FINAL REPORT

WTFRC Project #AH-02-211 **WSU Project #13C-3655-3298**

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

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Original objectives of the project:

1. Determine how to control an Apogee-induced second shoot growth flush in midsummer using Apogee applications at or near the time of the start of that flush. Evaluate rates, timings and number of applications for effects on control of a second growth flush.
2. Evaluate the efficacy of cyclanilide, alone or in combination with other bioregulators, for the induction of branching of various apple cultivars under orchard conditions.
3. Determine whether commercially available gibberellic acid formulations containing GA_4 and GA_7 can be used in conjunction with conventional thinning practices to reduce or overcome alternate bearing in difficult apple cultivars such as 'Fuji' by means of controlling flower initiation in the "off" season. Evaluate GA rates and timings on return bloom in the "on" year and assess the economic potential for such treatments to suppress alternate cropping.

Additional objectives added later:

1. Evaluate ethephon applications to cropping apple trees to determine efficacy for increasing bloom under cropping conditions.
2. Expand the gibberellic acid (GA) / return bloom control program to include other cultivars.

Significant findings:

- A minimum of three Apogee applications was necessary in vigorous 'Fuji' trees to reduce a second flush. Even with five applications, a small second flush still occurred.
- Three applications of Apogee vs. Regalis at the same concentration (the European formulation of prohexadione-Ca) showed that Regalis controlled shoot growth more rapidly than Apogee but the subsequent second flush was stronger, canceling out the earlier benefit from Regalis.
- Products containing GA_4, GA_{4+7} and GA_7 alone effectively reduced return bloom in 'Fuji' apple trees treated in the "off" year. However, due to increased fruit set of the remaining flowers, GA in the "off" year tended to shift the alternating pattern to the subsequent year but did not smooth out year-to-year fluctuation in yield.
- Aggressive thinning every spring tended to increase alternation relative to "normal" thinning in non-GA-treated trees, but this effect was not as strong in GA-treated trees.
- In striking contrast to 'Fuji', "off"-year 'Cameo' trees carrying no crop and treated with GA isomers showed NO bloom reduction response to the applied GA.

- Ethrel applied after the cell-division phase of fruit growth (30, 45, and/or 60 days after full bloom) to moderately cropping 'Golden Delicious' trees did not improve return bloom.
- Cyclanilide sprayed on tree trunks in the fall or spring or applied in paint directly to apple buds during the dormant period in early spring or at green-tip did not produce any growth response at all.
- Cyclanilide applied after shoot growth had begun produced the typical lateral branching on the new, growing shoots.

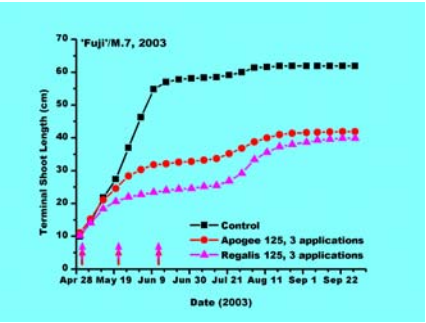
Methods:
Over the three-year period of this project, trials were established in both cropping and non-cropping apple trees to determine effects of various bioregulator products on both growth and fruiting behavior. All trials employed single- or double-tree plots in randomized complete-block designs.

Results and discussion:
During the course of this project, progress was made on all objectives. Detailed results are not available for 2004 projects as of this writing (September 2004) but observations will be reported here. The following results and conclusions have been obtained during the three years of this project:

A. Control of vegetative growth with Apogee (Prohexadione-Calcium)

1. Apogee (6 oz/100 gallons) applied three to five times at 3-week intervals reduced the second growth flush in vigorous, cropping 'Fuji' apple trees. The more applications made, the better the control of shoot growth. It appears important to maintain a regular schedule of Apogee applications once an Apogee growth control program is started. Once control of growth has been lost by interrupting the application schedule, it is very difficult to re-establish with later treatments.

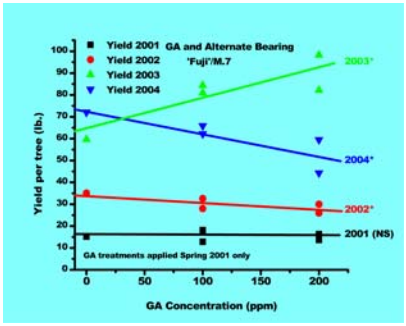
2. Regalis is the European formulation of prohexadione-Ca. Regalis and Apogee were applied three times to vigorous 'Fuji' trees. Regalis reduced shoot growth more quickly than did Apogee (see graph). However, when the second growth flush began in July, regrowth was faster in the Regalis-treated trees, and final shoot growth was identical from both programs. These observations support the theory that GA precursors accumulate when prohexadione is active; when this inhibition diminishes, those precursors are quickly converted to active GA forms, stimulating the second flush.



B. Gibberellic acid and thinning for control of alternate bearing

1. Gibberellic acid isomers GA_4, GA_{4+7} and GA_7 all reduce flowering in 'Fuji' apple trees under low-cropping conditions. GA_7 is the more effective isomer so flowering reduction is greater as the proportion of this isomer increases in the applied product.
2. GA reduced return bloom linearly for all GA products up to 56% at up to 200 ppm. The degree of reduction was directly related to the percentage of GA_7 in the applied product, with GA_4 showing the smallest amount of reduction.
3. In one trial, applying GA products to "off"-year 'Cameo' trees at the same concentrations and timings as used successfully with 'Fuji' apple produced no effect at all on return bloom. This curious observation has led to a detailed study of the relationship, if any, between crop load and GA-mediated bloom reduction.

4. In all GA trials where return bloom was reduced, some degree of increase in percentage fruit set was observed. This increase tended to diminish the effectiveness of GA treatment for controlling alternate bearing.
5. Over four years, GA treatment the first "off" year only (2001) did not reduce overall alternation of yield over the subsequent three years (see graph); alternation still continued, but the cycle was shifted to the opposite year and cyclic behavior was increased somewhat by GA treatment in 2001.
6. In 2002, one year after GA treatment, yields were decreased in proportion to GA concentration the previous year, despite an increase in fruit set.
7. Over four years, total yield and overall bienniality index were unchanged by a single GA treatment at the start of the trial. These observations suggest that GA may have to be introduced more frequently to manage flowering in severely alternating trees.



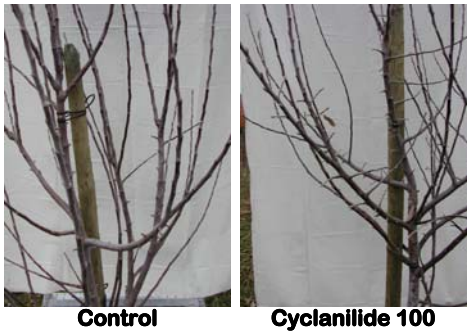
8. Aggressive thinning was combined with GA treatments in one trial. Aggressive thinning reduced yield compared to "normal" thinning each year it was applied; however, aggressive thinning did not reduce the year-to-year alternation of yield.
9. Further work is needed to better understand cultivar interactions with GA treatments, whether GA can be used more frequently to help manage flowering as a method to assist in controlling alternate bearing, and whether very low crop loads interfere significantly with the GA control over return bloom.

C. Ethephon for stimulation of flowering in bearing trees as a strategy for helping control alternate bearing

1. Ethrel applied twice at 500 ppm between 30 and 60 days after flowering (after the end of cell division) had no effect on return bloom in moderately cropping 'Golden Delicious' trees.
2. Applications of Ethrel at either 300 or 600 ppm were made twice between 30 and 60 days after flowering (after the end of cell division) in 2004 to moderately cropping 'Honeycrisp' trees. Bloom data will be collected in 2005.

D. Effects of cyclanilide on branch development in the orchard

1. Cyclanilide at up to 15,000 ppm was sprayed on trunks of young 'Cameo' apple trees in October or early March. Some phytotoxicity was observed during the growing season in trees treated with the highest concentration. Very limited lateral branching was stimulated by the highest concentration, but the effect was of little horticultural significance.
2. Cyclanilide was applied at up to 5,000 ppm to buds of 'Scarletspur Delicious' and 'Granny Smith' prior to budbreak to see if this product could overcome apical dominance and stimulate bud development from "blind wood" sites on limbs when growth activity began. All such treatments to pre-existing dormant buds were ineffective.
3. Cyclanilide at up to 1,000 ppm was painted on buds on trees of 'Scarletspur Delicious' and 'Granny Smith' at green-tip to determine if cyclanilide could overcome apical dominance at the time and induce lateral branching from buds that would otherwise remain dormant. No budbreak or lateral branch development was observed.
4. Applications of cyclanilide (100 ppm) and/or Promalin (250 ppm) were made to one-year-old 'Scarletspur Delicious' trees in May, when new shoots were about 6 inches in length. Cyclanilide was very effective for stimulating bud activity and lateral branch development (see Figure). Promalin was less effective, and there was no interactive effect on branching of the two products together.



5. In 2004, a trial was established in a replant-site new planting of sleeping-eye trees of 'Honeycrisp'/M.9 to assess whether this product could assist in programming the development of lateral branches where desired on the new 'Honeycrisp' shoots as they developed. Cyclanilide (100 ppm) and Promalin (500 ppm) were applied separately or together and compared with leaf removal or no treatment under three soil regimes, two of which received fumigation and one of which was left unfumigated.
6. The unfumigated trees grew poorly and did not respond at all to any branching treatment. Lack of fumigation is not an option for such a new planting if satisfactory tree growth is to be obtained.
7. Cyclanilide was particularly effective in stimulating branching when applied according to the timing criterion developed in other work. This research is promising and deserves additional attention for this type of planting, where specific branching development is a part of the canopy-development plan.
8. Cyclanilide does not induce lateral branching under poor vigor conditions. Trees must be in the highest vigor to produce a good result from cyclanilide or Promalin.

Summary:
Apogee can be used effectively to control vegetative growth. Critical factors that affect the outcome of an Apogee program include 1) maintaining a sequence of applications without interruption during the period of establishing control over growth; 2) applying at least three sprays of Apogee when growth is vigorous, 3) getting to know your orchard so that you can determine whether you need more than three applications for successful control, 4) not letting applications lapse beyond three weeks between sprays. It is possible to start Apogee applications after shoot growth is well underway (e.g., at 12 inches or so of growth), but control will be significantly less. Do not expect improvement in return bloom from treatment with Apogee. Apogee does not appear to impair fruit size.

GA applied shortly after bloom can effectively reduce return bloom in "off"-year 'Fuji' trees that otherwise would initiate a "snowball" bloom that favors continued alternation of production. Despite an increase in fruit set due to the lesser amount of bloom, fruit load and yield are reduced in the growing season one year after GA is applied. So far, results have shown that a single such application of GA effectively shifts alternation to the opposite cycle but has not moderated the tendency for alternation. These results clearly indicate that other interventions are required in seriously alternating cultivars if the alternating behavior is to be controlled. Applying an aggressive thinning strategy in conjunction with and in seasons after treatment with GA reduces yield, as expected. However, in one GA trial where aggressive thinning was applied for three years in succession, alternation was not controlled and trees displayed a strong tendency for continued alternation. When GA reduces bloom, more resting spurs are created. Increased fruit set thus must be due to clustering, i.e., more fruits per fruiting spur. Do those resting spurs initiate flowers as well as resting spurs on trees with less clustering?

Ethephon is registered for use on apple trees in early summer for stimulation of flower initiation. This approach could have benefit if used in the "on" year in conjunction with GA in the "off" year to better manage flowering. However, the reliability of ethephon for return-bloom stimulation in cropping trees when applied well after bloom is unclear. In one trial in 2003, ethephon applied 30 to 60 days after flowering did not improve return bloom. Another trial with higher ethephon concentrations was established in 2004. Bloom results will be assessed in 2005.

Cyclanilide is a very effective inducer of lateral branching in apple trees. However, extensive trials in the last three years have shown very clearly that its beneficial effects are limited to breaking apical

dominance in vigorously growing shoots only. Cyclanilide cannot induce latent buds or pre-existing buds on 1-year-old or older wood to break and grow in the spring. Cyclanilide may have a valuable role in managing branch development in the growth of sleeping-eye trees or other young trees where desired branch location is known and treatments can be applied at an appropriate timing to induce lateral branches in the proper locations. Cyclanilide only works effectively in trees of the highest vigor. Poor-vigor trees will show NO branching response to cyclanilide.

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Summary of total project costs:

Project duration:	Three years
Total project costs:	$58,011