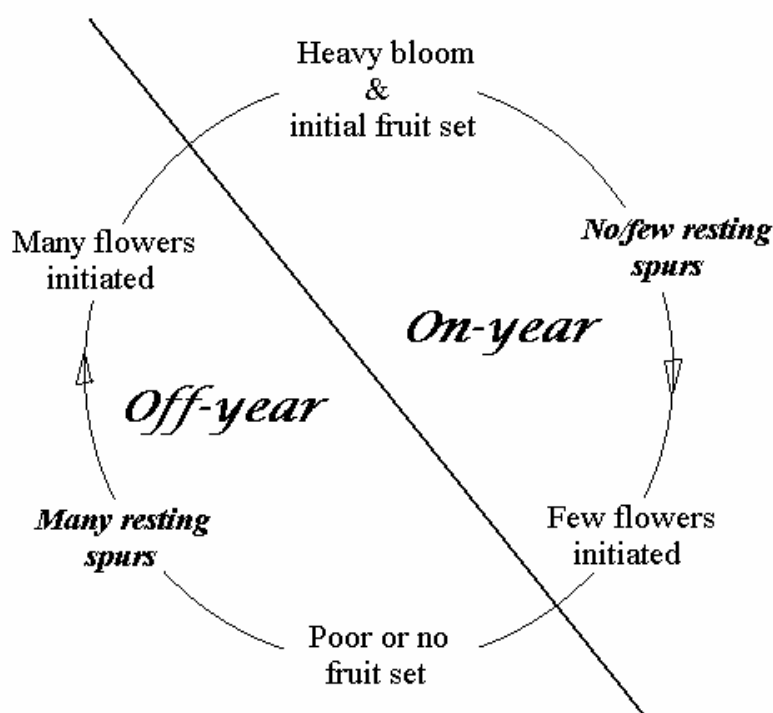
waves of fruit drop. The second drop often goes unnoticed and is of pollinated flowers in which some development is apparent. In these fruit the ovule was probably fertilised, but for some reason development is interrupted. These fruit fall behind in size, the pedicel becomes yellow, and the partially developed fruit drops.

The third drop, referred to as December drop in Australia, or June drop in the northern hemisphere, is the most obvious because the fruit are larger and more apparent beneath the tree. These fruit usually have below optimum seed numbers or seeds are aborted. They fall behind in development because they are less able to compete for metabolites, attracted strongly by large seeds in other fruits and the vegetative growing points which are very active at this time. This December drop can be particularly pronounced at high temperatures which promote high rates of metabolism.

### 1.3 Biennial bearing

Apples are, by nature, biennial bearing. If left to themselves they produce a heavy crop one year (*on-year*) followed by a light or no crop the next year (*off-year*). Biennial bearing in apple is due to lack of floral initiation in the on-year (Figure 1) which leads to no or poor return bloom the following year. Biennial bearing can also be induced by pruning or chemical treatment.

Figure 1: typical biennial bearing cycle as exhibited in pome fruits



Once started, this alternate cropping cycle is largely self-perpetuating as crop numbers have a major influence on the potential crop for the following year. **However, by careful tree management this biennial bearing cycle can be broken to allow consistent cropping from year to year.**

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To prevent biennial bearing the delicate balance between fruit set, flower bud formation and shoot growth must be altered in favour of the reproductive process. While a number of cultural techniques such as pruning, tying down of branches, fruit thinning by hand, use of dwarfing rootstocks, and fertiliser regimes are used, the use of plant growth regulators have proved to be invaluable.

In some strongly biennial cultivars which are self fertile and consequently have fruits with many seeds, the thinning of young fruitlets is too late to prevent inhibition of flower bud formation - these cultivars require thinning of flowers.

Even when the seed content of fruits is not particularly high, heavy crop loads are likely to inhibit flower initiation and flower development and reduce cropping the following year. This explains the biennial bearing pattern often observed in long-term production records. Fruit thinning should be done within 4-5 weeks of flowering to overcome biennial bearing. No thinning or delayed thinning may result in the complete inhibition of flower formation or a delay in initiation until late in the season.

### Regulating crop load

Crop regulation or thinning is the removal of excess fruit and/or flowers, and is one of the most important management practices undertaken by orchardists. Application of chemicals known as plant bioregulators (PBRs) to reduce crop load is known as chemical thinning. Chemical thinners are either caustic materials which desiccate or burn the female reproductive parts of the flower, preventing pollination and fertilisation; or hormonal growth regulators which mimic natural plant hormones, altering the physiological processes within the tree.

Effective crop regulation reduces biennial bearing, and increases fruit size, colour and quality. Fruit size at harvest is directly related to the earliness and degree of thinning, provided tree and spur vigour are adequate.

#### *2.1 Objectives of thinning*

The ideal thinning practice is to remove the bulk of the excess fruit as early in the season as possible. The aims of the thinning program should be to:

1. produce an optimum crop every year, and get good return bloom, ie. eliminate biennial bearing
2. achieve this optimum crop load with the largest possible number of fruit in the desired size range
3. minimise hand thinning
4. minimise the amount of chemical used with correct timing and application of spray
5. maintain or improve fruit quality, and
6. reduce the risk of under- or over-thinning by using a 'best practice' program.

#### *2.2 Pruning*

Pruning should be considered an integral part of any thinning program. Well sized, high quality fruit are associated with open, healthy trees. Tree canopies need to be opened up by removing old, weaker wood and unwanted, vertical wood. Replacement wood, which subsequently forms the new spurs, must be catered for.

The healthier and more vigorous the flower buds the better the fruit will be. In pome fruits the best fruit occurs on younger spurs (2-4 year old). Adequate light penetration is also important for the production of good quality fruit, particularly where good flower bud initiation and fruit colour are required.

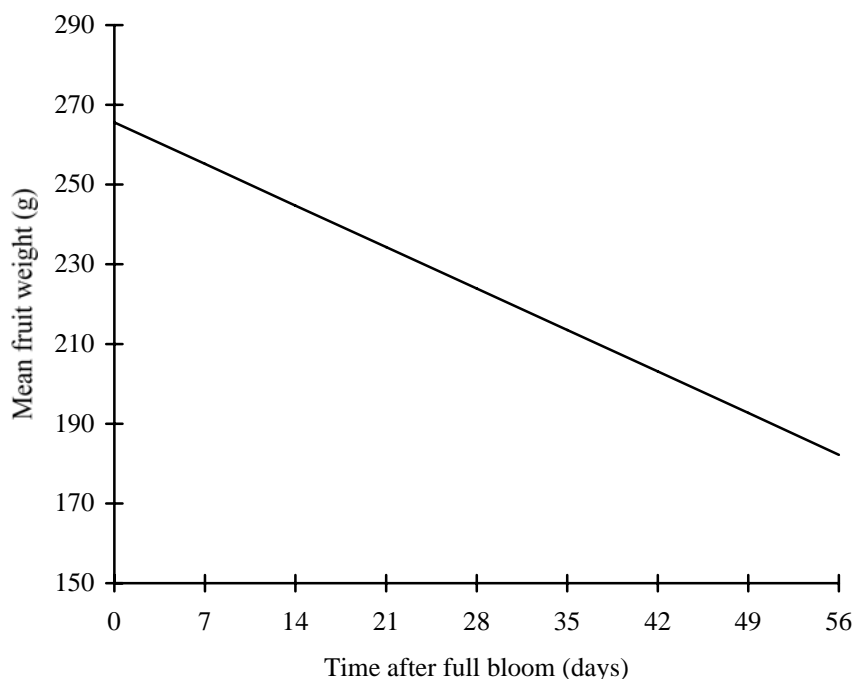
#### *2.3 Time of thinning*

If excess fruit is removed before fruit cell division is complete and total fruit cell numbers have been determined there is the likelihood that cell numbers can be

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increased, thus leading to potentially larger and denser fruit. When thinning is delayed until several weeks after flowering substantial nutrient reserves are wasted producing fruit which are later removed. It is more efficient to remove excess fruit early so these reserves go to fruit destined to remain on the tree. The longer the delay in thinning the less effective it is in increasing fruit size. Figure 2 shows that for similar crop loads a delay in thinning of eight weeks results in a 33% loss in individual weight.

Figure 2: the effect of time of thinning on fruit size of 'Fuji' apple (data from Jones et al 1992)



### 2.4 Level of thinning

Most apple cultivars require some degree of thinning. In order to crop trees consistently every year over 90% of the flowers/potential fruitlets need to be removed from the tree within six weeks of flowering. To see how this figure is arrived at, let's look at a couple of examples.

- (i) An average sized mature vase tree has up to 1,500 buds with 5 flowers per bud. This equates to 7,500 flowers or potential fruit per tree.  
For a good commercial crop load we need about 500 fruit per tree.  
From these figures, we can calculate the percentage of flowers that need to set to obtain this crop load, ie  $500 / 7500 * 100 = 7\%$   
In other words we need to prevent 93% of the flowers from setting fruit.
- (ii) Alternatively, if we take a 2m central leader tree with 600 buds, or 3000 flowers, and a desired crop load of 200 fruit. Thus we need  $200 / 3000 * 100$ , or 7% of flowers to set.



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Natural abscission is not sufficient for thinning purposes and occurs too late to obtain fruit size benefits and prevent biennial bearing.

An upper limit of fruit size exists for each variety. This limit is also influenced by orchard management and seasonal conditions. Once the crop load of a tree has been reduced to a level that will allow the remaining fruit to achieve this size, further thinning will only serve to reduce yield. The aim is to produce the greatest number of fruit of the desired size and quality without impacting on return bloom. It is well recognised that some cultivars such as 'Golden Delicious' can be cropped at higher levels than cultivars such as red 'Delicious' and 'Fuji' without return bloom problems.

The degree of thinning depends on many factors, such as the desired fruit size for a particular market, amount of pruning, blossom density and strength, and degree of initial set. The full range of these variables must be addressed in forming a thinning strategy for each cultivar.

## Available chemical thinning agents

Chemicals used for thinning are grouped according to application timing:

1. *bloom* or *blossom thinners* are applied at flowering. Blossom thinners are often called primary thinners
2. *post-bloom thinners* are applied after flowering is complete - usually anywhere from 10 to 40 days after flowering. Post-bloom thinners are also referred to as secondary thinners.

There are now three blossom thinners and two post-bloom thinning bioregulators registered for use on apples in Australia (Table 1), giving Australian growers a greater choice than most other countries. Good thinning outcomes can be achieved at a low level of risk by adopting a series of sprays, rather than using a single strong dose of one bioregulator.

*Table 1: Bioregulators registered for use as thinning agents on apples in Australia*

<i>Generic name</i>	<i>Trade name</i>	<i>Chemical name</i>	<i>Type of thinner</i>
NAA	-	1-naphthalene acetic acid	Blossom
ethephon	Ethrel / CEPA	2-chloroethyl phosphonic acid	Blossom
ATS	Culminate	Ammonium thiosulphate	Blossom
Carbaryl	Sevin	1-naphthyl (N)-methyl carbamate	Post-bloom
Thiram	TMTD	Bis (dimethyl thio-carbomoyl) disulphide	Post-bloom
BA / benzyladenine	CyLex	N-(phenyl)-1H-purine 6-amine	Post-bloom

### 3.1 Ethephon

Australia is one of the few countries where ethephon is used successfully for thinning. Ethephon can be a vigorous thinner, completely removing weak spurs or depleting fruit positioned low on the tree more easily than from the more vigorous higher spurs.

*Application timing:* The effective time frame for ethephon use is from balloon blossom (BB) through to 7 days after full bloom (dAFB). Ethephon can also be used to remove the later opening flowers on first year wood when they reach balloon blossom.

*Concentration:* In general, concentrations of 30-50 ppm ethephon are recommended for younger trees, with concentration increasing up to 100-150 ppm for mature trees. We recommend that no more than 200 ppm be applied even in difficult to thin trees, as high rates can affect fruit quality.

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*Complete fruit removal:* Although ethephon also thins effectively at around 40 dAFB it does not improve fruit size and can cause yellowing of the fruit at harvest. However, if the crop is damaged, eg. by hail, it can be completely removed from the tree with ethephon at 40-50 dAFB. This not only saves hand removal of the crop but has a positive effect in encouraging return bloom.

*Advantages:*

- improves return bloom
- early thinning
- discriminates against late blossom at balloon stage of development
- can be used for complete removal of damaged crops at 40-50 dAFB

*Disadvantages:*

- can depress fruit size if used at higher rates or too late
- has a tendency to flatten fruit
- weather dependent – affected by temperature

### 3.2 NAA

NAA has been the most widely used thinner in Australia for more than 30 years. As our level of knowledge of NAA has increased, the recommendations for its use have altered.

*Application timing:* We now recommend that NAA be applied as a blossom or primary thinner from full bloom (FB) up to 7 days AFB, however in most other countries NAA is still applied much later as a post-bloom spray. Despite the fact that NAA can thin most cultivars between full bloom and 21 dAFB, the earlier it is applied the better the response in fruit size. Late applications also tend to encourage the formation of pygmy fruit and reduce seed numbers.

*Concentration:* The effectiveness of NAA as a thinner varies markedly with cultivar. Easy to thin cultivars such as ‘Democrat’ and ‘Granny Smith’ can be successfully thinned with concentrations as low as 4 to 5 ppm, whereas difficult to thin cultivars such as ‘Golden Delicious’ may require 2 sequential sprays of up to 12 ppm. The first spray is applied at FB and the second follows at 3 to 7 dAFB.

NAA promotes vegetative growth. This can be advantageous in green apples such as ‘Golden Delicious’ or ‘Granny Smith’, but can be a distinct disadvantage in red apples where extra vegetative growth shades the fruit, inhibiting red colour production.

*Interactions:* NAA interacts with other PBRs containing the gibberellins GA<sub>4+7</sub>. Hence it is not compatible with formulations such as Cytolin<sup>®</sup> when applied at the normal recommended rate. However, if the rate of NAA is reduced to 3-4 ppm then a Cytolin / NAA program works well.

*Advantages:*

- early thinning

*Disadvantages:*

- high concentrations & late applications often produce pygmy fruit
- tendency to reduce seed numbers
- weather dependent – affected by temperature and humidity
- rewetting with light rain/dew can cause overthinning
- can depress fruit size if used at higher rates or too late
- can cause fruit russetting
- interacts with PBRs containing GA<sub>4+7</sub>

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## 3.3 *Culminate*

Ammonium thiosulphate (ATS) has recently been registered under the trade name Culminate<sup>®</sup> [Ferro Corporation (Australia) Pty Limited]. Culminate is a desiccant or blossom burner, and prevents fertilisation from occurring by burning and killing the style and stigma of the flower, thus preventing pollination. It has a physical mode of action rather than hormonal, making it less dependent on weather conditions than NAA or ethephon.

*Rate of application:* The recommended application rate for apples is 0.75 - 1.0% v/v. Rates of 1.0 to 1.5% have been successful on the pear cultivar *Packham's Triumph*, while a rate of 2.0% effectively thinned Nashi pears.

While leaf damage does occur with desiccants, the degree of damage that occurs when using the recommended rates does not affect fruit development, size or quality. It should also be noted that the degree of desiccation can be influenced by temperature – with higher temperatures resulting in greater desiccation.

*Application timing:* Time of application is critical in achieving a satisfactory level of thinning. The chemical must be applied **when sufficient flowers have already been fertilised** to give a good crop load. Multiple application is recommended. The first application should be applied at around 20% bloom. By this stage more than enough flowers should have set fruit for a good commercial crop. However, if conditions are unfavourable for pollination, ie cool wet weather with few active bees, then this spray should be delayed. The second application should be applied at 80% bloom to remove most of the later opening flowers. In cultivars with an extended flowering period, such as Gala, three applications may be necessary.

*Spray volume:* At this stage, Culminate needs to be applied at high volumes, ensuring thorough wetting of the trees. Ensure the sprayer is properly calibrated to give even coverage over the whole tree - poorly calibrated sprayers are likely to result in uneven thinning across the tree. Low volume concentrate spraying is not advised as this is likely to result in an extreme desiccating action, resulting in severe burning of foliage and death of buds.

## 3.4 *Carbaryl / Thiram*

Carbaryl is regarded as a mild thinner and usually only removes the slower growing fruit within bunches. In Australia carbaryl is used as a post-bloom or secondary thinner, usually in a tank mix with thiram. This combined carbaryl/thiram spray has the advantage that it leaves only the largest fruit on any spur, rarely removing all the fruit within a bunch.

*Application timing:* The use of carbaryl is strongly discouraged until well after flowering to avoid bee deaths. The best time to apply carbaryl/thiram is from 14 to 60 dAFB, which is well after bees have been removed from the orchard. At this time it can be used efficiently as a joint thinner and insecticidal/fungicidal cover spray. Repeat applications may be applied at 7 - 10 day intervals. Application should cease when the required crop load has been achieved or at 60 dAFB, whichever comes first.

While application of blossom sprays (ethephon, NAA or Culminate) is recommended prior to carbaryl, carbaryl can also be used as a thinner on trees where the use of a

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primary thinner is not warranted, either because the trees are young or because of sparse blossom buds.

*Concentration:* Carbaryl should be used at the recommended label rate. Increasing concentration has no additional thinning effect, nor does thinning efficiency improve with the addition of wetters.

*Application conditions:* Carbaryl is temperature dependent, requiring warm dry conditions for effective thinning. The warmer the temperature the greater the thinning effect. Application should be delayed under cool (<18°C) or humid slow drying conditions, or if a cold night (<3°C) is forecast after spraying, as russet can occur if cool or damp conditions follow application of carbaryl.

*Disadvantages:* Carbaryl is a persistent pesticide that is toxic to bees and beneficial species important in integrated pest management programs. It is also toxic to mammals, and has been found in waterways. When applied under inappropriate conditions, carbaryl can cause fruit russetting. Carbaryl can leave residues on fruit, and its use is banned on fruit being exported to countries such as Taiwan.

### 3.5 CyLex

The active ingredient in CyLex<sup>®</sup> is the cytokinin 6-benzyladenine (BA), which is found naturally in plants. CyLex is a secondary thinner designed for use on trees that have been treated at flowering with one of the primary thinners Culminate, ethephon, or NAA.

*Application timing:* CyLex can be applied from as early as 10 dAFB and up to 22 dAFB, depending on cultivar. Although the label also indicates a fruit size range, CyLex should not be applied until at least 10 dAFB.

Application times vary slightly between cultivars:

<i>red Delicious, Golden Delicious</i>	10 - 20 dAFB
<i>Fuji, Gala</i>	15 - 22 dAFB

To date, there is no recommendation for either *Pink Lady* or *Sundowner*. There is some evidence to suggest that a much later time of application may be effective on these cultivars, however further work is needed on timing. CyLex has been shown to be effective on Packham pears as late as 40 dAFB.

*Concentration:* The recommended application rate of CyLex is 150 ppm applied as a fine mist. Spray volume is dependent on the size of trees - good tree coverage is important without overspraying. Application to runoff can result in the active ingredient being dragged off the tree, rendering it less effective.

*Application conditions:* CyLex is temperature dependent, the warmer the temperature the more effective it will be. Ideally it should be applied on a rising temperature curve, with maximum daily temperatures in excess of 15°C. You should be looking for the best available weather during the recommended application period.

Caution is advised in using CyLex when the dormancy breaker Waiken<sup>®</sup> has been applied, as we have seen overthinning in a number of trials where CyLex was used on trees that had received Waiken. In this situation careful fruitlet counts should be

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undertaken after the application of primary thinners to determine whether further thinning is necessary.

*Advantages:* consistent thinning  
non persistent and non-toxic  
OK for IPM programs, doesn't harm bees, predatory mites or other beneficial insects  
increases fruit size independently of the thinning effect  
increases fruit firmness  
metabolises quickly and does not leave residues

*Disadvantages:* temperature dependent – needs warm to hot conditions

### ***3.6 Recommended application times and conditions***

Despite the limitations of these bioregulators, a chemical thinning program produces markedly superior results to hand thinning, both economically and in terms of tree physiology. However to achieve good thinning and fruit quality, all thinning bioregulators need to be applied at the appropriate physiological stage of the tree and under the climatic conditions which are best suited to each bioregulator. Optimum timing and application conditions for each thinning bioregulator are shown in Table 2.

A non-ionic surfactant such as Kendeen (Tween 20) is recommended with all thinners, except for carbaryl/thiram.

# Appendix 4

Table 2: Available thinning bioregulators and the conditions for application

Thinner	Application timing	Conditions for application	Advantages	Disadvantages
Ethrel	BB to 7 dAFB	dry, 16 - 24°C	<ul style="list-style-type: none"> <li>improves return bloom</li> <li>early thinning</li> <li>thins late blossom on 1<sup>st</sup> year wood</li> <li>OK for IPM programs</li> <li>complete removal of damaged crops</li> </ul>	<ul style="list-style-type: none"> <li>can depress fruit size</li> <li>tendency to flatten fruit</li> <li>weather dependent</li> </ul>
NAA	FB to 7 dAFB	humid, 14 - 24°C	<ul style="list-style-type: none"> <li>early thinning</li> <li>OK for IPM programs</li> </ul>	<ul style="list-style-type: none"> <li>can depress fruit size</li> <li>tendency to reduce seed numbers</li> <li>can cause pygmy fruit</li> <li>rewetting can cause overthinning</li> <li>can cause fruit russeting</li> <li>interacts with Cytolin</li> <li>weather dependent</li> </ul>
Culminate	20 & 80% bloom	dry	<ul style="list-style-type: none"> <li>early thinning</li> <li>OK for IPM programs</li> <li>Can also be used on late blossom</li> <li>not as weather dependent as NAA/Ethrel</li> </ul>	<ul style="list-style-type: none"> <li>high volume application</li> <li>rewetting can cause phytotoxicity</li> </ul>
Carbaryl / thiram	14 -60 dAFB	20°C plus and dry before and after application	<ul style="list-style-type: none"> <li>mild bunch thinner</li> <li>can be applied every 7-10 days</li> </ul>	<ul style="list-style-type: none"> <li>persistent pesticide</li> <li>cannot be used with IPM program</li> <li>risk of residues</li> <li>temperature dependent</li> <li>can cause fruit russeting</li> </ul>
CyLex	Fuji & Gala 15-22 dAFB red Delicious & Golden Delicious 10-20 dAFB	} dry, warm } max. daily temp at least 15°C } warm day after application }	<ul style="list-style-type: none"> <li>increases fruit size</li> <li>increases fruit firmness</li> <li>fruit sugar content may be increased</li> <li>non-persistent and non-toxic</li> <li>OK for IPM programs</li> </ul>	<ul style="list-style-type: none"> <li>temperature dependent</li> </ul>

BB = balloon blossom

FB = full bloom

DAFB = days after full bloom

## Factors affecting thinning and fruit quality

Thinning decisions are difficult as many factors affect the end result. In addition, the level of risk that the orchardist is willing to take and issues such as the desired fruit size also need to be taken into account. While each factor can individually influence the outcome of thinning programs, more commonly there are interactions between several factors.

### 4.1 Cultivar

Thinning strategies cannot be transposed from one cultivar to another as each cultivar responds differently to chemical thinning agents. Some cultivars have a strong tendency towards biennial bearing, and early thinning in these cultivars is particularly important. Spur bearing cultivars tend to be more difficult to thin than non-spur bearers.

### 4.2 Rootstock

Rootstocks and interstocks have a direct effect on thinning outcomes. Dwarfing trees tend to be more precocious than vigorous trees, with considerably greater blossom densities. The more dwarfing the rootstock the more difficult thinning becomes.

### 4.3 Tree history

*Tree age:* Crop load capacity increases as trees mature. Young trees tend to be irregular in their cropping pattern, and react in an unpredictable manner to chemical thinners. Hence, it is preferable to control crop load on young trees by hand thinning until trees settle into a regular bearing pattern.

*Previous crop load:* A previously heavy crop can influence the production of flowers in the current year, and can also influence the potential of those flowers to set.

*Blossom:* Blossom density and the strength of the blossoms is related to last year's crop load. A heavy crop last year means a lack of blossom this year.

*Tree vigour:* Vigorous vegetative growth of trees can reduce fruit set in both young and mature trees. It is risky to start a normal spray thinning program on vigorously growing trees with poor blossom.

*Pruning effects:* Severe pruning can remove significant numbers of competing flower buds, rendering the remainder more difficult to thin. Removing competing flower buds before thinning can be an advantage in producing large fruit, particularly if the weaker flower buds are removed by selective pruning. Reduced flower competition also improves pollination as there are fewer flowers for the bees to visit.

*Previous exposure to bioregulators:* Both ethephon and NAA are more effective on apple trees that have not been previously exposed to these chemicals.



# Appendix 4

## 4.4 Climate

Climatic conditions affect a range of physiological processes within the tree, all of which can impact on the thinning result. The degree of winter chilling can affect dormancy break and flowering, while poor weather conditions during the flower initiation period can result in weak, poor quality blossom. Pollination and fertilisation are also influenced by weather conditions.

Weather has an important impact on the effectiveness of chemical thinners. In addition, weather conditions during flowering and the early post-bloom period often allow only small windows of opportunity to apply sprays.

*Temperature:* Temperature at the time of spraying can be critical. Chemicals which are readily and rapidly absorbed by the plant (leaves and/or flowers) tend to be effective under warm fast-drying conditions, while chemicals which are not easily absorbed, such as NAA, require damp slow-drying conditions. The thinning effectiveness of ethephon has been shown to increase as the ambient temperature rises. Higher temperatures also increase the thinning effect of CyLex and carbaryl. Both CyLex and carbaryl are more effective if temperatures increase for 2-3 days following application.

Cold weather before, during and after flowering can increase russet damage of fruit in susceptible cultivars. Frost can affect fruit set directly and/or result in severe russetting.

*Humidity:* Activity of NAA is enhanced under humid, slow-drying conditions. High humidity, however, can cause fruit russetting.

*Wind:* As well as speeding up the drying time of applied sprays, wind velocity can impact on the amount of spray reaching the target. Under moderate to strong wind conditions, a large proportion of the spray is deflected from the target.

*Rain:* In damp wet weather, fruit set tends to be lower due to reduced bee activity leading to poor pollination. Heavy rain following chemical application can wash the chemical from the tree, while light rain occurring after the chemical has dried leads to re-wetting and reactivation, particularly with NAA. This can lead to over-thinning or under-thinning, depending on prevailing weather conditions.

## 4.5 Pollination

Insufficient cross-pollination results in low seed numbers, poor fruit set and other problems such as misshapen fruit, lower calcium levels in the fruit and poor fruit size. Most cross-pollination in pome fruits is performed by bees.

## 4.6 Choice of bioregulator

Satisfactory thinning can be achieved at a lower risk if a strategy of using a series of sprays is adopted, rather than using one strong dose of a single chemical.

There are a number of factors to be aware of when deciding on thinning programs. Both NAA and Ethrel are extremely weather dependent and thus tend to be unpredictable in their thinning effect if not applied under ideal conditions. Culminate appears to be influenced by temperature, but not to the same degree as NAA or Ethrel. CyLex is also dependent on temperature, losing efficacy under cooler conditions.

## Appendix 4

Carbaryl is a persistent pesticide that is toxic to bees and beneficial species important in integrated pest management programs. It is also temperature dependent, requiring warm dry conditions for effective thinning.

To achieve good results, both in terms of level of thinning and fruit quality, all chemical thinners need to be applied at the appropriate physiological stage of the tree and under the climatic conditions that are best suited to each chemical.

### 4.7 Spray application

*Size of tree:* tree size and shape directly influence spray application. The aim is to prevent under or over thinning or zonal inconsistencies within the tree.

*Coverage:* for effective thinning every flower needs to be challenged, therefore proper tree coverage is important. The only way to achieve this is by careful nozzle selection and good sprayer calibration.

### 4.8 Other

The factors discussed above often interact to varying degrees, complicating the thinning equation even further. However awareness of some of the issues listed in Table 3 will improve the success rate when applying chemical thinners.

**Table 3: factors causing variability in thinning**

<i>Factors making thinning easier</i>	<i>Factors increasing the difficulty of thinning</i>
<ul style="list-style-type: none"> <li>• Non-spur bearing cultivars</li> <li>• Very vigorous vegetative growth</li> <li>• No previous history of growth regulators</li> <li>• Over-crowded trees with shaded spurs</li> <li>• Upright branches</li> <li>• Trees provided with high levels of nitrogen</li> <li>• Drought or over-watering in spring</li> <li>• Heavy blossom</li> <li>• Short bloom period</li> <li>• Poor pollination</li> <li>• Poor fertilisation – few seeds per fruit</li> <li>• Cold, cloudy weather – low photosynthesis</li> <li>• Warm to hot – good thinning with ethephon, carbaryl and CyLex</li> <li>• Humid and warm – good absorption and thinning with NAA</li> </ul>	<ul style="list-style-type: none"> <li>• Spur bearing cultivars</li> <li>• Moderate or low vegetative growth</li> <li>• Previous application of ethephon, NAA</li> <li>• Trees with good light exposure</li> <li>• Horizontal branches</li> <li>• Trees with adequate nitrogen levels</li> <li>• Water supply adequate in spring</li> <li>• Moderate blossom</li> <li>• Long bloom period</li> <li>• Good pollination</li> <li>• Good fertilisation – many seeds per fruit</li> <li>• Weather ideal for photosynthesis</li> <li>• Cold – poor thinning with ethephon, NAA, carbaryl and CyLex</li> <li>• Dry, windy and quick drying – poor thinning with NAA</li> </ul>

## Appendix 4

### *4.9 Impact of chemical thinning on fruit quality*

The earlier thinning is performed, regardless of the method of thinning, the larger the fruit size at harvest. Fruit size can be increased by either increasing the number of cells, or increasing the size of cells. An increase in cell size tends to lead to poorer quality fruit, whereas increasing the number of cells without increasing cell size produces larger, denser fruit. Early thinning, ie before cell division is complete, usually stimulates cell division as more resources are available for the fruit remaining on the tree, thus leading to higher cell numbers. Bioregulators such as Cytolin and CyLex also stimulate cell division, increasing fruit cell numbers.

While there are major benefits in using chemical thinning agents there can also be drawbacks, with fruit quality affected by some chemicals under certain conditions.

*Fruit size:* NAA can result in the formation of pygmy fruit in apple. At higher concentrations or later application timings both NAA and ethephon are likely to depress fruit size, counteracting the benefits gained by early thinning. Ethephon also has a tendency to flatten fruit. This fruit flattening effect can be counteracted by the use of PBRs such as Cytolin, however this is an added cost.

CyLex has the added advantage over other thinners of increasing fruit size independently of the thinning effect. It does this by increasing the number of cells in the fruit, leading to better fruit quality and an increase in fruit firmness. Fruit sugar levels are also increased by CyLex.

*Seed numbers:* both NAA and carbaryl can reduce seed numbers in pome fruit or cause abortion of fertilised seeds. This problem of reduction in seed numbers increases proportionately the later after full bloom that the NAA is applied, or with carbaryl the nearer to full bloom. As seed number affects fruit quality and fruit size this is a most undesirable side effect.

*Russetting:* if applied under cool temperatures or high humidity carbaryl may cause skin russetting, thus downgrading fruit. NAA may also cause russet under humid conditions. Application of any chemical after a prolonged cool wet period is likely to result in an increase in fruit russet.

Notwithstanding all these negatives it is still possible to produce good results and high quality fruit with chemical thinners.

## Spray application and efficiency

### 5.1 Factors affecting spray efficiency

A wide range of factors impact on spray efficiency. These include:

- climatic conditions, before, during and after spraying
- tree factors such as size, shape, density, spacing and growth stage
- sprayer factors such as sprayer selection and set up, speed of travel, the use of propelled air, air pattern and velocity, and spray nozzle pattern
- the addition of spreaders and stickers to the spray solution
- carrier volume, and the range and size of spray droplets

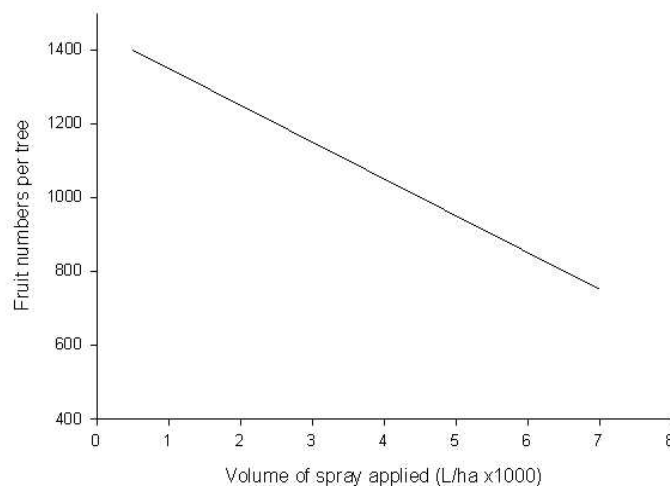
Work by the Tasmanian researchers Oakford, Jones and Bound over a ten year period has reinforced the use of spray thinning as an accurate method of assessing the value and efficiency of spraying systems. Chemical thinning agents are polar and are not translocated within the tree, hence coverage is critical in achieving optimal results.

### 5.2 Spray volume

Volume rate or carrier volume describes the quantity of water applied per hectare to carry the chemical to the target.

*High volume* or dilute spraying means spraying to the point of runoff and beyond, completely wetting the tree. A rough guide to the volumes required for effective tree coverage is to allow 1,000 L of water for every metre of tree height – thus for 4 metre trees, the spray volume should be 4,000 L/ha. For effective coverage using airblast sprayers with traditional hydraulic nozzles, water volumes need to be kept high (Fig 3).

*Figure 3: Relationship between volume of spray and thinning of red Delicious with ethephon (data from Jones et al. 1991)*



## Appendix 4

*Low volume* or concentrate spraying involves applying less water volume per hectare, but uses nozzles which produce a greater number of smaller evenly sized droplets. The key to successful low volume application lies in using nozzles which deliver droplets in a narrow range of sizes between 100 and 170 microns ( $\mu\text{m}$ ) in diameter. The application of fine droplets is critical, since this results in an even distribution of spray with minimal waste or runoff. Using standard high volume nozzles and reducing the sprayer output **DOES NOT** achieve effective low volume spraying.

Controlled Droplet Application (CDA) machines utilising the Micron and Micronaire systems are at least as biologically effective at 200 L/ha as an air-blast sprayer at 6,000 L/ha. These machines are also capable of producing excellent results at ultralow volumes as low as 25 L/ha.

Airshear machines are most effective in the range 100-400 L/ha. At higher water volumes, airshear nozzles lose their efficiency due to flooding of the nozzles, affecting the ability of the nozzle to atomise the spray liquid properly. In Australia and New Zealand airshear machines are commonly used for fruit thinning at around 250 L/ha.

Hydraulic nozzles which are able to produce a narrower droplet spectrum of fine droplets at lower water volumes (eg. Delevan, Albuz) than the traditional hydraulic nozzles, can now be used at lower pressures, achieving droplet sizes of 100 to 150  $\mu\text{m}$ . Fitted to a standard air-blast sprayer these nozzles are able to operate efficiently at low pressure at volumes as low as 200 L/ha. The advantage of this technology is that these nozzles can be fitted to existing air-blast sprayers, offering an opportunity for orchardists to convert to low volume spray application for the cost of the nozzles and a low-pressure gauge.

Most agricultural chemicals have been developed and rates determined using high-volume spraying techniques. In low volume spraying, maintenance of the dosage rate is important to avoid loss of efficacy of the chemical, hence the amount of chemical needs to be equilibrated to that which would be used for high volume spraying. Appendix 2 describes how to calculate chemical rates for low volume spraying.

### *5.3 Limitations of high volume spraying*

High volume spraying requires complete coverage of the target, leaving a thin film of spray solution remaining on the plant. Although still in use in many areas today, high volume spraying has many limitations:

- The wide droplet spectrum produced results in wastage of as much as 80% of the spray through runoff and drift.
- Slow tractor speeds are required in order to achieve good spray penetration and uniform deposition of spray.
- The time taken to apply high volume sprays, combined with the need to refill the sprayer tank several times per hectare, raises the cost of spraying and increases the difficulty of applying sprays in a timely manner, particularly when there are weather constraints.

These limitations mean that productivity in terms of area covered is not very efficient.

## Appendix 4

### 5.4 *Environmental impact*

Despite all the modifications used to improve accuracy, wastage is still a major problem with high-volume air-blast spraying. Spray drift pollution from hydraulic air-blast sprayers, caused by small droplets of  $< 50 \mu\text{m}$  can be deposited up to 100 m from the sprayer source and is a major problem in urban and semi-urban areas.

The high proportion of large droplets produced means that there is considerable wastage of spray, apart from drift, through either runoff or deflection of large droplets from the target. Splash and runoff can pose a larger problem than drift. As well as leading to possible phytotoxicity through an accumulation of spray liquid at the leaf tip, runoff also leads to soil and water contamination.

Canopy development has a major influence on spray drift, with 25 times less drift from a fully foliated canopy compared with a dormant canopy. The proximity of the sprayer relative to the edge of the sprayed block is an additional major factor influencing spray drift.

### 5.5 *Advantages of low volume spraying*

One of the benefits claimed for low-volume spraying is that chemical rates may be reduced. The Tasmanian research group demonstrated that reducing chemical dosage rates of PBRs to 25% or 50% of the full rate is too low, however they achieved good results with a 25% reduction of the chemical dose rate, which is equivalent to 75% of the full rate.

Low volume spraying represents substantial benefits over traditional HV methods. The reduction in spraying time by up to 60% means significant savings to orchardists and allows timing of sprays to be optimised. Environmental issues are becoming more prominent, and any methods which reduce both atmospheric and ground water pollution require serious consideration. Hence, the ability of low volume sprayers to reduce spray wastage and pollution from drift and runoff are of major importance.

### 5.6 *Practical application*

For effective thinning every flower needs to be challenged, therefore proper tree coverage is important. It is difficult to apply thinners uniformly, and often the most heavily treated portions of the tree are those which need the least thinning. Spraying should be done in calm conditions using well maintained and calibrated sprayers to optimise tree coverage. Most chemical thinners can be applied at either high or low volume, however at this stage it is recommended that Culminate be applied only at high volumes. The important thing to remember if using normal air-blast equipment with traditional high volume hydraulic nozzles is that water volumes need to be kept high to ensure proper tree coverage. A rough guide for water volumes used for dilute spraying is 1,000 litres of water for each metre of tree height.

If using low spray volumes chemical dosage rates need to be equilibrated to those used in dilute spraying, so effectively the spray is being concentrated - thus the term *concentrate spraying*. Whatever system used to apply sprays make sure that it is properly calibrated and good tree coverage is being achieved. Many poor results are due to using unproven technology.

## Developing structured thinning programs

Achieving target crop loads and fruit size with optimal fruit quality every year is dependent on having a reliable thinning program in place. For consistent cropping every year over 90% of the potential fruitlets need to be removed from the tree within six weeks of full bloom. Natural abscission accounts for the removal of 50-60% of fruitlets during the period from flowering to 8 weeks after full bloom (AFB) but this is insufficient for thinning purposes and most of it occurs too late to obtain fruit quality or size benefits, or to prevent biennial bearing.

If the implications of crop loading are properly understood, it is often easier to decide on thinning strategies. The earlier thinning takes place the greater the influence on fruit size. Hand thinning can improve fruit size, but as it is normally carried out after the flower initiation process has been completed this is too late to overcome the inhibitory effect of the young fruitlets on flower formation for the next year. In addition, by the time hand thinning is completed fruit size has already been determined.

### *6.1 Review of thinning principles*

To achieve all the benefits from thinning, trees need to be thinned early and aggressively. Chemical thinning is designed to remove excess fruit as early as possible. As a result, competition from unwanted fruit is eliminated early, resulting in good fruit size and good return bloom.

The improvement in return bloom produced by thinning is a result of increasing the number of spurs with no fruit during the period of flower initiation that occurs within 6 weeks of flowering. Crop fluctuations from year to year can be substantially reduced by controlling cropping on about half the spurs in a tree every year.

### *6.2 Objectives of thinning programs*

The aims of the thinning program should be to:

1. produce an optimum crop every year, and get good return bloom, ie. eliminate biennial bearing
2. achieve this optimum crop load with the largest possible number of fruit in the desired size range
3. minimise hand thinning
4. minimise the amount of chemical used with correct timing and application of sprays
5. maintain or improve fruit quality, and
6. reduce the risk of under- or over-thinning by using a 'best practice' program.

## Appendix 4

### 6.3 Developing thinning programs

To avoid biennial bearing and achieve an optimum crop of high quality fruit every year good tree management is important. The ideal thinning practice is to remove the bulk of the excess fruit as early in the season as possible. Ideally a thinning program should commence with pruning and be followed by a program combining blossom and post-bloom thinners to remove most of the excess flowers/fruit.

The recommended approach is to use one of the registered blossom thinners, Culminate, Ethrel or NAA, during the flowering period, followed by a post bloom thinner (either CyLex or carbaryl/thiram) from around 10 days after full bloom. Staging the application of thinners allows lower quantities of chemical to be used at each timing, thus reducing the risk of over thinning. If the chemical thinners have been effective all that should then be required is a subsequent light hand thin to remove damaged fruit or break up any remaining bunches.

Choice of thinning chemical is important, some cultivars do not respond well to some chemicals, and hence should be avoided. The currently recommended chemical/cultivar combinations are shown in Table 4.

Table 4: Recommendations for chemical thinners for each major apple cultivar

	Red Delicious	Golden Delicious	Fuji	Granny Smith	Gala	Pink Lady	Sun-downer
NAA @ FB	✓	✓	✓	✓	✓	✓	
Ethrel @ FB	✓	✓	✓			✓	✓
NAA after NAA	✓	✓	✓		✓	✓	
Ethrel after NAA		✓	✓				
Culminate	✓	✓	✓	✓	✓	✓	✓
Carbaryl/thiram	✓	✓	✓	✓	✓	✓	✓
CyLex	✓	✓	✓		✓		

In developing a thinning program, an awareness of the impact of each chemical thinning agent on fruit quality is also important.

If chemicals are applied under poor conditions they will not thin effectively and may cause russetting in some cultivars.

Remember that it is quite valid to choose to simply hand thin a valuable new cultivar, particularly as there is often little known about the reaction of new cultivars to chemical thinning agents. The only criteria that is important if this is the option taken is to ensure that the hand thinning is completed within 6 weeks of full bloom.

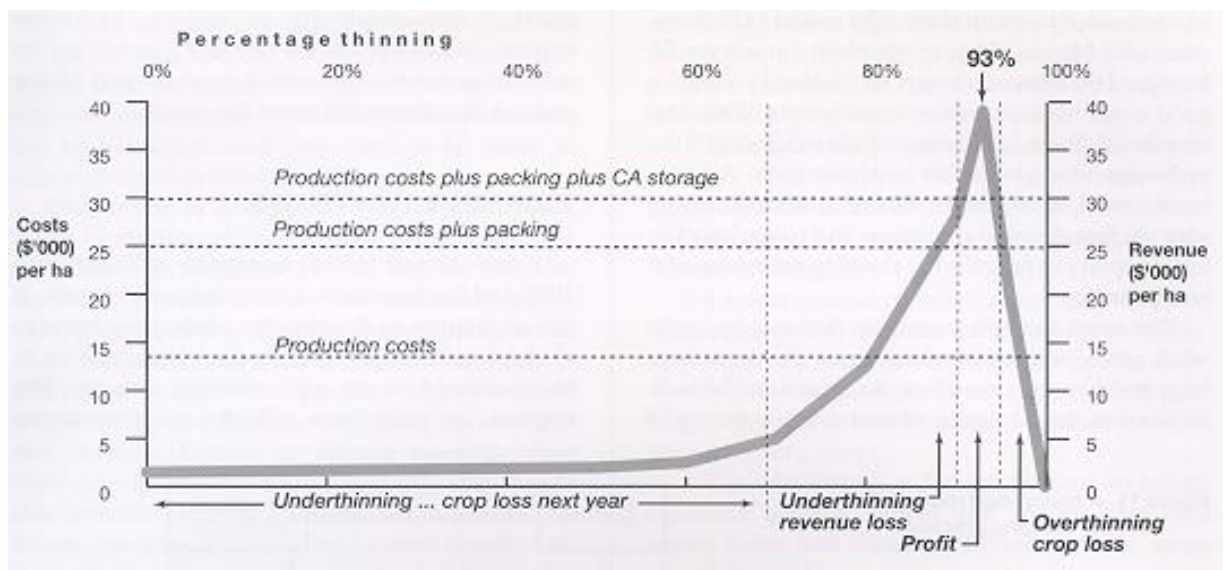


# Appendix 4

## 6.4 Risk management

There is no simple process that determines which thinning treatment should be applied to a crop. Many orchardists and scientists have puzzled over the problem of thinning and wondered why it is so complicated. Under-thinning and over-thinning can both lead to disastrous economic loss and a wrong decision can mean the end of a crop as an economic proposition. Thinning is, therefore, an exercise of not only applying known facts but of integrating them in a decision on commercial risk taking, which is an emotive situation. An attempt to explain the scale of the risk in diagrammatic form is shown in Figure 4. This explains how getting thinning right can yield high revenue and also how easy it is to fall short of the optimum by under thinning or over thinning.

Figure 4: Risk management in pome fruit production (from Jones et al 1998)



The question often asked by orchardists is “How can the optimum crop be produced regularly without taking high risks?” The answer is to introduce chemical thinning programs built on best practice and expert advice.

While most orchardists are concerned about over-thinning, many now recognise that the effects of under-thinning are more economically disastrous than over-thinning. Under-thinning means extensive hand thinning is required leading to higher costs, poor fruit quality and the potential for biennial bearing. If over-thinning occurs there will be no hand thinning expenses and return bloom the next year is assured. Under-thinning has no such bonuses.

It is of note that the more successful orchardists are particularly aggressive with their thinning programs. Achieving success in thinning means embracing risk, not ignoring it. Removing over 90% of the fruit from trees will never be without risk, but the aim is to reduce the risk to manageable proportions.

## Appendix 4

### 6.5 *Optimising your thinning program*

By adopting a program which involves a number of sequential sprays the risk of overthinning is reduced. This approach also allows use of lower doses of chemical, again minimising the risk.

Few orchardists know accurately if they have the right level of fruit on the tree during the period from flowering to 6 weeks AFB. At 20 days AFB a well thinned tree looks over-thinned to untutored eyes. For successful thinning fruit numbers need to be known early in the production cycle. The only way to get accurate data is to count the fruit on the tree to obtain a measure of crop load.

Removing 90% of the fruit will never be without risk, but the aim is to reduce the risk to manageable proportions. In addition to counting fruit, good records of each year's activities and outcomes are essential, helping to build up a picture of each block of trees.

An under-thinned crop is costly to produce, often yielding low revenue and producing poor quality fruit with lack of colour and flavour, and usually severely reducing next year's crop. If over-thinning occurs there will be no hand thinning expenses and return bloom the next year is assured. Under-thinning has no such bonuses! Economics strongly favour an aggressive thinning approach which is based on knowledge and records.

While thinning is a proven technique for reducing biennial bearing and improving fruit size and quality, it will not compensate for poor management of other orchard operations. Where an orchard is subjected to water stress or nutrition is lacking, thinning is unlikely to substantially increase fruit size or quality - the benefits of thinning are greatest where good management of all aspects of fruit production are employed.

There is no simple answer to the question "How do I thin my crop?" The two most important factors are application timing and ensuring that conditions are suitable for the particular chemical at time of spray application. Orchardists should be encouraged to discuss possible strategies with their neighbours and local grower group.

***If you have a program that works, stick to it.***

### 6.6 *Checklist*

Following is a checklist to help prompt you when developing and implementing thinning programs:

- *pruning should be the first stage of a thinning program*
- *structured thinning program using both blossom and fruitlet (post-bloom) thinners*
- *application timing*
- *weather conditions*
- *sprayer calibration*
- *hand thinning completed by December*
- *good records, including packouts are invaluable*
- *try new chemicals / techniques on a small area first*

## Assessing blossom density and fruit set

An assessment of blossom density can be useful in determining how aggressively to approach the thinning program, and can also be a guide for pruning.

To achieve all the benefits from thinning, fruit numbers need to be known early in the production cycle. At 20 days AFB a well-thinned tree looks over-thinned to inexperienced eyes. The only way to get accurate data is to count the fruit on the tree to obtain a measure of crop load.

### 7.1 Bud counting

To determine blossom densities, the number of mixed buds (usually referred to as blossom buds or clusters) on the tree are counted. If trees are small enough, the entire tree is counted. On large trees, counts can be undertaken on representative limbs.

Blossom density is normally calculated by dividing the number of flower buds (blossom clusters) by the trunk cross-sectional area (TCSA) of the tree, or branch if counts were undertaken on a single branch. Buds should be counted from the tip of the branch down towards its base. Once this is done, measure the girth or circumference of the branch or trunk just below where you finished counting. Calculate the branch or trunk cross-sectional area using the following formula:

$$\text{Area} = \text{girth}^2 / 4\pi, \text{ where } \pi = 3.14159$$

Blossom density (number of blossom clusters per cm<sup>2</sup> cross sectional area (CSA)) is calculated by dividing the number of flower buds (blossom clusters) by the branch or trunk CSA.

$$\text{Blossom density} = \text{No. blossom clusters} / \text{area}$$

Blossom density can be categorised as prolific, ideal or sparse. A rough guide to blossom density is:

- *prolific* blossom - more than 10 buds per cm<sup>2</sup> branch or trunk area
- *ideal* blossom - between 5 to 10 buds per cm<sup>2</sup> branch or trunk area
- *sparse* blossom - less than 5 buds per cm<sup>2</sup> branch or trunk area

Table 5 gives examples of blossom numbers in the different categories for a range of branch sizes.

## Appendix 4

Table 5: Sparse, ideal and prolific blossom numbers for a range of branch sizes.

Girth (cm)	Cross-sectional area (cm <sup>2</sup> )	Bud numbers		
		<i>Sparse</i>	<i>Ideal</i>	<i>Prolific</i>
2	0.32	1	2	4
4	1.27	5	10	14
6	2.86	11	21	32
8	5.09	20	38	56
10	7.96	32	60	88
12	11.46	46	86	126
14	15.60	62	117	172
16	20.37	81	153	224
18	25.78	103	193	284
20	31.83	127	239	350
22	38.52	154	289	424
24	45.84	183	344	504
26	53.79	215	403	592
28	62.39	250	468	686
30	71.62	286	537	788

### 7.2 Determining fruit numbers

A common and easy to determine measure of crop load is number of fruit per cm<sup>2</sup> CSA. This is obtained by counting the number of fruit set on either a whole tree or a representative branch, calculating the trunk (or branch) area, and dividing the number of fruit by trunk (branch) area.

$$\text{Fruit density (Fruit / cm}^2\text{ CSA)} = \text{No. fruit / area}$$

For most cultivars a crop load of 3-5 fruit per cm<sup>2</sup> CSA is acceptable.

If numbers are counted too early, before fruit has been shed, then the final crop load calculated will be lower than expected. Fruitlets which are going to abscise are usually easy to distinguish from fruit which has set, as the pedicel turns yellow as the abscission layer forms.

## Appendix 4

Table 6: Fruit numbers for a range of fruit densities, calculated for branch/trunk girths from 2 – 25 cm.

Girth (cm)	Cross-sectional area (cm <sup>2</sup> )	Fruit numbers			
		2 fr/cm <sup>2</sup> CSA	4 fr/cm <sup>2</sup> CSA	6 fr/cm <sup>2</sup> CSA	8 fr/cm <sup>2</sup> CSA
2	0.32	0.6	1.3	1.9	2.5
3	0.72	1.4	2.9	4.3	5.7
4	1.27	2.5	5.1	7.6	10.2
5	1.99	4.0	8.0	11.9	15.9
6	2.86	5.7	11.5	17.2	22.9
7	3.90	7.8	15.6	23.4	31.2
8	5.09	10.2	20.4	30.6	40.7
9	6.45	12.9	25.8	38.7	51.6
10	7.96	15.9	31.8	47.7	63.7
11	9.63	19.3	38.5	57.8	77.0
12	11.46	22.9	45.8	68.8	91.7
13	13.45	26.9	53.8	80.7	107.6
14	15.60	31.2	62.4	93.6	124.8
15	17.90	35.8	71.6	107.4	143.2
16	20.37	40.7	81.5	122.2	163.0
17	23.00	46.0	92.0	138.0	184.0
18	25.78	51.6	103.1	154.7	206.3
19	28.73	57.5	114.9	172.4	229.8
20	31.83	63.7	127.3	191.0	254.6
21	35.09	70.2	140.4	210.6	280.7
22	38.52	77.0	154.1	231.1	308.1
23	42.10	84.2	168.4	252.6	336.8
24	45.84	91.7	183.3	275.0	366.7
25	49.74	99.5	198.9	298.4	397.9

## Introduction to the ATP

The Apple Thinning Program (ATP) is an easy-to-use computerised expert system that has been developed for Australian conditions by researchers from the Tasmanian Institute of Agricultural Research (TIAR) and Department of Primary Industry, Water & Environment (DPIWE). The program was originally developed in the mid 1990's based on 15 years of verified research carried out in Tasmania combined with the experiences of many growers. Since its initial development, the program has been updated using information from other apple growing regions throughout Australia.

The Apple Thinning Program (ATP) has combined extensive research with feedback from Australian growers, resulting in a robust model for the determination and application of thinning spays for a range of cultivars. The ATP utilises an aggressive approach with the emphasis on achieving regular crops of optimum sized fruit and avoiding under-thinning which leads to small, poor quality fruit and biennial bearing.

### 8.1 Brief outline of ATP

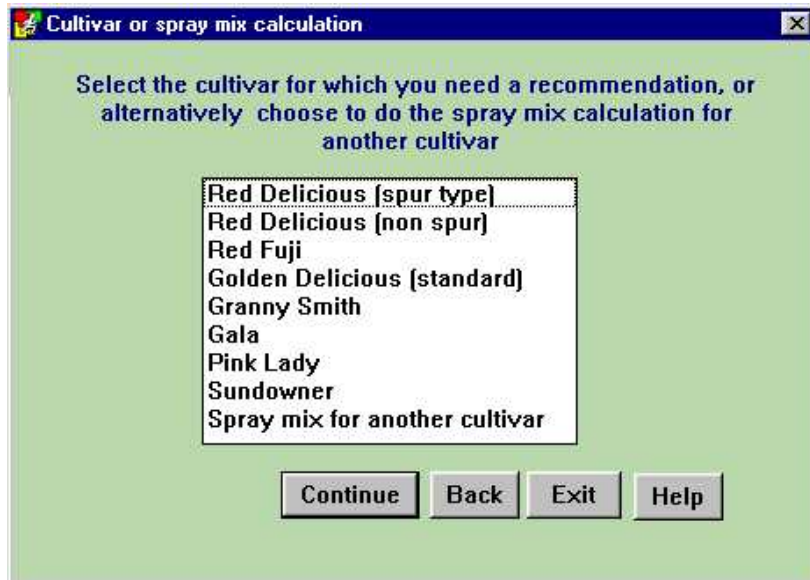


The ATP takes the grower through a series of questions relating to the block to be sprayed before calculating the concentration of chemical to be applied. In situations where thinning is not recommended or where responses to the questions asked indicate problems, the program issues a warning. After working through the program, a printed report can be obtained for each block detailing all the input parameters and the recommended application rate, including the amount of chemical to mix per 100 litres of water.

# Appendix 4

## 8.2 Cultivars

The program covers the more widely planted cultivars in Australia: red Delicious, Golden Delicious, Granny Smith, Fuji, Gala, Pink Lady and Sundowner. It also provides an option for the user to input their own rate and calculate the amount of chemical to place in the spray tank.

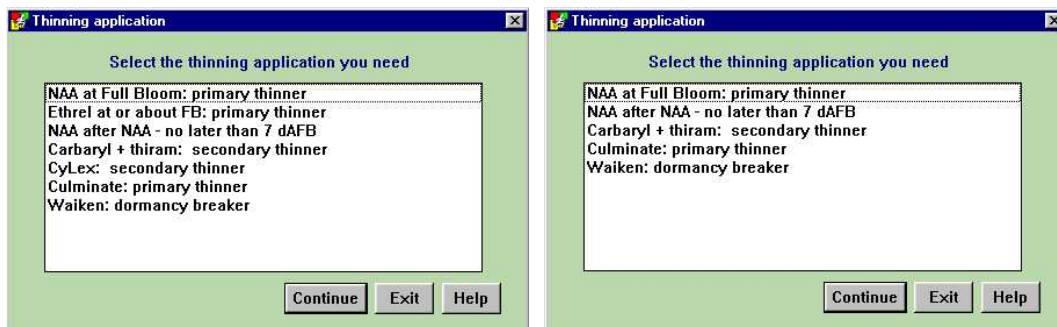


## 8.3 Choice of thinner

Chemical thinning agents included in the program are the primary thinners NAA, Ethrel and Culminate, and the secondary or post-bloom thinners CyLex and Carbaryl / Thiram. Options are also given for a second application of primary thinner. Information on the dormancy breaker Waiken is also included. The choice of chemicals given is dependent on the cultivar selected.

(a) red Delicious

(b) Gala



## 8.4 Further questions

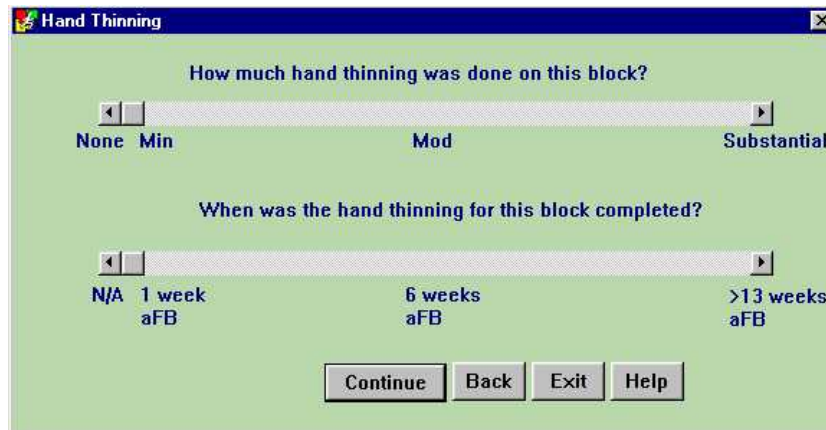
The program then takes the user through a series of questions relating to:

- rootstock and age of the block
- history of exposure to thinning chemicals
- target fruit size
- tree size
- previous crop load

# Appendix 4

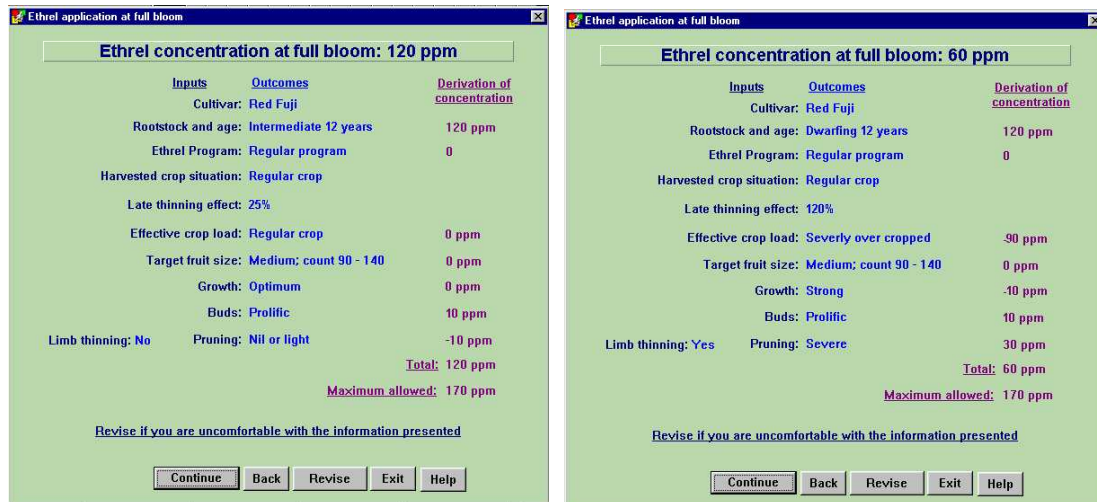
- hand thinning
- tree vigour
- blossom density this season
- level of pruning undertaken and whether the canopy is crowded or light reduced by the use of hail netting.

While most questions require a definitive answer, some such as that relating to hand thinning ask for a graded response.



## 8.5 Recommendations

The recommendation given is based on reconciling the responses to all the questions asked. There is a set of base questions which are used to establish the dosage of the selected bioregulator. This is then modified according to the response to the remaining questions. These derivations are shown on the screen to give the user an appreciation of the importance of the factors involved.



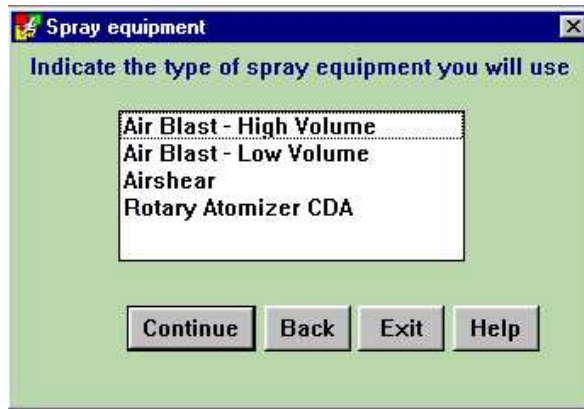
If the recommendation varies from what is expected, the revision chart allows the sequence to be studied in detail and gives the opportunity to revise base levels and modifications by revising responses to questions.



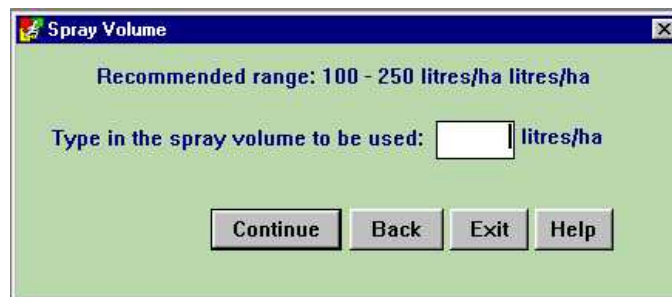
# Appendix 4

## 8.6 Spray equipment

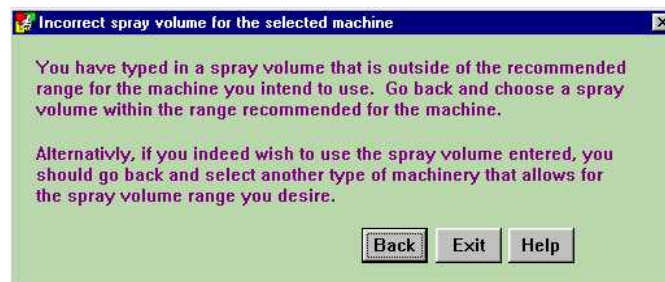
The amount of chemical to be added to the spray tank is also calculated by the program, taking into account the type of spray machinery to be used (high volume air-blast, low volume air-blast, airshear, or CDA rotary atomiser).



Each type of sprayer has an optimal operating volume and this is catered for in the program. The example below is for an air-shear sprayer.

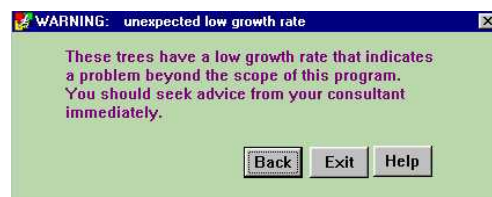
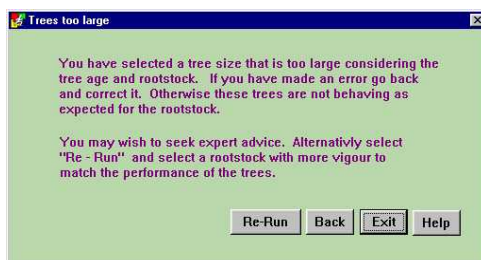


Where an inappropriate spray volume is entered, a warning is given.



## 8.7 Warnings

If responses to questions are at variance with earlier responses, the program will give a warning that the response is inappropriate or that expert assistance is required.



# Appendix 4

## 8.8 Report

A report outlining the responses and the final recommendation can be printed and/or saved. It is recommended that this report be filed along with a record of the final crop numbers, packout and quality of fruit for the block.

**Reports**

### The Apple Thinning Program

**Ethrel at or about full bloom**

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**Block:** v      **Date:** 26/07/2002  
**Cultivar, rootstock, age:** Red Fuji Intermediate rootstock 12 years  
**Ethrel program:** Regular program  
**Late hand thinning:** 25%      **Effective crop load:** Regular crop  
**Growth:** Optimum      **Buds:** Prolific  
**Pruning:** Nil or light      **Limb Thinning:** No  
**Machinery:** Airshear      **Spray volume:** 250 litres/ha

---

**Concentration in ideal conditions (19 deg. C at FB): 120 ppm**

**The effect of Ethrel depends on temperature and the stage of flowering**  
 The effect increases when applied early (up to 6dBBF), and also with warmer temperature.  
 Watch the weather forecast for a suitable fine day to spray. Use the table below to look up the mix equivalent to 120 ppm calculated for forecast maximum temperature and prevailing flowering stage.

**Look-up table of ml Ethrel in 100 litres of water against forecast maximum temperature (C) and prevailing flowering stage. Calculated for Airshear @ 250 litres/ha.**

Flowering stage	Forecast Max temperature (Degrees Celcius)											
	14	15	16	17	18	19	20	21	22	23	24	
<b>Blossom</b>												
<b>30% Open</b>	168	159	150	138	129	120	111	102	90	81	72	
<b>40% Open</b>	210	198	186	174	162	150	138	126	114	102	90	
<b>50% Open</b>	252	237	222	210	195	180	165	150	138	123	108	
<b>60% Open</b>	294	276	261	243	228	210	192	177	159	144	126	
<b>70% Open</b>	336	318	297	279	258	240	222	201	183	162	144	
<b>80% Open</b>	378	357	336	312	291	270	249	228	204	183	162	
<b>Full Bloom</b>	420	396	372	348	324	300	276	252	228	204	180	
<b>1. dAFB</b>	462	435	408	384	357	330	303	276	252	225	198	
<b>2. dAFB</b>	504	474	447	417	390	360	330	303	273	246	216	

**Follow with either Carbaryl+Thiram or CyLex**

Read HELP: "Mixture rate for Ethrel: temperature by flowering stage" Read HELP: "Notes on spray application"

The Apple Thinning Program was developed by the DPIWE Tasmania. New knowledge for the 2000 and 2001 versions was researched by the National Crop Regulation Program supported by Horticulture Australia.

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# Appendix 4

## 8.9 Selecting other options

When selecting other options, such as NAA after NAA, additional questions are asked and it is important to keep a record of the first spray applied and the weather conditions following application.

The image shows two screenshots of a software interface. The left window is titled "Information about the first application of NAA" and contains two text boxes for user input. The first box asks for the maximum temperature on the day of the first application, with options: Cold; 10 - 12 degrees C, Optimum; 13 - 18 degrees C, and Warm; 19 - 24 degrees C. The second box asks how rapidly the spray dried, with options: Quick; less than half an hour, Optimum; half an hour to two hours, and Slow; more than two hours. The right window is titled "Information about conditions on the following 5 days" and contains two text boxes. The first box asks for temperature conditions over the following 5 days, with options: Cold; three days below 13 degrees, Optimum; three days 13 - 18 degrees, and Warm; at least three days above 18 degrees. The second box asks for humidity conditions over the following 5 days, with options: Damp; showers for three days or more, and Dry; at least three days without rain. Both windows have "Continue", "Back", "Exit", and "Help" buttons at the bottom.

## 8.10 Help facility

There is an extensive Help facility which includes notes to assist growers on a range of topics, such as *pollination*, *cold weather and frost at blossom time*, and *windspeed guidelines for spraying*.

# Appendix 4

## Appendix 1: Blossom stages

*Plate 1: Pink bud*



*Plate 2: Balloon blossom*



*Plate 3: King petal*



*Plate 4: Full bloom (10% petal fall)*



*Plate 5: Calyx (100% petal fall)*



*Plate 6: Fruitlets 7-10 days after FB*



# Appendix 4

## Appendix 2: Calculating chemical rates

### High Volume (HV) → Low Volume (LV)

You need to know the following:

1. How many litres/ha you are applying with your existing HV sprayer.
2. How many litres/ha you will be applying with your new nozzle arrangement. (This means you will be relying on output charts for the new nozzles or you will need to field test your sprayer over a known area to determine the amount being applied (l/ha)).
3. Calculate the amount of chemical you are applying per ha at your HV application and this is the amount of chemical you will need added to each LV application rate. eg. If the HV rate is calculated at 2 litres of chemical/ha and the new LV rate is 500 l/ha then 2 litres of chemical is added to every 500 litres of water.

#### EXAMPLE 1

The following example gives the amount of NAA needed to be added to the tank when the volume is reduced from 4,000 l/ha to 250 l/ha. Points 1 and 2 above are already known. Therefore we only need to calculate the amount of chemical being applied in the HV application of 4,000 l/ha.

$$\frac{4,000 \text{ (litres)} \times 10 \text{ (ppm)} \times 0.1}{2^* \text{ (Active Ingredient \%)}} = 2,000 \text{ mls}$$

∴ 2,000 mls of NAA is added to each 250 litres of water. This means that we are still applying the same amount of active ingredient (ai)/ha as we were at the higher volume.

\* We have taken 2% NAA. Remember some NAA is 4%. Always check the label to make sure you are using the correct a.i.% to make the calculation.

#### EXAMPLE II

This example is applying 100 ppm Ethrel when volume is reduced from 3,000 l/ha to 100 l/ha.

$$\frac{3,000 \text{ (litres)} \times 100 \text{ (ppm)} \times 0.1}{48} = 625 \text{ mls}$$

This means that we apply 625 mls to every 100 litres in the tank if we spray at 100 l/ha.

One important point to remember is that the amount of wetter added to the tank does not need to be increased. For example if Tween 20 is used it only needs to be added at the rate of 1 ml/l of spray mixture.

## Appendix 4

A number of growers have used NAA 40 ml / 100L applied at 400 L/ha

⇒ total NAA / ha is 160 ml

Using the formula  $ppm = \frac{\text{amount of chemical (g or mls)} \times \%a.i.}{\text{no. litres} \times 0.1}$

40 ml 2% NAA per 100L is equivalent to 8 ppm

If we want 8 ppm to be applied at any given volume, to work out how much chemical is applied per hectare we can use the formula

$\text{grams or mls of concentrate} = \frac{\text{litres} \times \text{ppm} \times 0.1}{\%a.i.}$

If applying 4,000 L/ha  $\frac{4,000 \times 8 \times 0.1}{2} = 1,600 \text{ ml}$

If applying 2,000 L/ha  $\frac{2,000 \times 8 \times 0.1}{2} = 800 \text{ ml}$

If applying 1,000 L/ha  $\frac{1,000 \times 8 \times 0.1}{2} = 400 \text{ ml}$

If applying 800 L/ha  $\frac{800 \times 8 \times 0.1}{2} = 320 \text{ ml}$

Using the example of 40 ml NAA per 100 L applied at 400 L/ha  
(total NAA / ha is 160 ml)

to calculate ppm we use the formula above

$ppm = \frac{\text{amount of chemical (g or mls)} \times \%a.i.}{\text{no. litres} \times 0.1}$

Hence, at 4,000 L/ha dilute rate  $\frac{160 \times 2}{4,000 \times 0.1} = 0.8 \text{ ppm}$

at 2,000 L/ha  $\frac{160 \times 2}{2,000 \times 0.1} = 1.6 \text{ ppm}$

at 1,000 L/ha  $\frac{160 \times 2}{1,000 \times 0.1} = 3.2 \text{ ppm}$

at 800 L/ha  $\frac{160 \times 2}{800 \times 0.1} = 4 \text{ ppm}$

# Appendix 4

## Appendix 3: Calculation of ppm

The following two simple formulae can be used to:

- (i) calculate the concentration (ppm), if the amount of chemical in the spray mix is known,  
or
- (ii) calculate the amount of chemical to place in the spray tank if the concentration in ppm is known

### **FORMULA 1 - calculating concentration (ppm)**

$$\text{Concentration (ppm)} = \frac{\text{Amount of chemical (g or mls)} \times \% \text{ active ingredient (a.i.)}}{\text{no. of litres water} \times 0.1}$$

For this calculation you need to know:

1. the amount of chemical placed in the tank
2. the amount of water
3. the % active ingredient of the chemical

### **FORMULA 2 - calculating amount of chemical**

$$\text{grams or mls of concentrate} = \frac{\text{Concentration (ppm)} \times \text{no. of litres} \times 0.1}{\% \text{ active ingredient (a.i.)}}$$

For this calculation you need to know:

1. the concentration (ppm) of the chemical
2. the amount of water
3. the % active ingredient of the chemical

The amount of **active ingredient** (a.i.) of the chemical is listed on the label, however it is shown as g/kg or g/L, not as a percentage. To calculate the percentage a.i., multiply the g x 0.1

$$\text{eg Ethrel 480 g/L: } \% \text{ a.i.} = 480 \times 0.1 = 48\%$$

The following table gives percent a.i. for common thinning bioregulators & dormancy breakers

Ethrel	480 g/L	ethephon	48% a.i.
NAA	20 g/L	NAA	2% a.i.
NAA	40 g/L	NAA	4% a.i.
Bugmaster	800 g/L	carbaryl	80% a.i.
Culminate	782 g/L	ammonium thiosulphate (ATS)	78.2% a.i.
CyLex	20 g/L	6-benzyladenine (BA)	2% a.i.
Waiken	388 g/L	octadecenoic acid methyl ester	38.8%

**Example 1:** To calculate the ppm of Ethrel when 41.67 mls has been added to 100 L of water:

$$\text{Concentration (ppm)} = \frac{41.67 \times 48}{100 \times 0.1} = 200$$

**Example 2:** To calculate the amount of Ethrel required for 200 ppm in 100 L of water:

$$\text{mls of concentrate} = \frac{200 \times 100 \times 0.1}{48} = 41.67$$

Use of these two simple calculations means that all spray applications can be brought back to a standard base line of concentration (ppm) rather than amounts of chemical per spray vat or 100L

## Appendix 4

### Appendix 4: Thinning spray dilutions (Ethrel & NAA)

Ethrel (48% a.I.)		NAA (2% a.i.)		NAA (4% a.i.)	
ppm	ml required per 100 litres water	ppm	ml required per 100 litres water	ppm	ml required per 100 litres water
20	4.2	2	10	2	5
25	5.2	3	15	3	7.5
30	6.3	4	20	4	10
35	7.3	5	25	5	12.5
40	8.3	6	30	6	15
50	10.4	7	35	7	17.5
60	12.5	7.5	37.5	7.5	18.8
70	14.6	8	40	8	20
80	16.7	9	45	9	22.5
90	18.8	10	50	10	25
100	20.8	11	55	11	27.5
120	25	12	60	12	30
125	26	12.5	62.5	12.5	31.3
150	31.3	13	65	13	32.5
175	36.5	14	70	14	35
200	41.7	15	75	15	37.5
250	52.1	16	80	16	40
300	62.5	17	85	17	42.5