FINAL PROJECT REPORT

WTFRC Project Number: AH-05-507 **(WSU Project #13C-3655-5299)**

Project Title: Growth and crop load management in apple trees with bioregulators

PI: Don C. Elfving
Organization: WSU Tree Fruit Research and Extension Center
Telephone/email: 509-663-8181 x252; delfving@wsu.edu
Address: 1100 N. Western Avenue
City: Wenatchee
State/Province/Zip: WA 98801

Cooperators: Thomas D. Auvil, WTFRC; Eric A. Curry, USDA/ARS/TFRL; James R. McFerson, WTFRC; Dwayne Visser, WSU-TFREC

Other funding Sources

Agency Name: N/A

Total Project Funding: ***2005:*** 17,420 ***2006:*** 17,956 ***2007:*** 19,239

WTFRC Collaborative expenses:

Item	Year 3: 2007
Wages and benefits[1]	2,290
Travel[2]	200
Total	2,490

Footnotes:
[1]Calculate at $13/hour including benefits.
[2]Travel costs in 2007 based on fuel costs.

Budget History:

Item	Year 1: 2005	Year 2: 2006	Year 3: 2007
Salaries	8,000	8,400	8,820
Benefits	2,720	2,856	2,999
Wages	2,000	2,000	2,000
Benefits	200	200	220
Equipment	0	0	0
Supplies	1,000	1,000	1,000
Travel	3,000	3,000	3,500
Miscellaneous	500	500	500
Total	17,420	17,956	19,239

Original objectives of the project:

1. Evaluate GA effects on return bloom in several alternating apple cultivars, e.g., ‘Fuji,’ ‘Cameo,’ and ‘Braeburn.’
2. Examine single vs. multiple timings of various GA concentrations for efficacy in control of return bloom in apple to reduce amount of GA used, if possible.
3. Continue to test post-thinning ethephon as a method for stimulation of return bloom in cropping trees of several important apple cultivars, particularly those with alternate bearing problems.
4. Combine ethephon and GA programs in alternating cultivars as a possible strategy to help overcome alternate bearing.
5. Re-examine the integration of chemical thinning programs with GA/ethephon programs for beneficial effects on reduction of alternate cropping.
6. Test the use of cyclanilide and cytokinin bioregulators in high vigor sleeping-eye plantings for utility in programming lateral branch development into a specific canopy architecture as desired by the grower.

Additional objectives:

1. Evaluate various bioregulators for potential efficacy in stimulating bud activity and shoot growth on “blind wood.”

Significant findings 2005:

1. The alternating flowering and yield effects observed this year in ‘Fuji’ trees treated with GA in 2003 were a direct result of altered flowering in 2004, **NOT** of altered fruit or crop load that year. **Hence, flowering intensity alone in ‘Fuji’ apples can induce an alternating bloom and production cycle.** It is likely that this fact explains the difficulty in controlling alternate bearing in ‘Fuji’ trees with thinning alone.
2. Even high concentrations of ethephon applied twice after the thinning period is over did not produce reliable improvement in flowering in cropping trees. Induction of good return bloom in cropping trees is very difficult.
3. New GA/alternate bearing trials established in 2005 have examined using GA, BA/GA or combinations of NAA/ethephon to more closely control the flowering cycle as a strategy for developing better control methods for alternate cropping in difficult cultivars such as ‘Fuji.’
4. Cyclanilide works well for inducing branching in sleeping-eye trees, thus saving much labor cost, but it can reduce height growth to some degree.

Significant findings 2006:

1. Only the strongest bloom-suppressing GA treatment applied in 2003 (GA_7) continued to influence the flowering and yield of ‘Fuji’/M.9 trees in 2006. Results from this trial and others have shown that an alternating cycle can be induced by a practice intended to reduce alternate bearing. New trials exploring the potential for yearly interventions to control flowering are now underway.
2. When flowering is reduced due to GA treatment the previous year, the potential exists for an increase in fruit set to take place. This phenomenon was observed in one trial in 2006. An increase in fruit set, if significant, might offset the benefit of reduced flowering on subsequent cropping.
3. New GA/alternate bearing trials established in 2005 are testing the continued use of GA, or the application of BA/GA or ethephon to more closely control the flowering cycle as a strategy for developing better control methods for alternate cropping in difficult cultivars such as ‘Fuji.’ GA_{4+7} at 100 mg/liter, Promalin at 100 mg/liter or ethephon at 600 mg/liter were applied in 2006 to manage flowering for 2007 with the objective of evening out the bloom and yield.
4. Cyclanilide works well for inducing branching in sleeping-eye trees, thus saving much labor cost, but it can reduce height growth to some degree. A large comparison trial between Promalin and cyclanilide for branch induction in sleeping-eye ‘Fuji’/M.9 trees was undertaken in 2006.

Cyclanilide reduced leader-shoot elongation by about 30 cm, but may have induced thicker, better quality fruiting wood.

Significant findings 2007:

1. 2007 was the third year (second "off" year) of trials with GA and other bioregulators for control of alternate cropping in 'Fuji' and 'Braeburn trees. GA and Promalin applied in 2006 ("on" year) did not suppress return bloom in 2007 more than cropping alone. Only postbloom ethephon (Ethrel, 600 ppm, 6 weeks after full bloom) in 2006 improved the "off year" flowering and yield of 'Fuji' in 2007. Yield data in the 'Braeburn' trial were lost due to grower harvest.
2. Applications of cyclanilide continued to help produce branching at upper wires during the second (final) year of canopy development in sleeping-eye 'Aztec Fuji'/'Mark' apple trees in a high-density trellised planting. The grower made an observation that the cyclanilide-treated trees, though somewhat shorter than the Promalin-treated trees, had what looked to be more robust future fruiting wood. Follow-up studies will attempt to determine if there is a significant difference in early fruiting performance based on which branching agent is used during canopy development.
3. Cytokinin or cytokinin/gibberellin treatments in 2006 induced up to 5-fold increases in bud activity in latent buds on feathers of Jazz® ('Scifresh')/M.9 apple trees. A small percentage of those activated buds showed the presence of flower clusters in spring, 2007, but no effect of any cytokinin or cytokinin/GA combination on flower initiation itself was observed. A very few of these clusters set a fruit in 2007. Follow-up is planned to see if latent buds initiated into activity in 2006 will form spurs and flower more profusely in 2008, as would be normally expected.
4. Three cytokinins tested on 'Scifresh' latent buds in 2007 induced latent buds to break and grow. The cytokinins were thidiazuron, KT-30 chlorfenuron (CPPU, Kim-C1) and Prestige chlorfenuron (CPPU, Valent). Adding GA_{4+7} (ProVide) either alone or in combination with the cytokinin had no beneficial effect on bud development. Crushing the bark of young sleeping-eye 'Honeycrisp' and 'Fuji' apple trees at the trellis wire(s) where additional branches were needed did not increase branching. Treating crushed areas with cytokinins at up to 5,000 ppm also did not induce additional branch development. Higher concentrations may be required, but a limited number of available buds at each site may also account for the lack of new shoots.

Results and discussion

A. Control of flowering with GA in alternating apple cultivars (Objectives 1, 2, 4, & 5).

1. Previous trials showed the capacity of severely alternating cultivars to maintain this biennial cycle when treated with GA for inhibition of flower initiation. In fact, a single GA treatment can induce a continuing biennial cycle that can last for at least 4 years. In the various trials undertaken during this project, control of return bloom as a strategy for overcoming alternation has proven difficult. Supplementing an initial treatment with annual follow-up treatments that include: a) GA alone, b) GA + BA for some thinning or c) a late postbloom ethephon treatment to stimulate return bloom has also not proven to be consistently effective. In 2005, we reported evidence that the amount of bloom itself can induce bienniality in the absence of a significant difference in fruit load. This fact may be a part of the root cause of the stubbornly biennial behavior of some cultivars, such as 'Fuji' or 'Cameo'. If so, a more consistent flower-induction-controlling methodology is needed to attack this problem.

B. Induction of flowering with ethephon (Objective 3.)

1. In the alternate-bearing trials in this project, ethephon was applied annually in June to trees of 'Fuji'/M.26 and 'Braeburn'/M.9 that either received GA_{4+7} or were not treated during the first trial year ("off" year). While this strategy has not consistently led to improvement in return bloom, bienniality indices suggest that this approach may have merit. Perhaps higher doses or multiple applications can improve the response. The ethephon treatments applied in 2006 were

quite effective in 2007. What was it about the 2006 season that made this treatment stand out? Unfortunately we do not know.

C. Programming the induction of lateral branching in sleeping-eye apple trees with bioregulators (Objective 6).

1. In 2006, a test was established in newly planted 'Fuji'/M.9 apple trees to compare the effects of Promalin vs. cyclanilide in relation to stimulation of lateral branching at sequential trellis wires as the central leader developed vertically. Cyclanilide and Promalin sprays were applied to the shoot tips and nearby leaves whenever the shoot tip reached a wire. Cyclanilide was as effective as Promalin for inducing lateral shoots at wires, but resulted in somewhat shorter leader development (20-30 cm less). In year 2, a continuation of the program with lower concentrations of cyclanilide reduced the inhibitory effect of the bioregulator on leader extension growth while still producing good branch development. The lateral shoots developed from cyclanilide-treated trees appear a bit more "robust", leading to the supposition that they may produce better fruit when they begin to bear.

D. Stimulation of bud activity on "blind wood" in apple (New Objective 1).

1. Three cytokinins were tested for efficacy in stimulating growth activity from latent buds in five trials with 'Scifresh' (Jazz), 'Cameo' and 'Granny Smith' apple trees. Thidiazuron (TDZ) painted onto the basal halves of feathers at green-tip in second-leaf and newly planted Jazz trees produced a strong budbreak response. When applied at 2,500 mg/liter a.i., chlorfenuron (CPPU) was also effective, but 6-BA (Maxcel) produced only a marginal effect on budbreak, even at 5,000 mg a.i./liter. Although budbreak was induced, very few of the activated buds formed any sort of shoot. Combining nicking cuts with TDZ application to lateral shoots of 'Cameo' trees at green-tip produced the strongest budbreak response, but nicking only improved the response by about 10%. Crushing shoot bark in conjunction with other applications did not improve the response. High concentrations of TDZ, CPPU and 6-BA were applied to two-year-old wood and the base of one-year-old leader shoots on three-year-old 'Honeycrisp'/M.9 trees. The older wood produced almost no response, while the leader shoots did show some evidence of increased budbreak, but the overall response was poor. Higher concentrations might have helped, but the low vigor of the trees may have been the principal factor limiting the growth response. Good vigor is an important factor facilitating the bud development response to exogenous applications of cytokinins. Interestingly, the addition of GA in these trials did not have the bud-growth-stimulating effect seen when similar treatments are applied to sweet cherry.

Acknowledgments:
The assistance and support of the following persons and organizations are gratefully acknowledged: Dave Allan, Travis Allan, Bruce Allen, Tom Auvil, Bill Borton, Humberto Camacho, Felipe Castillo, Phil Dormaier, Dan Fulbright, Mark Gores, Jeff Henry, Steve Hull, Dr. Chris Ishida, Rick Kamphaus, Heidi Künzel, Dr. Jim McFerson, Chris Olsen, Byron Phillips, Steve Scheib, Major Tory Schmidt, Dr. Earl Seeley, David Silvernail, Kris Thomas, Dwayne Visser, Allan Bros. Orchards, Apple-Eye Orchards, BASF Corp., Bayer Environmental Science, Blue & White Orchard, Borton & Sons Orchards, Columbia Reach Pack, Inc., Dormaier Orchards, Firewood Orchards, Gores Orchards, Highland Partnership, Mountain View Orchards, Valent BioSciences, Washington Tree Fruit Research Commission, WSU Agricultural Research Center.

Publications 2007:

Elfving, D.C. and D.B. Visser. 2007. Improving the efficacy of cytokinin applications for stimulation of lateral branch development in young sweet cherry trees in the orchard. HortScience 42:251-256.

Elfving, D.C., S.R. Drake, A.N. Reed and D.B. Visser. 2007. Preharvest applications of sprayable 1-methylcyclopropene in the orchard for management of apple harvest and postharvest condition. HortScience 42:1192-1199.

Schmidt, T.R. and D.C. Elfving. 2007. Crop load management of apple via induced plant stress. J. Amer. Pom. Soc. 61:167-169 (2nd place U.P. Hedrick award 2007).

Elfving, D.C. and D.B. Visser. 2007. The use of bioregulators in the production of deciduous fruit trees. Acta Hort. 727:57-66.

Elfving, D.C. and D.B. Visser. 2007. Optimizing vegetative and reproductive growth. Proc. Wash. State Hort. Assn. 102:55-56.

Elfving, D.C. 2007. Bioregulator sprays. p. 74-86. *In*: T.J. Smith (coord.). 2007 Crop Protection Guide for Tree Fruits in Washington. EB 0419.

Elfving, D.C. and D.B. Visser. 2007. Bioregulator effects on growth, flowering and cropping in apple trees. Poster, Wash. State Hort. Assn. Annual Meeting, Wenatchee, WA.

Elfving, D.C. and D.B. Visser. 2007. Branch induction in pear trees with bioregulators. Poster, Wash. State Hort. Assn. Annual Meeting, Wenatchee, WA.

Elfving, D.C. and D.B. Visser. 2007. Bioregulators for managing growth, cropping and fruit quality in sweet cherry. Poster, Wash. State Hort. Assn. Annual Meeting, Wenatchee, WA.

Manuscripts accepted for publication:

Lenahan, O., M. Whiting, and D. Elfving. Gibberellic acid is a potential sweet cherry crop load management tool. Acta Horticulturae.

Schmidt, T.R., D.C. Elfving et al. GA and fruit maturity. HortTechnology.