Research Grant Proposal for 2021

State Horticultural Association of Pennsylvania

Title: Targeted Blossom/Green Fruit Thinning with Variable Rate Sprayer

Personnel: *Long He* (PI), Department of Ag & Bio Engineering, Penn State Fruit Research and Extension Center, P. O. Box 330, Biglerville, PA 17307. Phone: 717-677-6116, Email: luh378@psu.edu.

James Schupp (Co-PI), Fruit Research and Extension Center, Biglerville, PA 17307

Daeun Choi (Co-PI), Department of Ag & Bio Engineering, University Park, 16802

Paul Heinemann (Co-PI), Department of Ag & Bio Engineering, University Park, 16802

Duration of Project: Continuing project; Year 2/2

Project Budget: $11,569 (Year 2)

Justification:

Blossom or green fruit thinning is a critical task for crop load management in the apple production. Normally, as high numbers of flowers per tree set fruit (Figure 1), a reduction in the number of fruits per tree by thinning is necessary, both for optimal fruit development and good return bloom. Thinning can be carried out during bloom (flower thinning), but it is more often done later (fruit thinning), because growers want to be certain that fruit set is adequate. Manual thinning, chemical thinning, and mechanical thinning are typically the ways that growers used to thin the fruit crops, for both blossom and green fruit thinning.

Figure 1. Illustration of blossoms and green fruits in apple trees which may request thinning

Hand thinning could selectively remove these excessive blossoms or green fruits and achieve good crop load management. However, it is very time-consuming and costly to adjust blossom numbers or remove green fruits by hand. It would be neither practical nor economical to conduct thinning for a large number of trees manually. In most cases, manual thinning is used for follow-up to the chemical thinning. Mechanical thinning typically uses rotary brush type mechanism to remove blossoms from the trees (Seehuber et al., 2012). However, the mechanical blossom thinning was most effective in stone fruits, such as peaches. It could cuase plant damage and possibly disease spreading for apples (Kon et al., 2013; Ngugi and Schupp, 2009).

Chemical fruit thinning has been widely studied on different crops, such as apples, peaches, pears, and olives (Einhorn and Arrington, 2018; Giovanaz et al., 2016; Looney, 2018; Fernández et al., 2015). Chemical thinning is becoming one of most important spray practices for many apple growers (Greene and Autio, 2012). The greatest problem with chemical thinning is the inconsistency of response. Sub-optimal thinning, namely massive chemical application for thinning, may cause excessive crop density, small fruit size, and poor return bloom; or low final fruit set and loss of yield. Therefore, it is important to improve the precise and accuracy of the chemical thinning process. Targeted thinning, defined as accurate spray to the tree canopy based on the density and distribution of the blossoms/green fruits, would be a potential method to address this issue. Furthermore, the targeted application of caustic blossom thinner might also reduce risk of damage to leaves- phytotoxicity.

Some studies have reported on targeted spraying for reducing pesticide use for orchard fruit trees. For example, ultrasonic sensors (Stajnko et al., 2012) and Lidar scanner (Jeon and Zhu, 2013) were used for targeted spraying to reduce chemical use for fruit orchards. While, these systems are mainly for identifying the absence of the tree canopies in the tree row, and skipping the spray to the areas without canopies. No study has been reported on the targeted chemical thinning by detecting the density and distribution of blossoms and small fruits. There are two major tasks in the targeted spray system, including detection of blossoms and green fruits in the tree canopy, and applying chemical thinner to the targeted locations with variable spray rate. We have some preliminary studies on the machine vision to identify apple blossoms and green fruits (Dr. Choi), and intelligent sprayer (ongoing, Dr. He). Dr. Schupp has extensive experience on crop load management. This proposal will integrate the expertise from these three aspects. More studies will be needed to target the density and location of these blossoms or green fruits in the tree canopy, thus, to provide the decision-making strategies to chemical thinning. At the end, the integrated system will be tested in the orchard environment.

The **primary goal** of this study is to conduct targeted and precision spray for blossom/green fruit thinning with better efficacy of chemical usage and crop load management.

Brief Summary for Year 2020

This project is a continuation from 2020. The overall project goal and research objectives are in our original proposal, which is attached. A series of studies have been conducted in Year 2020 as the proposal described. First, the brief review and summary of the activities and corresponding results are as follow:

1) Evaluation of targeted and precise crop thinning

A series of green fruit thinning tests were conducted in the 2020 season to evaluate different thinning methods in a 'GoldRush' tall spindle apple orchard at the Fruit Research and Extension Center. The four thinning methods (Figure 1) include: chemical thinning with airblast sprayer (Treatment 1 – massive spraying), chemical thinning with handheld sprayer (Treatment 2 – targeted fruit cluster thinning), manual thinning (Treatment 3), and no thinning (Control). Fifteen trees were used for each treatment (except only six trees for the 'Control'). The two chemical thinning methods were carried out on May 25th, 2020, on a calm and sunny day, and the hand thinning was done on June 11th, 2020. The chemicals include Exilis 9.5 SC (6BA)@150 ppm, Carbaryl 4L@600 ppm, and Regulaid surfactant@0.125%. The airblast sprayer used about 7 gallons mix, and the handheld sprayer used about 4 gallons mix.

Figure 1. Field tests of different thinning methods, airblast sprayer (left), handheld sprayer (middle, no field test picture), and hand thinning (right, with an Equilifruit disc).

In early November 2020, the test trees were harvested, and the fruits were collected and graded in an automated grading system. The average number of fruits per tree, the average of fruit weight per tree, and the average single fruit weight were analyzed (Figure 2).

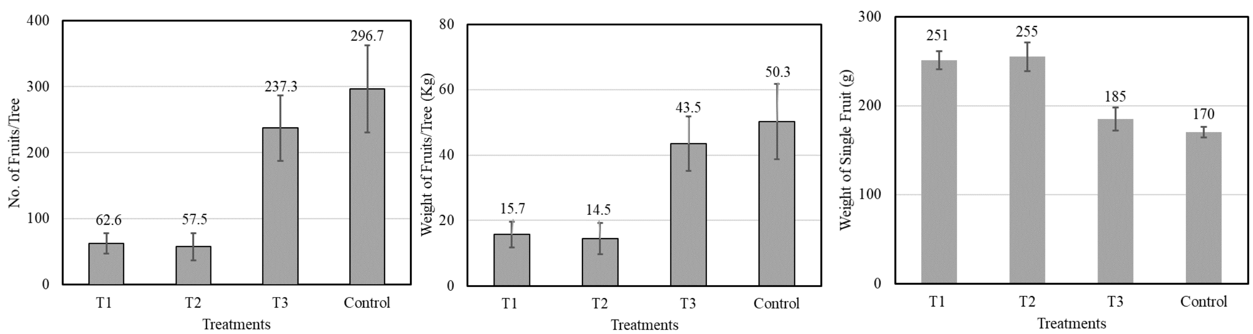

Figure 2. The results of crop yield and quality for the four thinning methods: number of fruits per tree (left), weight of fruits per tree (middle), and weight of single fruit (right).

The two chemical thinning methods had the least number of fruits per tree, as well as the weight of fruits per tree. The single fruit size was much bigger compared to the hand thinning and no thinning. There was only a slight difference between the two chemical methods, and both were over-thinned. The results also indicated the uncertainty of chemical thinning with weather dependence. For the handheld sprayer, we applied thinner to all the fruit clusters (three or more fruits) possibly leading to over thinning. An equilifruit disc was used to guide the decision of fruits remaining on a branch based on the branch diameter. It is likely that we did not remove enough fruits with hand thinning, which resulted in many small fruits. The possible reason is that there were too many secondary branches growing from the renewed cuttings, while we considered each individual one of these secondary branches as a fruiting branch. Therefore, in the future, we either should remove some of these secondary branches, or we should leave less fruits than suggested by the disc.

2) Preliminary studies on the blossom/green fruit detection

To apply precise chemical thinning, the information such as the location and distribution of blossoms and green fruits is necessary. We have started to conduct preliminary studies on blossom detection. Figure 3 shows two different methods we are exploring, one is using bounding boxes to identify blossom clusters, and the other one is to identify individual flowers. For precision chemical thinning, identifying objects at cluster level should be sufficient. The pixel-leveled annotation is much more time consuming, but it may be necessary for robotic operations (single crop-level thinning or pollination).

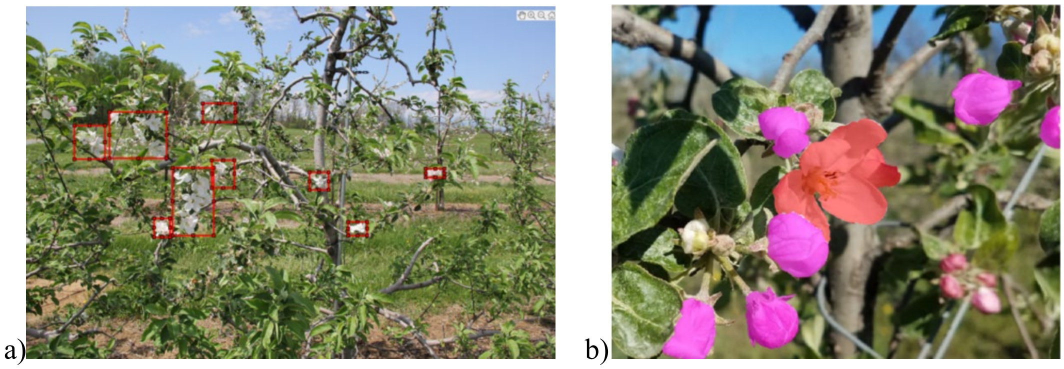

Figure 3. a) Bounding box labeling for detecting blossom clusters, and b) pixel-level flower labeling for detecting individual blossoms

Meanwhile, we are working on green fruit detection with machine vision system to identify the fruits to be removed. During the study in 2020, we also determined that using the airblast sprayer will be very difficult for precise chemical thinning because each nozzle will cover a relatively large section of tree canopy. Therefore, we will investigate a vertical boom type spraying system for this application in the coming season.

Major Research Activities Planned for Year 2021

1) Continue another year of field test with different thinning methods

We are planning to conduct the field test for another year on the proposed four thinning methods, especially the target chemical thinning and hand thinning. The outcome is expected to provide guideline information for both precision chemical thinning (using sprayer) and robotic green fruit thinning (using robotic system).

2) Detection of blossoms/green fruits to identify the distribution of blossoms/fruits

A large number of images will be acquired in 2021 during full bloom stage and green fruit stage (fruit size of ~17-25 mm). Algorithms will be developed or improved to identify the blossom clusters and fruit clusters in the tree canopy. With the identification of the blossom and fruit clusters, the crop density maps will be generated for each individual tree. It is expected that crop density maps will be used to guide the control of sprayers to apply chemical thinner to the tree.

3) Preliminary test on the precision spraying for crop thinning

A prototype of a vertical boom type sprayer will be developed. An array of nozzles (four to six in this study) will be installed at one side of the sprayer. Each nozzle can be individually controlled by a PWM (pause width modulation) solenoid valve. A microcontroller will be used to control these valves. The system will be functionally tested in the lab and possibly in a small-scale field test. The prototype is expected to assist the development of future full scale precision chemical thinning sprayer system for tree orchards.

References:

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Budget and Justification (Year 2)

Budget: ($11,569 for Yr2)

	Year 2	
Salaries/Wages	$9,330	(One wage student and one summer graduate student)
Fringe	$739	
Materials/Supplies	$1,000	(Sprayer nozzles, pump, controller, etc.)
Travel	$500	(Field test, local presentation, etc.)
Total	$11,569	