**FINAL PROJECT REPORT** **YEAR**: 3 of 3

**Project Title:** Apple Crop Load Management

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**Cooperators**: Stefano Musacchi (WSU), Sara Serra (WSU), Karen Lewis (WSU), Gerardo Garcia, Manoella Mendoza, private chemical companies

**Total Project Request:** **Year 1:** $0 **Year 2:** $0 **Year 3:** $0

**Other funding sources:** **Awarded**
**Amount:** $127,283 (4 year total)
**Agency Name:** NIFA – SCRI: Precision Crop Load Management for Apples (PD: Terence Robinson, Cornell University)
**Notes:** funding primarily supports 2 research assistants for 3 months/year to be shared with co-PIs Musacchi and Lewis; selected trial sites will be jointly utilized for WTFRC and SCRI projects

**Other funding sources:** **Requested**
**Amount:** Unknown
**Agency Name:** Contract work with private chemical companies (i.e. Adama, Fine Americas, Valent)
**Notes:** amount requested & awarded typically offsets all costs (excluding PI salary) associated with execution of trial protocols; annual total contributions from registrants (typically $30-50K) vary depending on trial number and complexity of protocols

**WTFRC Budget**

| Item | 2021 | 2022 | 2023 |
|---|---|---|---|
| **Salaries** | na | na | na |
| **Benefits** | na | na | na |
| **Wages** | 28,000 | 28,000 | 28,000 |
| **Benefits** | 15,000 | 15,000 | 15,000 |
| **Travel** | 1000 | 1000 | 1000 |
| **Plot Fees** | 4600 | 4600 | 4600 |
| **Miscellaneous** | 400 | 400 | 400 |
| ***SCRI funding*** | *(20,000)* | *(20,000)* | *(20,000)* |
| ***Contract funding*** | *(29,000)* | *(29,000)* | *(29,000)* |
| **Total net cost** | **$0** | **$0** | **$0** |

**Footnotes:**
All budget figures are rough estimates and will change depending on the number of trial sites and complexity of individual trial protocols in any given year; regardless of costs incurred, external funding should likewise adjust to offset cost totals
NOTE: Budget for informational purposes only; research is funded through WTFRC internal program

**OBJECTIVES:**

1. Ongoing screening of novel thinning chemistries (i.e. metamitron) for bloom and post-bloom thinning of apple including development of best practices regarding rates, timings, and use of adjuvants.

2. Ongoing screening of plant growth regulators (i.e. gibberellins) with potential to influence shoot growth, flowering, fruit set, fruit growth, fruit quality, etc. to the benefit of commercial apple production.

3. Collaborate with state and national research team on SCRI grant "Precision Crop Load Management for Apples."

**SIGNIFICANT PROGRESS & FINDINGS:**

**No thinning treatment produced significant reductions in fruit set or increases in harvest fruit size vs. untreated controls in 2023 chemical thinning trials on Honeycrisp and Cripps Pink (Table 2)**

**Despite generally favorable conditions for chemical thinning in 2023, WTFRC field trials were sprayed during cooler temperatures, perhaps leading to more modest thinning results**

**The most efficacious options for chemical bloom thinning of apple continue to be spray oil + lime sulfur programs (Table 1)**

**Despite more moderate performance in recent years, metamitron continues to consistently reduce fruit set, improve harvest fruit size, and increase return bloom (Tables 2 & 3)**

**ACC and ABA thinning programs have yet to show clear efficacy in WTFRC trials (Table 2), but are often reported to be successful in other settings**

**$GA_7$ (Arrange) inhibited return bloom in a 2022 Golden Delicious trial (Table 4), demonstrating the product's potential to mitigate biennial bearing for conventional and organic apple growers**

**Collaborative research efforts improve our understanding of cropping physiology and help develop new models, strategies, and technologies to improve crop load management of WA apples**

**BACKGROUND:**

After years of robust efforts to evaluate various aspects of bloom and postbloom chemical thinning programs, our current focus is to screen new chemistries and provide collaborative support for external research programs working on crop load and canopy management. Most of our current trials are funded in part or wholly by third party companies that contract our services to independently evaluate their products alongside industry standard programs. We continue to evaluate the relative success of thinning programs through three measurable targets which are directly tied to a grower's economic bottom line:

1. Reduced fruit set and need for 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.

**BLOOM THINNING:**

Much of our early work in chemical thinning (1998-2010) focused on screening of dozens of potential bloom thinners including various formulations of salts, sulfur compounds, oils, weak acids, and bioregulators. Very few of those products proved to be sufficiently efficacious, whether alone or in combination with other products, to offer viable options for commercial use. Over time, programs featuring the use of lime sulfur, whether applied by itself at higher concentrations (6-8%) or partnered with various spray oils at lower concentrations (2-3%) emerged as relatively consistent performers effective at achieving the three primary goals for chemical thinning described above.

With a lack of novel blossom thinning chemistries emerging in recent years, we have conducted relatively few bloom thinning trials in the last decade. In 2023, however, we did execute two very basic experiments at the WSU Sunrise Research Orchard near Rock Island in support of the Precision Apple Crop Load Management (PACMan) project. The intent of the trials was to develop field data for new versions of the Pollen Tube Growth Model (PTGM) being developed by Brent Arnoldussen at Cornell University. Trials were conducted on Gala and Jonagold with protocols only featuring a standard rate of JMS Stylet Oil + lime sulfur vs. an untreated control. Spray timings were determined by the experimental pollen tube growth models being investigated by Arnoldussen and did not necessarily align with timings that would have been suggested by the standard PTGM. The spray programs did not demonstrate any thinning or increases in fruit size in either variety (data not shown), but hopefully the data generated by detailed counts of flowers and fruit set will prove to be helpful in the potential development of an improved PTGM.

Table 1 summarizes the results of more than 200 chemical bloom thinning trials conducted by the WTFRC since 1999 including the 2023 PTGM trials, indicating how frequently various thinning chemistries produced results in fruit set, harvest fruit size, and return bloom that were statistically superior to untreated control treatments in those field trials.

**Table 1. Incidence and percentage of results significantly superior to untreated control. Apple chemical bloom thinning trials. WTFRC 1999-2023.**

| Treatment | Fruitlets/100 blossom clusters | Harvested fruit size | Return bloom[1,2] |
|---|---|---|---|
| ATS | 15 / 60 (25%) | 10 / 63 (16%) | 4 / 55 (7%) |
| NC99 | 15 / 32 (47%) | 7 / 34 (21%) | 2 / 28 (7%) |
| Lime sulfur | 26 / 58 (45%) | 12 / 52 (23%) | 9 / 52 (17%) |
| CFO + LS | 62 / 115 (54%) | 27 / 106 (25%) | 22 / 105 (21%) |
| JMS + LS | 14 / 26 (54%) | 8 / 25 (32%) | 4 / 22 (18%) |
| WES + LS | 15 / 32 (47%) | 5 / 31 (16%) | 4 / 31 (13%) |
| ThinRite | 7 / 22 (32%) | 0 / 23 (0%) | 0 / 12 (0%) |

[1]Does not include data from 2023 trials.

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

**POSTBLOOM THINNING:**

Our primary focus for postbloom chemical thinning research continues to be to identify and develop alternatives to carbaryl, which faces regulatory scrutiny as well as mounting pressure from elements of the consumer market seeking to reduce overall use of broad-spectrum pesticides. Even though WTFRC pesticide residue studies have been unable to detect any trace of carbaryl at harvest when used as a chemical thinner, some retail grocers have already established policies prohibiting the sales of produce which has been treated with specific pesticides, including carbaryl.

Fortunately for apple growers, there are multiple alternatives that are now or will soon be available for postbloom chemical thinning. Our ongoing trials seek to evaluate several of those products:

**Metamitron –** this chemistry was initially developed as an herbicide for use in sugar beets and is currently being developed by Adama. It is already registered as a postbloom thinner of apple in several countries including Italy, France, Spain, South Africa, Chile, and New Zealand under the trade name "Brevis." Metamitron has been shown to induce temporary reductions in carbon fixation by inhibiting Photosystem II; this effect tends to be more pronounced during weather conditions associated with increased carbohydrate stress in apple trees, namely when days are hot and cloudy and nighttime temperatures are warm.

We have been fortunate to work with metamitron since 2011 and have found it to be very effective under Washington field conditions. Our early metamitron studies explored various chemical formulations, application rates and timings, use of adjuvants, and combinations with other thinning chemistries. Results from these trials have been key in helping develop best use patterns for metamitron and will help guide the development of a product label when the commercial product is finally registered. Unfortunately for both the registrant and US apple industry, the registration process at the US EPA has been delayed several times, including a recent request that more work be done regarding protection of off-target animal species. Considering ongoing delays, it is most likely that a commercial product will be available to US apple growers for the 2025 growing season.

Much of our early work with metamitron utilized high product rates (64+ ounces/acre) and aggressive timings to establish its efficacy and to determine a red line of what would be "too much" for our conditions in WA. After several instances of over-thinning when the product was applied during hot conditions (85+ F), we concluded that more modest rates of 24-28 ounces/acre would be more appropriate for most chemical thinning scenarios, especially when the product would be tank-mixed with a non-ionic surfactant such as Regulaid, which consistently has improved thinning efficacy. Use of these lower rates in recent years has reduced the incidence of phytotoxicity as well as the degree of thinning.

Even though the 2023 chemical thinning season featured several hot days, they did not coincide well with the actual spray days for our field trials and likely led to some disappointing results. Table 2 reveals that metamitron treatments (ADA 46701) did not affect fruit set or size on Cripps Pink in Monitor or Honeycrisp in East Wenatchee, although the high rate of metamitron did reduce fruit set by 35%.

**ABA (abscisic acid) –** ABA has been sold by Valent under the trade name "ProTone" for a few years. It was initially registered to enhance color in table grapes but now also has a label for postbloom thinning of apples and pears. ABA is known to boost ethylene biosynthesis, causing increased abortion of developing fruit. It is generally considered to be a mild thinner of apples, but has been approved by OMRI, making it a welcome option for organic growers.

As with all other products tested, ProTone failed to provide significant thinning in our 2023 Honeycrisp trial (Table 2). This result was especially disappointing given that weather conditions were nearly ideal for ABA efficacy (85°F +) according to colleagues with extensive experience with the product. Our first-hand experience with ABA is still relatively limited and we look forward to the opportunity to use it across more cultivars, locations, and growing seasons.

**ACC (1-aminocyclopropanecarboxylic acid) –** ACC is a metabolic precursor of ethylene, which promotes fruitlet abscission in apples. Unlike ethephon which produces a sudden burst of ambient ethylene gas, ACC is taken up by the plant and subsequently metabolized, resulting in a more steady, controlled production of ethylene in the plant tissue. Research trials in the Eastern US have proven it to be an effective chemical thinner of apples, especially when applied late in the spring (15-20mm fruitlet size). Due to its efficacy at the tail end of chemical thinning season, ACC may offer some potential as a "rescue" thinner in circumstances when apple growers may feel they need additional thinning after assessing early fruit set. ACC was available for commercial use under the trade name "Accede" for the first time in the 2022 thinning season.

While Accede did not provide significant thinning in either 2023 trial, the 10-12 mm application timing did reduce fruit set numerically on Cripps Pink (Table 2). Interestingly, this result conflicts with reports from other research and demonstration trials which have suggested that ACC is more efficacious either prior to petal fall or after 15 mm fruitlet size. These reports of successful thinning with ACC come from credible sources and we will continue our field testing of Accede in hopes of finding similar results.

**BA (6-benzyladenine) –** BA is a cytokinin which can induce some fruitlet abortion and increase fruit size by promoting cell division. Previous WTFRC trials with BA have shown it to be a relatively weak thinner of apples in WA conditions and typically requires tank mixing with other chemistries like NAA or carbaryl to provide adequate reductions in fruit set. Many BA products including MaxCel and Exilis have been available to industry for several years, but in 2023 we had the opportunity to screen several new formulations (FAL 567, FAL 571, FAL 581) on Honeycrisp in East Wenatchee. Once again, our BA treatments did not produce any significant thinning effects (Table 2), but neither did any other thinning programs in this trial.

**Table 2. Crop load and fruit quality effects of postbloom thinning programs. WTFRC 2022.**

| Treatment | Fruitlets/100 floral clusters | Blanked spurs | Singled spurs | Harvest fruit weight | Relative box size | Russet free fruit |
|---|---|---|---|---|---|---|
| | | *%* | *%* | *g* | | *%* |
| **Cripps Pink / M.26 - Monitor** | | | | | | |
| Accede 34oz + Reg 16oz Petal fall | 94 bc | 45 ab | 29 | 189 | 96 | 94 |
| Accede 34oz + Reg 16oz 10-12 mm | 56 ab | 66 bc | 20 | 193 | 94 | 86 |
| Accede 34oz + Reg 16oz 16-18 mm | 100 c | 38 a | 34 | 182 | 100 | 94 |
| Accede 34oz + Reg 16oz 22-24 mm | 77 abc | 53 abc | 26 | 178 | 102 | 88 |
| ADA 46701 32oz + Reg 16oz PF | 104 c | 38 a | 34 | 186 | 98 | 84 |
| ADA 46701 32oz + Reg 16oz 10-12 mm | 74 abc | 51 abc | 32 | 188 | 97 | 81 |
| ADA 46701 32oz + Reg 16oz 16-18 mm | 84 abc | 49 abc | 28 | 183 | 99 | 83 |
| ADA 46701 32oz + Reg 16oz 22-24 mm | 82 abc | 48 abc | 30 | 180 | 101 | 95 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Carbaryl 4L 36oz + PoMaxa 3oz PF & 10-12 mm | 42 a | 70 c | 21 | 205 | 89 | *85* |
| Control | 80 abc | 48 abc | 31 | 186 | 98 | 96 |
| *Significance (p value)* | *0.000* | *0.001* | *0.097* | *0.153* | | 0.012 |
| | | | | | | |
| **Gale Honeycrisp / G.935 – East Wenatchee** | | | | | | |
| Accede 46 oz + Reg 16 oz | 109 ab | 49 ab | 15 | 193 ab | 94 | 0 |
| ADA 46701 24oz + Reg 16oz - Low | 89 ab | 56 ab | 14 | 187 ab | 97 | 4 |
| ADA 46701 30oz + Reg 16oz- Med | 105 ab | 47 ab | 20 | 214 b | 85 | 14 |
| ADA 46701 36oz + Reg 16oz - High | 67 a | 63 b | 18 | 203 ab | 89 | 4 |
| Exilis 9.5 25.6oz + Reg 16oz | 88 ab | 55 ab | 17 | 188 ab | 97 | 4 |
| FAL 567 51oz + Reg 16oz | 96 ab | 52 ab | 18 | 193 ab | 94 | 0 |
| FAL 571 124oz + Reg 16oz | 99 ab | 51 ab | 19 | 189 ab | 96 | 3 |
| FAL 581 12.8oz + Reg 16oz | 93 ab | 53 ab | 18 | 163 a | 111 | 0 |
| ProTone 33.1oz+ Reg 1 oz | 114 b | 44 a | 18 | 185 ab | 98 | 8 |
| Control | 102 ab | 49 ab | 19 | 182 ab | 100 | 1 |
| *Significance (p value)* | *0.055* | *0.117* | *0.877* | *0.110* | | *0.527* |
| | | | | | | |
| **SRO Gala / M.9 Nic 29 - Rock Island** | | | | | | |
| JMS Stylet Oil 1.5 gal + LS 2.5 gal | 72 | 54 | 25 | 136 | 134 | 9 |
| Control | 71 | 58 | 21 | 143 | 127 | 9 |
| *Significance (p value)* | *0.787* | *0.268* | *0.149* | *0.100* | | *1.000* |
| | | | | | | |
| **SRO Jonagold / M.26 - Rock Island** | | | | | | |
| JMS Stylet Oil 1.0 gal + LS 2.5 gal | 64 | 57 | 26 | 192 | 95 | 33 |
| Control | 68 | 57 | 24 | 192 | 95 | 45 |
| *Significance (p value)* | *0.627* | *0.951* | *0.676* | *0.980* | | *0.278* |

Given the variability in results from one chemical thinning trial to the next, it is important to look at the "big picture" of research data. Similar to an earlier table which demonstrated chemical bloom thinning results, Table 3 summarizes the results of every chemical postbloom thinning trial conducted by the WTFRC over the last 20 years. These findings confirm that apple growers can use thinning programs based on BA and NAA (naphthaleneacetic acid) and reasonably expect results comparable to those produced with thinning programs based on carbaryl. Further, Table 3 reveals the steady performance of metamitron, suggesting that when that chemistry is finally registered for commercial use, it may offer a more consistently efficacious option for postbloom thinning than any other program that is currently available to WA apple growers.

**Table 3. Incidence and percentage of results significantly superior to untreated control. Apple chemical postbloom thinning trials. WTFRC 2002-2023.**

| Treatment | Fruitlets/100 blossom clusters | Harvested fruit size | Return bloom[1,2] |
|---|---|---|---|
| BA | 7 / 32 (22%) | 0 / 33 (0%) | 0 / 32 (0%) |
| Carb + BA | 33 / 91 (36%) | 10 / 89 (11%) | 13 / 86 (15%) |
| Carb + NAA | 30 / 87 (34%) | 23 / 86 (27%) | 19 / 84 (23%) |
| BA + NAA | 20 / 42 (48%) | 9 / 41 (22%) | 9 / 38 (24%) |

| | | | |
|---|---|---|---|
| Metamitron | 20 / 36 (56%) | 16 / 35 (46%) | 10 / 32 (31%) |

[1]Does not include data from 2023 trials.

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

**GIBBERELLIC ACID FOR BLOOM INHIBITION:**

Our interest in using gibberellins to help promote annual cropping in apple grew out of several years of unsuccessful trials trying to promote return bloom with flowering promotors like auxins (i.e., NAA) and ethylene (i.e., ethephon). Despite enthusiastic testimonials from several prominent industry figures, we were simply unable to demonstrate any increase in flowering from summer applications of NAA or ethephon. We decided to instead, explore a strategy of attacking biennial bearing from the opposite direction by applying a flowering inhibitor like gibberellic acid (GA) in the "off" year of a biennial cycle in hopes of reducing the return bloom in the "on" year and ultimately producing more flowers in the subsequent "off" year approximately 23 months after the GA application.

This strategy has proven much more successful, and over 15+ years of testing, we have demonstrated the efficacy of several GA products at reducing return bloom and ultimately mitigating the amplitude of year-to-year swings in apple flowering. Most of our early work focused on $GA_3$ products like Falgro and ProGibb which are primarily used to delay harvest and promote fruit firmness in cherry. While these programs were effective and relatively inexpensive, the registrants of these products were reluctant to pursue expanded labels for chemistries whose patents had already expired. More recently, Fine Americas developed a formulation of $GA_7$ that has proven to be effective at lower concentrations than $GA_3$ products; that product is now sold as "Arrange" and is approved for use by OMRI, providing a valuable tool to organic growers who have limited chemical options for managing crop load.

As with $GA_3$ products, our work has shown Arrange to be most effective around 10mm fruitlet size timing. Generally speaking, most bioregulator spray programs benefit from multiple applications of lower doses but in prior trials, as was the case in a trial sprayed in the spring of 2022 on severely biennial Golden Delicious at WSU's Sunrise Research Orchard near Rock Island (Table 4). In that trial, all treatments with Arrange reduced flowering in 2023, but as is often the case in return bloom studies, the wide variability in the data precluded statistical significance for most treatment effects.

Arrange can be reasonably efficacious in a single dose, especially when partnered with an effective adjuvant. Based on our work with Arrange and other GA formulations, we feel that the best use pattern would be to make 2-4 weekly applications of reduced rates of the product starting around petal fall in a block with uniformly lightly cropped (but not blank) apple trees. Obviously, application of a GA product to the occasional heavily cropped tree would only further inhibit return bloom and increase the severity of its alternation. We look forward to a future with smart spray technology that allows prescriptive application of chemical thinners and plant growth regulators to individual trees based on their respective crop loads, but until then, growers with blocks that are mixed with heavily and lightly bloomed trees should consider spraying individual light trees with a handgun to bring the entire block into more synchronous and consistent cropping.

**Table 4. Effects on tree vigor, fruit size, and return bloom of GA applications. WTFRC 2022.**

| **Treatment** | **2022 harvest fruit weight** | **2022 relative box size** | **2023 return bloom** | **2023 return bloom/CSA** |
|---|---|---|---|---|
| | *g* | | *%* | *clusters/cm$^2$* |

| **SRO 1B Golden Delicious / Bud 9 - Rock Island** | | | | |
|---|---|---|---|---|
| Arrange 100 ppm Petal Fall | 218 | 83 | 3925 ab | 2.5 |
| Arrange 200 ppm Petal Fall | 199 | 91 | 2955 ab | 2.4 |
| Arrange 100 ppm 10 mm | 184 | 99 | 4341 ab | 2.7 |
| Arrange 200 ppm 10 mm | 199 | 91 | 3277 ab | 2.1 |
| Arrange 100 ppm Petal Fall & 10 mm | 201 | 90 | 2103 a | 2.0 |
| Control | 198 | 92 | 5015 b | 3.0 |
| *Significance (p value)* | *0.604* | *na* | *0.012* | *0.382* |

**COLLABORATIVE CROP LOAD MANAGEMENT RESEARCH:**

**"Precision Crop Load Management for Apples" (USDA-NIFA Specialty Crop Research Initiative (SCRI) - PD: Terence Robinson, Cornell) –** field work for project initiated in 2021 and includes trials in WA, NY, VA, MI, MA, and NC; objectives focus on development of predictive models and horticultural strategies to develop/optimize crop load, as well as development of vision systems, robots, & other automated tools to assess and adjust crop load as various phenological stages; WTFRC efforts have focused on:

- support for Musacchi group (WSU) including data collection and plot spraying to investigate effects of pruning severity and floral density on cropping in Gala and Honeycrisp
- facilitating evaluation of digital technology (Farm Vision/Pometa, Fruit Scout, Green Atlas) to count and measure buds, flowers, and fruit on the tree throughout the growing season
- execution of chemical bloom thinning field trials to help evaluate novel pollen tube growth models
- multiple outreach efforts including organization of field days, surveys, written reports, and oral presentations in several regional meetings

**"Maximize pollination window to improve fruit set in WA38" (PI: Serra) –** helped coordinate field activities including trial layout, data collection, spray application, reflective material deployment, sample collection, and harvest analysis; field trials showed few significant effects of application of ethylene-inhibiting materials (ReTain, Harvista) on WA38 yields and fruit quality, but deployment of a reflective material (Extenday) throughout the growing season did increase cumulative fruit yields and quality; see Serra final report for more detail

**"Smart Orchards Year 4 + Connectivity" (PI: Mantle) –** worked with Mantle, Hoheisel, Khot, and Washington Fruit to develop a differential chemical thinning spray strategy for the Grandview Smart Orchard (Honeycrisp) based on heat maps generated from digital scans of flower density and crop load in previous seasons; spray programs were executed by a variable rate sprayer with Smart Apply technology to deliver higher doses of chemical thinners to portions of the orchard with relatively higher bloom density; see Mantle report (WTFRC Technology Committee) for more detail

**Project Title: Apple Crop Load Management (2023)**
**PI: Tory Schmidt, WTFRC**

*Executive Summary*

Keywords: chemical thinning, PGR, return bloom

**Abstract:** The primary key to profitability in apple production is the ability to generate consistently high yields of quality fruit. Spiraling costs for labor and other inputs have put a premium on less expensive strategies to manage crop load including the use of chemical thinners and plant growth regulators. In this ongoing research, we sought to develop practical best use patterns for emerging chemistries for thinning and regulation of fruit set, fruit size, fruit quality, and flowering through a series of field trials. Further, we collaborated with other scientists and commercial interests in the development of new chemistries, models, and technologies to improve precision and reliability of commercial crop load management.

Project outcomes:

1. Identification of novel efficacious chemical thinners (i.e. metamitron) and PGRs (i.e. GA for floral inhibition) with practical commercial relevance.
2. Development of best use practices (timings, rates, use of adjuvants, etc.) for these products.
3. New collaborative working relationships with a broad range of scientists, chemical registrants, technology providers, and other allied industry vendors working in crop load management.

Significant Findings:

1. Metamitron shows great promise as a postbloom chemical thinner of apple in WA conditions, providing consistent results across multiple years, locations, and cultivars.
2. ABA and ACC have demonstrated efficacy as chemical thinners in other settings, but not in preliminary WTFRC trials.
3. $GA_7$ is effective at inhibiting floral initiation in apple and offers a new tool for organic and conventional growers to manage annual cropping.
4. Emerging digital imaging and sprayer technologies offer potential to manage crop load on an individual-tree basis in the coming years.

Future Directions:

1. Provide outreach/guidance to industry when the new metamitron product is labeled and released.
2. Ongoing screening and refinement of new chemistries for crop load management.
3. Investigation of developing technologies with implications for crop load management (i.e. digital vision/crop mapping, smart sprays, robotic pruning/thinning/picking machines).
4. Further collaboration with other scientists to improve knowledge of physiology of apple cropping and predictive models to help manage it effectively.