FINAL PROJECT REPORT **YEAR**: 3 of 3
WTFRC Project Number: na

Project Title: Chemical thinning of apple

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Budget 1:
Organization Name: WTFRC **Contract Administrator:** Kathy Schmidt
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Item	**Year 1:** 2005	**Year 2:** 2006	**Year 3:** 2007
Salaries			
Benefits			
Wages	30,000	30,000	30,000
Benefits (16%)	4,800	4,800	4,800
Equipment			
Supplies	3,000[1]	3,000[1]	3,000[1]
Travel	500	500	500
Miscellaneous			
Total	**38,300**	**38,300**	**38,300**

Footnotes: [1] Chemicals, fruit purchase
NOTE: Budget for informational purposes only; research is funded through WTFRC internal program

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
- Investigate influence of important variables (drying conditions, spray technology, carrier volume) on chemical thinner efficacy and fruit finish
- Expand collaborative efforts with other research programs

SIGNIFICANT FINDINGS:

Effective chemical thinning programs reduce hand-thinning, improve fruit size and quality, and increase return bloom; bloom thinners generally achieve these goals more consistently than postbloom programs (Tables 3, 7)

Fruit size and return bloom are often improved by chemical thinners, even when fruit set is not significantly reduced (Tables 3, 7)

Oil (dormant, summer, vegetable, fish) + lime sulfur programs are the most efficacious options for bloom thinning; results with Crocker's Fish Oil are most consistent (Table 3)

Thinning programs using high rates of lime sulfur or oil + lime sulfur are gaining industry acceptance and generally superior to ATS programs (Table 3)

Novel bloom thinning programs including Raynox, vinegar + oil, urea, Pacific Natural fish emulsion + lime sulfur, NAA, ethephon, and Tergitol have been largely ineffective in WTFRC trials (data not shown)

Thinning efficacy and fruit finish were not clearly affected by variations in spray technology (AccuTech vs. Proptec vs. airblast), carrier volume (100 vs. 200 gal/acre), or drying conditions (dawn vs. noon vs. dusk sprays) of chemical thinning programs in WTFRC trials (Tables 4, 5); trials will be repeated in 2008

All formulations of BA (MaxCel, Exilis Plus, Riteway, Genesis) perform equally well for postbloom thinning and fruit sizing (data not shown)

BA + carbaryl thinning programs give results equal or superior to NAA + carbaryl or ethephon + carbaryl programs; BA often shows a positive effect on fruit size (Tables 6-9)

Additive effects of bloom thinning + postbloom thinning increase chances for successful crop load management (Tables 8, 9)

Factorial field trials indicate that chemical thinning (bloom and postbloom) and PGR (BA or BA+GA) programs are not affected by the presence/absence of Extenday throughout the growing season, including at time of application; trials should be repeated to corroborate initial results (data not shown)

Screening of new thinning chemistries (organic acids, essential plant oils) supplied by Rom program (U of Arkansas) has yielded few positive results, but salicylic acid and clove oil warrant further investigation (data not shown)

Summer applications of NAA have not increased return bloom in WTFRC trials; summer applications of ethephon have sporadically yielded positive results (data not shown)

Earlier work (Schmidt, Elfving) suggests use of gibberellins in "off" years may help mitigate biennial bearing; field trials will be evaluated in spring of 2008

Collaborative efforts across disciplines, institutions, and regions (Greene, McArtney, Hirst, Schupp, Yoder, Rom, Fallahi, Sugar, van Nocker, Whiting, Elfving, Schrader, Beers, Xiao, Lewis, Toye) have increased relevance and impact of all crop load management research

BACKGROUND:

The internal research program of the WTFRC conducted 19 apple chemical thinning trials in commercial orchards around the state of Washington in 2005, 18 more in 2006, and another 15 in this past season. Results from these trials add to our already sizable body of chemical thinning data, drawing from approximately 200 field trials since 1998 on eleven cultivars and ten rootstocks representing all important growing districts in the state. The downward trend in trial number reflects a shift in focus in our program away from screening of various chemical thinners toward more intricate trials focused on questions about comprehensive crop load management, plant physiology, and variability in treatment response. Three 2007 trials were applied by grower-cooperators, with the balance being applied by WTFRC staff using the Proptec research sprayer; historically, roughly half of our trials have been applied by grower-cooperators with their own equipment.

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.

Our protocols generally call for two applications of each bloom thinning program, at 20% and 80% full bloom. Likewise, most postbloom thinning programs are applied twice, typically at 5mm and 10mm fruitlet size. Programs investigated over the course of this project 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, additional chemical thinning programs were left to the discretion of individual grower-cooperators as long as all experimental plots received the same treatments.

Table 1. Typical chemical thinning programs evaluated. WTFRC 2005-2007.

BLOOM THINNERS
3.4 – 4 gal Ammonium thiosulfate (ATS)/A
5 gal NC99/A
6-8% Lime sulfur (LS)
2% Crocker's Fish Oil (CFO) + 2-4% LS
2% Pacific Natural Fish Emulsion + 2.5% LS
1% Wilbur-Ellis Supreme Oil (WES) + 3% LS
5% Canola, Corn, or Soybean Oil Emulsion
2% Canola, Corn, or Soybean Oil Emulsion + 2% LS
10% Vegetable Oil Emulsion (VOE)
17% VOE + 17% Vinegar
15% GS Long thinner (unnamed)
40 lbs Urea/A
2 pts Tergitol/A
20% Raynox
3 pts Ethrel (ethephon)/A
3 oz NAA/A
POSTBLOOM THINNERS
1.5-3 qts Sevin (carbaryl)/A
3 qts MaxCel, Exilis, Genesis BA (BA)/A
1-3 pts Ethrel (ethephon)/A
3 oz NAA/A
2 oz Amid Thin (NAD)/A

BLOOM THINNING:

While chemical bloom thinning was the primary focus of the WTFRC internal program crop load management research program several years ago, its prominence in our research portfolio has begun to decline, due in part to our success in establishing effective lime sulfur-based programs which are gaining widespread use in commercial operations. Our work with bloom thinners is now increasingly geared toward increasing their predictability, supporting research to explore their molecular and physiological effects, and understanding their role in comprehensive crop load management programs. We continue to screen new chemistries which may offer alternatives to currently available options (Table 1); unfortunately, none of the materials currently under evaluation have demonstrated enough thinning efficacy, practicality, and commercial viability to merit beta testing on a larger scale.

In 2007, we did have encouraging results from both clove oil and salicylic acid in cooperative trials with Curt Rom and Jason McAfee (U of Arkansas), who are working to identify novel chemistries (primarily plant oils and organic acids) which may act as pollenicides to achieving fruit thinning. We plan to continue this collaboration in 2008 to confirm these results. Additionally, we have achieved modest success in thinning with vegetable oil emulsions tank mixed with lime sulfur (Table 2). While these programs have not been as effective as other options, they are potentially important to both conventional and organic growers if fish- and petroleum-based oils become more scarce and expensive.

Table 2. Crop load effects of bloom thinning programs. WTFRC 2006.

Trial	Thinning program	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit weight	2007 return bloom
			%	%	g	%
Gala / Bud.9	Lime sulfur	75 ab	56 ns	22 ns	182 ns	160 ab
- Chelan	CFO + LS	69 b	60	20	185	166 a
	Canola oil emulsion	85 ab	53	20	179	75 c
	Canola oil emulsion + LS	90 ab	51	22	179	121 abc
	Corn oil emulsion	72 ab	58	20	187	91 bc
	Corn oil emulsion + LS	80 ab	56	20	178	109 abc
	Soybean oil emulsion	85 ab	54	19	183	109 abc
	Soybean oil emulsion + LS	80 ab	55	21	176	134 abc
	NC99	68 b	62	18	189	113 abc
	Control	97 a	51	19	176	114 abc

No thinning program we have evaluated yet outperforms oil + lime sulfur combinations. Table 3 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 3. Incidence and percentage of results significantly superior to untreated control. Apple chemical bloom thinning trials WTFRC 1999-2007.

Treatment	Fruitlets/100 blossom clusters	Harvested fruit size	Return bloom[1,2]
Ammonium thiosulfate	15 / 55 (27%)	10 / 58 (17%)	3 / 46 (7%)
NC99 (Mg^{++}/Ca^{++} Cl^- brine)	15 / 30 (50%)	7 / 32 (22%)	2 / 26 (8%)
Lime sulfur	25 / 54 (46%)	12 / 48 (25%)	9 / 45 (20%)
Crocker's Fish Oil + lime sulfur	57 / 96 (59%)	25 / 88 (28%)	19 / 78 (24%)
JMS Stylet Oil + lime sulfur	14 / 24 (58%)	8 / 23 (35%)	4 / 22 (18%)
Wilbur-Ellis Supreme Oil + lime sulfur	14 / 27 (52%)	4 / 26 (15%)	4 / 26 (15%)
Vegetable Oil Emulsion	13 / 29 (45%)	4 / 28 (14%)	2 / 29 (7%)

[1]Does not include data from 2007 trials.

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

VARIABLES AFFECTING THINNING EFFICACY AND FRUIT FINISH:

While our results have clearly demonstrated the efficacy of several chemical thinning programs, we seek to improve their consistency and predictability. We have conducted a series of trials to investigate the effects of drying conditions, spray technology, and application carrier volume on efficacy of proven chemical bloom and postbloom thinning programs and their impact on fruit finish.

Table 4. Chemical thinner drying condition effects on crop load and fruit finish. WTFRC 2007.

Trial	Treatment	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit weight	Relative box size	Russeted fruit
			%	%	g		%
Golden	Bloom+PB – 6 AM	51 ab	57 ns	35 ns	188 ns	101	29 a
Delicious/	Bloom+PB – Noon	64 ab	49	40	185	103	20 ab
M.26	Bloom+PB – 6 PM	56 ab	57	34	206	93	27 a
- Manson	PB only – 6 AM	51 ab	59	32	183	104	12 b
	PB only – Noon	71 ab	50	33	192	99	24 ab
	PB only – 6 PM	47 b	63	28	194	98	17 ab
	Control	80 a	49	30	187	102	21 ab
Fuji/M.26	Bloom+PB – 6 AM	89 ns	49 ns	24 ns	199 ab	96	50 ns
- Manson	Bloom+PB – Noon	93	42	31	197 ab	97	32
	Bloom+PB – 6 PM	86	45	32	197 ab	97	46
	PB only – 6 AM	114	32	34	184 b	104	45
	PB only – Noon	112	32	34	194 ab	98	41
	PB only – 6 PM	83	45	34	201 a	95	47
	Control	95	41	33	190 ab	100	56

Table 4 represents two trials in which identical bloom (CFO + LS) and postbloom (carbaryl + BA) chemical thinning programs were applied at different times of the same days. Morning applications were typically during cool (53-58ºF) and damp, but warming conditions; midday conditions featured temperatures continuing to rise from 60-65ºF; evening sprays occurred in relatively dry conditions cooling from 62-67ºF. As in 2006, treatments on Golden Delicious reduced fruit set, but trends in data were not clear enough to be statistically significant. No thinning was observed by any treatment in Fuji, and no treatment in either trial showed any effect on fruit finish. Inconsistent and/or contradictory data has made interpretation of results from these trials difficult in both 2006 and 2007; we plan to try these programs one last time in 2008.

Table 5. Chemical thinner spray technology and carrier volume effects on crop load and fruit finish. WTFRC 2007.

Trial	Sprayer	Carrier volume	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit weight	Relative box size	Russeted fruit
		gal/acre		%	%	g		%
Fuji/M.26	AccuTech	100	64 ns	59 ns	24 ns	298 ab	64	52 ns
- Quincy	AccuTech	200	59	58	28	298 ab	64	47
	Proptec	100	79	49	60	306 a	62	45
	Proptec	200	60	60	24	306 a	62	54
	Turbo-mist	100	63	58	27	305 a	63	34
	Turbo-mist	200	65	54	30	284 b	67	40
	Control	na	73	53	28	296 ab	64	49

At another site, we applied identical chemical thinning programs at consistent timings using different sprayers and carrier volumes (Table 5). Despite using aggressive thinning programs, we observed no effects on fruit set or fruit finish, let alone discerning any trends relative to spray technology or dilute vs. concentrate spraying.

POSTBLOOM THINNING:

The primary focus of our postbloom thinning work is to identify effective programs which do not rely on carbaryl, which is facing considerable regulatory pressure. While 2007 trials showed few treatment effects (Table 6), we are encouraged by past successes with BA + NAA programs (Table 7). Table 7 also confirms our past assertions that carbaryl + BA programs are often superior to standard carbaryl + NAA programs. Perhaps most striking about Table 7 is the overall dearth of significant effects from any postbloom chemical thinning program; when compared to the general success rates of bloom chemical thinners (Table 3), it becomes all the more clear that early, aggressive thinning is critical to effective crop load management.

Table 6. Crop load effects of postbloom thinning programs. WTFRC 2007.

Trial	Treatment	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit weight	Relative box size	Russeted fruit
			%	%	g		%
Gala / M.26	BA	73 ns	51 ns	30 ns	220 ns	87	32 ab
- Orondo	BA + ethephon	65	55	30	215	89	14 bc
	BA + NAA	61	53	36	217	88	20 abc
	NAA	71	52	30	225	85	32 ab
	NAA + ethephon	62	56	30	219	87	34 a
	Carbaryl	56	60	27	220	87	20 abc
	Carbaryl + ethephon	68	51	34	221	86	12 c
	Carbaryl + BA	67	54	31	235	81	37 a
	Carbaryl + NAA	60	56	32	212	90	35 a
	Control	67	55	29	210	91	10 c
Braeburn/	BA	50 ns	62 ns	27 ns	185 abc	103	5 ns
M.9	BA + ethephon	40	66	28	178 bc	107	7
- Grandview	BA + NAA	50	63	27	180 bc	106	5
	NAA	42	66	28	187 abc	102	7
	NAA + ethephon	38	66	30	169 c	113	4
	Carbaryl	47	61	33	192 abc	99	10
	Carbaryl + ethephon	33	73	21	196 ab	97	11
	Carbaryl + BA	43	66	27	207 a	92	12
	Carbaryl + NAA	46	62	31	188 abc	101	9
	Control	55	56	34	174 bc	110	12

Table 7. Incidence and percentage of results significantly superior to untreated control. Apple chemical postbloom thinning trials WTFRC 1999-2007.

Treatment	Fruitlets/100 blossom clusters	Harvested fruit size	Return bloom[1,2]
6-benzyladenine (BA)	2 / 18 (11%)	0 / 19 (0%)	0 / 16 (0%)
Carbaryl + BA	23 / 65 (35%)	7 / 65 (11%)	7 / 54 (13%)
Carbaryl + naphthaleneacetic acid (NAA)	9 / 46 (20%)	6 / 46 (13%)	3 / 40 (8%)
Carbaryl + NAA + ethephon	0 / 5	0 / 5	2 / 5
Carbaryl + BA + NAA	0 / 8	0 / 8	3 / 8
BA + NAA	2 / 6	0 / 6	0 / 2

[1]Does not include data from 2007 trials.

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

COMBINED BLOOM AND POSTBLOOM PROGRAMS:
Our results continue to demonstrate that comprehensive chemical thinning programs are typically necessary to reduce crop load to appropriate levels. Table 8 details that modest effects were obtained by either approach individually, but only when bloom and postbloom programs were combined was fruit set significantly reduced. Likewise in grower-applied trials on 'Pacific Rose' and 'Fuji,' the additive effects of CFO + LS and carbaryl + BA delivered positive results (Table 9). Our 2007 'Honeycrisp' trial further reinforced that postbloom thinning with BA + NAA can be as effective as carbaryl-based programs.

Results from trials sprayed with the Proptec paralleled those from grower-applied trials for several years after our program purchased it in 1999; in recent seasons, however, we have not seen as much consistency in results from Proptec trials as those applied by grower-cooperators (Table 9). We plan to replace our aging sprayer in 2008 and hope that the new machine will both reflect innovative spray technology and produce results which more tightly reflect those of typical commercial sprayers.

Table 8. Crop load effects of bloom + postbloom thinning programs (Proptec). WTFRC 2006.

Trial	Bloom thinner	Postbloom thinner	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit weight	2007 return bloom
				%	%	g	%
Golden Delicious/	ATS		47 a	65 bc	25 a	198 bcd	43 b
M.7	ATS	Sevin + NAA	41 ab	68 bc	24 a	220 ab	94 ab
Othello	ATS	Sevin + MaxCel	15 c	88 a	11 b	209 abcd	98 ab
	CFO + LS		35 ab	71 bc	22 ab	187 cd	44 b
	CFO + LS	Sevin + NAA	35 ab	70 bc	26 a	210 abc	110 ab
	CFO + LS	Sevin + MaxCel	25 bc	78 ab	18 ab	219 ab	121 a
		Sevin + NAA	40 ab	68 bc	25 a	227 a	66 ab
		Sevin + MaxCel	31 abc	75 abc	20 ab	211 abc	105 ab
		MaxCel	33 ab	72 bc	23 a	199 bcd	76 ab
	Control		46 a	63 c	29 a	182 d	46 b

Table 9. Crop load effects of chemical thinning programs (grower applied). WTFRC 2007.

Trial	Bloom thinner	Postbloom thinner	Fruitlets/100 floral clusters	Blanked spurs	Singled spurs	Harvest fruit weight	Relative box size	Russeted fruit
				%	%	g		%
Pacific Rose/	CFO + LS		68 b	63 a	18 ns	282 ab	68	18 ns
M.26	CFO + LS	Carbaryl + BA	60 b	64 a	20	321 a	59	28
- Brewster		Carbaryl + BA	72 b	60 a	20	279 ab	68	28
	Control		92 a	52 b	19	267 b	71	22
Fuji/M.9	CFO + LS		119 b	43 b	20 b	222 ns	86	80
- Royal City	CFO + LS	Carbaryl + BA	90 c	53 a	20 b	239	80	93
		Carbaryl + BA	99 c	49 ab	22 b	233	82	92
	Control		143 a	29 c	27 a	231	83	100
Honeycrisp/	CFO + LS	BA + NAA	64 b	57 a	27 ns	260 ns	73	72 ns
M.9	CFO + LS	Carbaryl + BA	63 b	58 a	26	255	75	86
- Wiley City	CFO + LS	Carbaryl + NAA	66 b	56 ab	26	236	81	66
	CFO + LS	None (control)	78 a	51 b	28	250	76	74

RETURN BLOOM PROGRAMS:

We have been disappointed by our inability to increase return bloom with summer NAA programs like those used successfully by researchers in North Carolina and many Washington growers. Despite following advice for treatments from those researchers and growers, as well as the manufacturer, we have rarely observed significant effects on flowering from any NAA program in 4 years of trials. Return bloom was increased sporadically in those trials by summer ethephon applications, but even those results have not been consistent enough to inspire any degree of confidence. We will strive to conduct future return bloom trials using other spray technologies to determine whether our poor results may be in part related to use of our Proptec sprayer.

In 2007, we initiated a new series of trials to investigate application of GA_3 (Falgro) to *reduce* return bloom in blocks set up to be heavily cropped in 2008. The material was applied at 10mm fruitlet size in three lightly cropped Fuji blocks around the state; the effect of these treatments will not be clear until spring of 2008. The manufacturer of Falgro (Fine) has expressed a willingness to register their product for this use if results are promising and we are hopeful this approach can help growers mitigate biennial bearing in their apple blocks.