FINAL PROJECT REPORT (2002-2004)

PROJECT TITLE: Chemical alternatives for cost-effective apple crop load management

PI: Jim McFerson, WTFRC
Washington Tree Fruit Research Commission
1719 Springwater Ave, Wenatchee WA 98801
ph: 509-665-8271; email: mcferson@treefruitresearch.com

CO-INVESTIGATORS: Tom Auvil, Felipe Castillo, Tory Schmidt, WTFRC

OBJECTIVES:

- Evaluate pre-bloom, bloom, and post-bloom chemical thinning agents with particular focus on complete programs to achieve three goals:
    1. Minimize costs of green fruitlet thinning
    2. Maximize fruit quality
    3. Encourage annual bearing
- Improve understanding of mechanisms and physiology of thinning agents utilizing whole and partial canopy photosynthetic analysis
- Analyze financial impacts of thinning programs using commercial warehouse packouts for large trials
- Utilize greenhouse crabapple program as model system for material screening and physiological work
- Expand collaborative efforts with other research programs

SIGNIFICANT FINDINGS 2002-2004:
Chemical bloom thinning programs greatly enhance successful crop load management

Effective bloom thinning programs usually reduce hand-thinning and frequently improve fruit size, quality, and return bloom to levels of statistical significance

Comprehensive review of 120 bloom thinning trials reveals spray oil + lime sulfur tank mixes are most efficacious programs

Many spray oils (dormant, summer, vegetable, fish) are effective in combination with lime sulfur; Crocker's Fish Oil programs were successful most often

Lime sulfur may be used alone at higher rates to produce results intermediate between oil + lime sulfur and ATS

ATS and NC99 programs can reduce fruit set and improve harvest fruit size, but rarely improve return bloom and are thus generally inferior to lime sulfur programs

Regardless of timing, rate, number or method of application, no bloom thinning treatment consistently improved or damaged fruit finish vs. an untreated control

Lime sulfur bloom thinning sprays helped suppress powdery mildew (see Xiao report)

Whole and partial canopy photosynthesis analyses revealed transient depression of carbon assimilation in trees treated with lime sulfur thinning programs (see Whiting report)

Based on large-scale trials with packout information, effective bloom thinning programs are beneficial horticulturally and economically, even when thinning effects appear modest

Greenhouse crabapple studies provide reasonable model systems for winter material screening and physiological work, but cannot reliably predict thinning responses in commercial orchards

Acquisition of a third-party label by Pest Management Northwest for Rex Lime Sulfur (Orcal) now allows growers to legally apply a range of successful chemical bloom thinning programs, including organic systems

Postbloom chemical thinners (carbaryl, NAA, NAD, ethephon, BA) can reduce crop load, but generally have greater impact on fruit size, quality, and return bloom when "set up" by effective blossom chemical thinners

Pure BA formulations increase thinning when tank mixed with carbaryl, but generally do not provide adequate thinning as stand-alone products

Initial attempts at collaboration involved a range of scientists (see Table 8)

Future progress requires more intensive collaborative efforts across disciplines, institutions, and regions

BLOOM THINNING:

<u>Trial background:</u>

The internal research program of the WTFRC conducted 22 apple chemical thinning trials in 2004 at eleven commercial orchard sites around the state of Washington, bringing the total number of trials to approximately 100 for the three year duration of this project, and more than 150 since 1998. Our data reflect results from replicated experiments in all important growing districts in the state on eleven cultivars and ten rootstocks.

Our protocols generally call for two applications of each bloom thinning programs, at 20% and 80% full bloom. In previous seasons, Vegetable Oil Emulsion (VOE) was sprayed at first bloom and 80% bloom, but earlier timing studies suggested little benefit to spraying early, so in 2004, VOE was applied at the same timings as other programs for the sake of convenience. Roughly half of our trials were applied by grower-cooperators with their own equipment (typically airblast sprayers), while the other half was applied by WTFRC staff with our PropTec research sprayer. Our standard programs are reflected in Table 1; in programs which show a range of possible rates, higher concentrations are typically reserved for cultivars known to be difficult to thin, such as Fuji and Golden Delicious. In most cases, postbloom chemical thinning programs were left to the discretion of individual growers-cooperators as long as all experimental plots received the same treatments.

Table 1. Chemical thinning programs evaluated. WTFRC 2004.

3.4 gal Ammonium thiosulfate (ATS)/A
5 gal NC99/A
6-8% Lime sulfur (LS)
1-3% Crocker's Fish Oil (CFO) + 2-4% LS
1% JMS Stylet Oil (JMS) + 2-3% LS
0.5% Wilbur-Ellis Supreme Oil (WES) + 2-3% LS

3-4% Orcal Freedom Oil (OFO) + 2-3% LS
2-4% Tetrasul
1.75-2.5 pts Tergitol/A
8-10% Vegetable Oil Emulsion (VOE)

Chemical thinning goals

We have identified three measurable targets which are directly tied to a grower's economic bottom line:

1. Reduction of green fruitlet hand-thinning
2. Improved fruit size and quality
3. Increased return bloom / annual bearing

The degrees to which our chemical thinning programs achieve each of these goals are reflected in our data labeled fruitlets/100 floral clusters, harvest fruit size, and percent return bloom, respectively. These three parameters are shown in Tables 2 and 3, reporting 2003 trial work, and further highlighted in Table 6, which summarizes our trial results over the past several years.

Table 2. Thinning efficacy of bloom thinning programs applied by grower-cooperators. WTFRC 2003.

Trial	Thinning program	Fruitlets/100 floral clusters	Blanked spurs	Harvest fruit diam	Return bloom 2004
			%	in	%
Granny Smith	CFO+LS 2x	64 ns	51 ns	2.96 ns	121 ns
Brewster	Control	67	46	2.96	67
Braeburn	CFO+LS 2x	18 c	82 a	3.01 ns	169 a
Brewster	WES+LS 2x	34 b	68 b	3.05	101 ab
	ATS 2x	50 a	54 c	3.05	86 b
	Control	52 a	53 c	3.01	112 ab
Golden Delicious	CFO+LS 2x	57 b	57 a	3.08 a	6 ns
George	WES+LS 2x	97 a	34 b	2.94 c	28
	LS 2x	95 a	33 b	3.03 b	11
	NC99 2x	61 b	53 a	3.03 b	9
	Control	101 a	33 b	2.98 c	20
Golden Delicious	CFO+LS 3x	40 d	68 a	2.99 a	1 ns
George	WES+LS 3x	77 b	46 c	2.97 a	9
	LS 3x	66 bc	50 bc	2.94 ab	15
	NC99 2x	50 cd	60 ab	2.98 a	26
	Control	106 a	30 d	2.90 b	21
Fuji	CFO+LS 2x	84 b	42 a	3.18 ns	12 ns
Royal City	LS 2x	77 b	39 a	3.23	0
	NC99 2x	80 b	41 a	3.18	0
	Control	101 a	31 b	3.15	2

Table 3. Thinning efficacy of bloom thinning programs applied by WTFRC staff with PropTec tower sprayer in cooperator orchards. WTFRC 2003.

Trial	Treatment (2 apps)	Fruitlets/100 floral clusters	Blanked spurs	Harvest fruit diam	Return bloom 2004
			%	in	%
Gala	NC99 2x	70 b	49 cd	2.85 cd	98 ab
Chelan	VOE 2x	50 c	62 ab	2.97 a	108 ab
	1 VOE, then 1 NC99	63 bc	62 ab	2.91 b	149 a
	Best LS	46 c	67 a	2.83 cd	84 ab
	Rex LS	58 bc	56 bc	2.86 bc	89 ab
	CFO+Best LS	55 bc	57 abc	2.87 bc	92 ab
	CFO+Rex LS	46 c	65 ab	2.86 bc	80 b
	WES+ Rex LS	54 bc	60 abc	2.85 cd	99 ab
	JMS + Rex LS	62 bc	54 bc	2.87 bc	104 ab
	Control	94 a	41 d	2.81 d	117 ab
Pacific Rose	ATS	69 ab	37 e	2.97 ns	27 ab
Brewster	Sil+ATS	63 bc	48 abc	2.92	20 ab
	Reg+ATS	53 c	52 a	2.96	34 ab
	LS	66 abc	46 abcd	2.96	23 ab
	Sil+LS	79 a	40 cde	2.98	35 ab
	Exit+LS	78 a	39 de	2.94	0 b
	CFO+LS	73 ab	40 cde	2.96	17 ab
	WES+LS	55 c	52 ab	3.01	34 ab
	VOE	53 c	53 a	2.99	58 a
	Control	76 ab	44 bcde	2.99	12 ab
Pink Lady	ATS	64 ab	55 ab	2.84 bc	88 ns
E Wenatchee	Sil+ATS	46 cd	62 a	2.91 a	102
	Reg+ATS	46 bcd	62 a	2.89 ab	94
	LS	65 a	47 b	2.85 bc	95
	Sil+LS	57 abcd	56 ab	2.81 c	111
	Exit+LS	56 abcd	58 ab	2.85 bc	107
	CFO+LS	62 abc	55 ab	2.82 c	137
	WES+LS	40 d	68 a	2.85 bc	111
	VOE	42 d	66 a	2.88 ab	89
	Control	58 abcd	61 a	2.85 bc	88

<u>2004 trials</u>

As in previous years, trial results from 2004 have confirmed that bloom thinning programs based on lime sulfur are effective in terms of reducing fruit set (Table 4). This reduction in crop load, however, did not translate into improved harvest fruit size at most trial sites, perhaps because many Washington orchards enjoyed above-normal fruit size due in part to relatively poor fruit set (note the high rates of blanked spurs for control treatments in Table 4). While ATS is a popular commercial option for Washington growers, its performance in our trials remains inferior to those of lime sulfur programs, and even more so to oil + lime sulfur programs. Return bloom data will be collected for all trials in the spring of 2005.

Table 4 also showcases results from a Gala trial in Othello in which we tried several novel bloom thinning materials. While the practicality of commercial use of some of these products is questionable, the results have largely been positive, and we are particularly interested in gaining more experience with the new vegetable-based spray oil (OFO) from Orcal. Several of these programs were tested in our greenhouse crabapple screening trials before application in commercial settings.

Table 4. Efficacy of bloom thinning programs. WTFRC 2004.

Trial	Thinning program	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest box size
			%	%	
Gala / Bud.9	1% CFO + 4% LS	56 b	63 a	24 ab	100 ns
Chelan	2% CFO + 2% LS	58 b	62 a	22 ab	103
	2% CFO + 3% LS	58 b	62 a	22 ab	104
	0.5% WES + 3% LS	62 b	56 ab	31 a	100
	1% WES + 2% LS	69 b	56 ab	24 ab	108
	6% lime sulfur	71 b	52 ab	28 ab	98
	8% lime sulfur	62 b	57 ab	28 ab	99
	NC99	67 b	56 ab	26 ab	105
	JMS + LS	81 b	51 ab	22 ab	102
	Control	114 a	42 b	18 b	105
Fuji / M.26	ATS	41 abcd	67 bcd	26 a	70 ns
Quincy	CFO + LS	37 bcd	73 abcd	20 ab	75
	WES + LS	26 cd	80 abc	15 ab	70
	OFO + LS	21 d	82 ab	14 ab	73
	Lime sulfur	27 cd	79 abc	16 ab	76
	Tetrasul	12 d	89 a	9 b	80
	VOE	29 bcd	76 abc	19 ab	69
	2 pts Tergitol	58 ab	62 cd	23 a	77
	2.5 pts Tergitol	54 abc	62 cd	21 ab	78
	Control	67 a	57 d	26 a	77
Gala / M.26	CFO + LS	41 abcd	62 bcd	34 ab	108 ns
Othello	5% OFO (no LS)	19 d	83 a	16 c	98
	4% Tetrasul	35 bcd	67 abc	31 abc	103
	2 pts Tergitol	43 abc	59 bcd	39 ab	102
	Kaligreen	52 ab	50 cd	47 a	105
	Molasses	49 abc	56 cd	40 ab	104
	Vinegar	49 abc	54 cd	43 a	103
	Vinegar + VOE	26 cd	75 ab	23 bc	104
	VOE	39 bcd	64 abcd	33 abc	106
	Control	62 a	45 d	48 a	114

<u>Fruit finish</u>

While some have adopted a number of the thinning programs we have evaluated, many growers express concern over fruit finish issues. We continue to carefully evaluate fruit sampled from every trial for russet on fruit flanks, shoulders, and in stem bowls. Despite rigorous application of conservative grading standards (e.g. all fruit with any visible russet is graded as "russeted," regardless of degree) we have been unable to discern that any of our treatments have had a consistent effect, positive or negative, on fruit finish. We have observed isolated cases of fruit marking in sprayer blast zones, which may offer some new research directions. At any rate, attention to fruit finish will continue to be a high priority in our programs.

The “Big Picture”

One enduring hallmark of crop load management research on any tree fruit is the considerable variation in results. We aspire consistently achieve results like those from our 2003 Honeycrisp trial in Wiley City (Table 5).

Table 5. Thinning efficacy, fruit quality, and return bloom as affected by three bloom thinning programs. Honeycrisp/M9 Wiley City WA 2003.

Treatment	Fruitlets/ 100 blossom clusters	% blossom clusters blanked	Harvest fruit diam (cm)	Relative box size	Soluble solids (% Brix)	% titratable acids	% fruit russeted	% return bloom 2004
CFO + LS	71 b	51 a	7.93 a	84	13.8 a	0.56 a	73 ns	52 a
LS	74 b	53 a	7.77 b	88	13.6 a	0.54 a	60	40 a
ATS	100 a	42 b	7.71 bc	90	12.8 b	0.49 b	73	12 b
Control	107 a	44 b	7.57 c	95	12.8 b	0.47 b	56	9 b

While this trial provided very positive results, they cannot be considered typical of data through the years. As with any type of research, we feel it is important to examine an entire body of work, rather than “selected results.” Table 6 summarizes results from all apple bloom thinning trials conducted by the WTFRC since 1999, reflecting a very conservative standard by which to assess our most frequently studied programs.

Table 6. Incidence and percentage of results significantly superior (p=.05) to untreated control. Apple chemical bloom thinning trials WTFRC 1999-2004.

Treatment	Fruitlets/100 blossom clusters	Harvested fruit diam	Return bloom[1,2]
Ammonium thiosulfate	13 / 41 (32%)	9 / 44 (20%)	2 / 33 (6%)
NC99 (Mg^{++}/Ca^{++} Cl^{-} brine)	14 / 26 (54%)	7 / 28 (25%)	2 / 22 (9%)
Lime sulfur	25 / 48 (52%)	12 / 42 (29%)	9 / 36 (25%)
Crocker's Fish Oil + lime sulfur	50 / 68 (74%)	24 / 63 (38%)	12 / 45 (27%)
JMS Stylet Oil + lime sulfur	14 / 23 (61%)	8 / 22 (36%)	4 / 20 (20%)
Wilbur-Ellis Supreme Oil + lime sulfur	14 / 22 (64%)	4 / 21 (19%)	3 / 16 (19%)
Vegetable Oil Emulsion	13 / 18 (72%)	4 / 17 (24%)	2 / 15 (13%)

[1]Does not include data from 2004 trials.

[2] (no. blossom clusters year 2/sample area) / (no. blossom clusters year 1/sample area)

This “big picture” view of more than 100 trials shows clearly that oil and lime sulfur tank mixes have yielded positive results more consistently than have desiccating salts such as ATS or NC99, especially with respect to return bloom. It is worth noting that this table reflects only statistically significant results and we observe positive trends for all of these programs much more frequently than these numbers suggest. While the benefits of these chemical thinning programs are self-evident, future research should seek to increase their consistency and predictability, as well as better understanding their influence on postbloom chemical thinning programs.

Economic analysis

In 2003, we convinced a Columbia Basin grower and his packinghouse to allow us to segregate fruit from a bloom thinning trial with four replicates of four treatments on a plot-by-plot basis and to pack each of these 16 field plots as separate lots. The grower generously shared with us his expenses for each of these plots, as well as packout and economic return information. From these data, we were able to conduct thorough economic analysis of this trial (Table 7).

Table 7. Horticultural and economic impacts of chemical bloom thinning of Fuji / MM.106. WTFRC 2003.

	Fruitlets / 100 blossom clusters	Yield / tree	Mean box size	Return bloom 2004	Fruit packed	Gross grower return / tree	Net return / tree vs. control
		pounds		%	%	US $	US $
CFO + LS	84 b	84.5 ns	80 ns	12 ns	83 ns	41.22	+ 1.69
Lime sulfur	77 b	87.0	77	0	76	42.80	+ 3.19
NC99	80 b	80.7	80	0	77	38.19	- 1.20
Control	101 a	84.5	82	2	73	39.28	na

While moderate thinning did not translate into larger fruit size at harvest, fruit quality, as demonstrated by percentage of fruit packed, was generally superior to control in all treatments. When factoring in all crop load related costs (chemicals, sprayer, hand-thinning), this grower enjoyed increased returns of approximately $600/acre and $1100/acre for bloom thinning with CFO + LS and lime sulfur, respectively. Financial returns for NC99 were hurt by a notable loss in yield.

This trial was successful in achieving the first goal of chemical thinning (reduced hand-thinning), but had mixed results with the second goal (improved packout and fruit size) and third goal (improved return bloom). This particular block was in severe alternation due to a major frost during bloom in 2002 which dropped the entire crop, causing the return bloom figures in 2004 to be less than impressive. However, the increased bloom in 2004 for CFO +LS should not be taken lightly, as the grower will likely benefit horticulturally and financially for years to come by reducing the severity of alternation in these plots.

Collaborative research

Cooperative work between the WTFRC and other researchers has accelerated our understanding of many diverse aspects of apple crop load management (Table 8). Early success of these collaborations underscores the need to expand them in future studies.

Table 8. Highlights of WTFRC collaborative research on apple chemical thinning 2002-2004.

Scientist	**Institution**	**Focus Area**
Brunner/Doerr	WSU	Bloom thinner (lime sulfur) effects on mite populations
Byers	Virginia Tech	Novel bloom thinners, pollen tube development
Greene	Univ Mass	Predictive modeling of fruit set
Elfving	WSU	PGR effects on vegetative/reproductive site balance
Fallahi	Univ Idaho	Tergitol as a bloom thinner
Horn/Baker	Orcal Inc	New sulfur products, LS label registration support
Lakso/Goffinet	Cornell	Carbohydrate modeling in fruit set and development
McArtney	NC State	Mid-summer PGRs to promote return bloom
Rom	Univ Arkansas	Organic chemical thinning programs, pollen germination
Schreiber	Pest Mgmt NW	Chemical bloom thinning label for lime sulfur programs
Schupp	Cornell/Penn St	Efficacious use of oil + lime sulfur programs
Xiao	WSU	Bloom thinner (lime sulfur) effects on powdery mildew
Whiting/Lombardini	WSU	Physiological effects of bloom thinners (whole canopy Pn)

POSTBLOOM THINNING:

As regulatory pressure mounts on carbaryl, the industry standard for postbloom chemical thinning, the search for new alternative materials becomes increasingly urgent. The primary new development in recent years for postbloom chemical thinning has been the market introduction of high-concentration benzyladenine (BA) products, such as MaxCel (Valent) and Exilis (Fine Agrochemical). These products have been formulated to virtually eliminate residues of gibberellic acids (GA) that were present in older BA formulations such as Accel (Valent). Previous research has shown BA to have modest thinning effects and capacity to increase fruit size above and beyond the expected effect from crop load reduction.

Our main focus in postbloom thinning has been to evaluate BA products against or in combination with standard materials such as carbaryl and NAA. Table 9 demonstrates that most of our trials have suggested that BA might be an adequate thinning replacement for NAA when tank-mixed with carbaryl, but that effect is not always consistent (Brewster Granny Smith). We sometimes observe that carbaryl + BA programs yield larger fruit at harvest than do carbaryl + NAA programs (Azwell Gala), but not nearly with the consistency we would prefer. As with our bloom thinning work, we suspect that potential fruit sizing benefits of these programs were somewhat muted by a statewide trend for large fruit in 2004.

Table 9. Efficacy of postbloom thinning programs. WTFRC 2004.

Trial	Thinning program	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit diam
			%	%	cm
Gala / M.9	Sevin + NAA + Regulaid	41 a	61 b	37 a	7.35 a
Othello	Sevin + NAA + CFO	34 ab	68 ab	31 ab	7.23 ab
	Sevin + 3pts Exilis + Reg	38 ab	64 ab	34 ab	7.26 ab
	Sevin + 4pts Exilis + Reg	33 b	71 a	28 b	7.28 ab
	Control	40 a	65 ab	30 ab	7.14 b
Gala / M.9	Sevin + NAA + Regulaid	40 b	65 ns	29 ns	6.92 ab
Azwell	Sevin + NAA + oil	46 ab	64	26	7.02 ab
	Sevin + 3pts Exilis + Reg	40 b	68	25	7.09 a
	Sevin + 4pts Exilis + Reg	38 b	67	28	7.08 a
	Control	53 a	64	30	6.86 b
Pink Lady / M.7	Genesis BA	54 b	62 b	24 ns	7.72 bc
Mattawa	Exilis	60 b	59 bc	27	8.03 ab
	MaxCel	64 ab	54 bc	31	7.73 bc
	Sevin + Exilis	25 c	77 a	21	8.20 a
	Control	85 a	48 c	28	7.65 c
Fuji / M.26	Sevin + NAA + Ethrel	113 a	27 ns	45 b	7.16 b
Wiley City	Sevin + Exilis	93 b	27	55 a	7.56 a
	Sevin + MaxCel	89 b	28	58 a	7.14 b
Gala / B.118	Sevin + NAA + Regulaid	27 a	74 b	24 a	6.95 a
Brewster	Sevin + MaxCel	21 b	81 a	18 b	6.80 b

Golden Del / sdlg	Sevin + NAA + Regulaid	55 a	50 b	46 a	7.45 ns
Brewster	Sevin + MaxCel	41 b	61 a	36 b	7.60
Granny Smith / M.26	Sevin + NAA + Regulaid	47 b	61 a	31 b	no data
Brewster	Sevin + MaxCel	58 a	52 b	37 a	no data

While they do not appear at this point to be effective replacements for carbaryl as a postbloom thinner, BA products offer interesting possibilities for crop load management. Although they are relatively expensive, we hope that new marketplace competitors will drive down the cost of all products.

We have been very fortunate to work with many of the best growers and consultants in the state for the last several years and greatly appreciate their generosity, support, and friendship.

Project Title: Chemical Alternatives for Cost-Effective Apple Crop Load Management
PI: Jim McFerson
3 year project total: $68,000

Item	2002	2003	2004
Salary			
Benefits			
Timeslip	16,000	16,000	8,000[2]
Benefits (~16%)	2,500	2,500	1,250
Supplies	8,500[1]	8,500[1]	4000[1]
Travel	250	250	250
Total	27,250	27,250	13,500

Funded through internal program budget
[1] Chemicals, fruit purchase
[2] Castillo's wages were covered by internal program salary budget