Implementing the Pollen Tube Growth Model on NEWA

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Keywords: apple, crop load management, crop modelling, thinning, Malus ×domestica (Borkh.)

This research was partially supported by the New York Apple Research and Development Program

The Pollen Tube Growth Model (PTGM) is an empirically-derived model that increases the precision of bloom thinning for apple orchards. In the Eastern U.S., fruitlet thinning at 10 mm has been the standard practice for conventional apple growers, most likely because of perceived risk of frost damage and poor pollination, previous experiences with ineffective bloom thinning materials, poor understanding of the appropriate application timing, and the potential for fruit russet from liquid lime sulfur and other caustic materials. However, compared with fruitlet thinning, chemically thinning apple flowers often produces larger fruit at harvest, greater return bloom, and reduces biennial bearing. Precisely timed chemical bloom thinning provides apple growers with a significant advantage in producing high yields of the best quality fruit.

"A new computer model is now available on the NEWA website which can help growers precisely time thinning sprays during bloom. It is named the pollen tube growth model (PTGM). This model will expand available thinning options and methods for apple growers and it will help growers who use bloom thinning to increase the precision of achieving their target crop load."

How the Pollen Tube Growth Model Works

The PTGM was developed through a decade of research at Virginia Tech (Yoder et al. 2009; Yoder et al. 2013). By conducting temperature-controlled studies in growth chambers, researchers were able to create variety-specific, temperature-based models for apple pollen tube growth. The pollen tube growth rates are then used to estimate the length of time between pollination and fertilization of apple flowers. Growth rate models have been developed for 'Cripps Pink' ('Pink Lady®'), 'Fuji', 'Gala', 'Golden Delicious', 'Granny Smith', 'Honeycrisp', and 'Red Delicious'. Models for additional varieties are currently under development at Virginia Tech and elsewhere. A "universal" pollen tube growth model that can be used for other varieties is currently being developed in Dr. Peck's lab.

To use the apple pollen tube growth rates for bloom thinning, the grower starts the model when the desired number of king bloom flowers are in full bloom (that is, when the petals no longer cover the reproductive organs thus allowing for cross-pollination). The desired number of open king bloom flowers is equal to the desired crop load and can be determined by counting the number of flower clusters per tree or by visually assessing potential bloom density in the orchard. Style length is measured on 25-50 flowers at this time with a ruler or caliper and an average style length is used to determine how far the pollen tubes need to grow in order to reach the ovule and fertilize the flower. Hourly temperatures recorded by weather stations in or near the orchard are used with the known temperature-dependent pollen tube growth rate equations to calculate cumulative pollen tube growth.

An initial chemical bloom thinning application is made when the modelled pollen tube lengths are equivalent to average style length. The supposition is that fertilization has occurred at this point. Assuming that pollen tubes must grow the entire style length on flowers that reached full bloom after an application of a bloom thinner, the model is reset after the bloom thinning application is made. Additional bloom thinning applications occur when pollen tubes have been modeled to reach 50% of the style length and should occur no later than 100% of the style length to prevent fertilization of additional flowers. Applications cease at the end of bloom. Typically, two applications are necessary each year, but more may be required for years with an extended bloom.

The PTGM has been field tested for bloom thinning in Washington, Virginia, and Pennsylvania (Peck et al. 2016; Peck et al. 2017; Kon et al. 2018). Most often, a caustic material, such as liquid lime sulfur (LLS) or ammonium thiosulfate (ATS) is used alone or in conjunction with an oil to damage the pollen tube and/or other reproductive organs. Common use rates of LLS in Washington State are between 1 and 5%. The lower rates are often used in combination with an oil. The specific oil type (fish, vegetable, or petroleum) appears to only have a minimal impact on thinning efficacy (Yoder et al. 2013). Both LLS and ATS can result in over-thinning, fruit russet, and foliage damage in some years, so growers should use these materials with caution. It may take several seasons to learn how to best use bloom thinners in commercial situations. Growers will also need to check labels to ensure that they are using the product in accordance with state and federal regulations. Some LLS products prohibit applications during bloom.

In addition to LLS and ATS, the biofungicide, Regalia® (Marrone Bio Innovations, Inc., Davis, CA), made from the extracts of Giant Knotweed [Reynoutria sachalinensis (F. Schmidt) Nakai syn. Polygonum sachalinense (F. Schmidt)],

has been found to function as an apple bloom thinner (Peck et al. 2016; Peck et al. 2017; Yoder et al. 2013). Regalia® can be a milder thinner than LLS. Our research found that thinning for both LLS and Regalia® was improved when the products were tank mixed with an oil. However, Regalia® is not explicitly labeled as a bloom thinner. Both LLS and Regalia® can be used for organic production and provide some control of apple scab [Venturia inaequalis (Cooke.) G. Wint.] and cedar apple rust (Gymnosporangium juniperi-virginiana Schwein.) when used as a bloom thinner (DeLong et al. 2018).

Plant growth regulators, including 6-benzyladenine (6-BA), naphthaleneacetamide (NAD), and 1-naphthaleneacetic acid (NAA), and endothall (an aquatic herbicide) have also been tested for use as bloom thinners with the PTGM. In unpublished tests conducted in a 'Cripps Pink' (Pink Lady®) orchard in Winchester, VA, two applications of NAD (at both 25 and 50 ppm) and of NAA (10 ppm) resulted in significantly less crop load compared with the unthinned control, while 6-BA (at both 50 and 100 ppm) was not different than the control (Peck, unpublished data). Kon et al. (2018) found that endothall (1,500 ppm) applied in accordance with the PTGM reduced crop load in both 'Gala' and 'Golden Delicious' orchards but did not find NAD (50 ppm) to significantly decrease crop load in a 'Golden Delicious' orchard. These authors also found that ATS (2%) reduced crop load when two applications were made in accordance with the PTGM but suggested that LLS provided the best overall thinning response.

Phytotoxicity and potential harm to pollinators is a concern for any material applied during bloom. Growers should work with extension specialists in their state to identify appropriate and legal materials for their orchard. Additionally, research is needed to identify the bloom thinning materials that match the crop load goals for different varieties and market destinations. Replicated field trials are currently underway at the New York State Agricultural Experiment Station in Geneva, and grower-cooperator trials have occurred in each of New York's main apple growing regions to further the understanding of bloom thinning materials in our region. Results from these projects will be made available in the near future.

The NEWA Interface

The PTGM will be available through Network for Environment and Weather Applications (NEWA), an online agricultural decision aid system operated by the New York State IPM Program in close collaboration with the Northeast Regional Climate Center (NRCC) at Cornell University. In 2018, the PTGM was programmed into NEWA for field testing by researchers and extension specialists. Over the course of the 2018 growing season, technical issues were resolved, and improvements made to the model user interface. In 2019, the PTGM will be available at: ptgm.newa.cornell.edu. This link will remain active until the NEWA website rebuild is completed.

The PTGM was designed with new features that depart from the way current apple resources and models are implemented on NEWA. The biggest of these is the ability for the website to save settings (for example, the weather station of interest) and management locations (that is, users can save orchard blocks by name and then return to those settings each time they log into the site). In order to make the PTGM available during the 2019 season—prior to the NEWA website relaunch, entered data will be saved to the local storage on your device. The data will be stored until the web browser cache is manually cleared. After the 2019 rebuild of the NEWA website, the PTGM settings will be saved in personal NEWA accounts and retrievable by logging in with your user name and password from any device.

Read the Documentation. The PTGM starts by default on a page that provides instructional documentation. Be sure to carefully read these instructions. If you need to refer back to this page, click the "i" button always located to the center left under the title bar.

Getting Started with PTGM. The PTGM organizes information by "Block." A block is a user defined farm management unit. For example, it might be an entire orchard or farm, a specific varietal planting, or other designation that fits within your farm management plan.

Create a New Block. Start by opening the PTGM page and clicking the + Block button to create a new Block. Choose a name for your block and select one of the seven available apple varieties. Next, select your State and then find your weather station or a suitable station near your farm. When complete, click the "Add Block" button (Figure 1).

The PTGM Parameters. After a new Block is created, select the 'Start Date' button to choose an exact date and time when the desired number of king blossoms were open (Figure 2). Then, enter the style length measurements by clicking 'Style Length' (Figure 3a). You will be presented with two entry options, both of which rely on growers to measure style lengths. Selection of the 'Insert average style length' option provides a single field for entry of an averaged style length (Figure 3a). The second option, 'Calculate average style length' permits the entry of single style length measurements from which the software will automatically calculate an average style length (Figure 3b). For this second option, click 'Cancel' once all the style lengths have been entered and your data will be saved. Style length can be measured with a ruler or caliper. Our data shows that there is enough block-to-block and year-to-year variability to warrant unique measurements for each block in each year that the model is being used.

Initial PTGM Output. After the start date and style length are entered into the PTGM, the display changes. A graph appears that shows the progression of the modeled pollen tube length relative to the grower-determined style length. A management message also appears above this graph, which can be toggled on and off by selecting the circular 'i' icon to the right side of the block's title bar. A button called 'Growth Table' can be clicked to view daily summaries of air temperature (°F), hourly and accumulated pollen tube growth (mm), and '% of Target' which is the modeled pollen tubes length relative to the style length. A third button to the bottom right called 'Growth Graph' can be clicked to show a graph of hourly temperatures over the period of time defined by the user (Figure 4). The PTGM uses forecasted hourly temperatures for five days into the future. If you hover your cursor over the graph, a display pops up showing 1) date and time, 2) relative pollen tube growth, and 3) cumulative HrG (Hourly Growth). The Growth table described earlier provides these values in a different format (Figures 5a and 5b). As the modeled pollen tube length approaches the style length, growers are advised to make a bloom thinning application.

Set your Spray Dates. After the first application has occurred, the grower will need to enter the exact date and

time by clicking the 'Set 1st Spray' button. The model will reset pollen tube growth to zero at that time. Repeat the process with a second spray by clicking 'Set 2nd Spray', but only after the first spray has been entered. Then, once more, with a third spray using 'Set 3rd Spray'. Application dates and times are then displayed in the output graph (Figure 6).

Editing Existing Blocks. Name, apple variety, state, and station can be modified after initial entry by clicking the 'Edit' icon to the right side of a Block header bar. Dates including model start, first spray, second spray, third spray, and end date can also be modified from this interface (Figure 7).

Viewing Multiple Blocks. The PTGM allows multiple blocks to be viewed in a summary format. If you have multiple blocks entered, click the second button from the left under the model title that says 'Blocks (#)' and a summary of blocks, each with start date, respective spray dates, intervening pollen tube development (as a %) and end date will be presented. To view a single Block from this multiple-view interface select an item from the 'Block List' drop down to the upper right under the model title bar (Figure 8).

Getting Help. First refer to the model documentation by click the "i" button which is always located to the center left under the title bar. This provides context and defines important input parameters. If you are unable to solve a problem or experience an unexpected technical glitch with the PTGM, contact the NEWA Help Desk by email at support@newa.zendesk.com. This will generate a work ticket and a staff member will troubleshoot the problem with you.

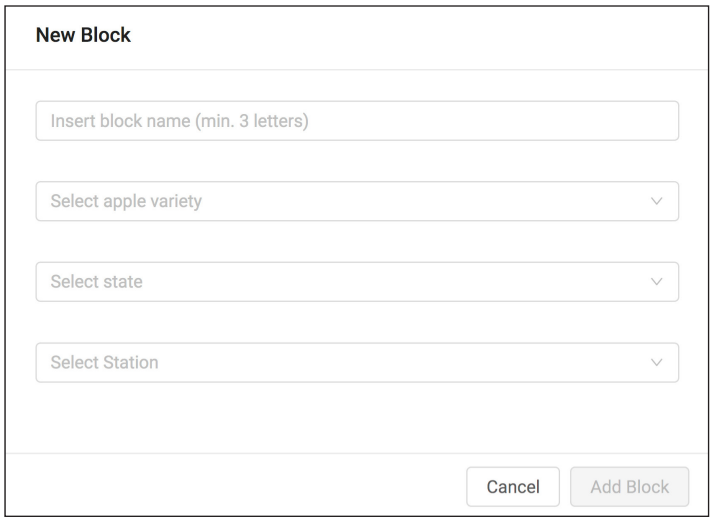


Figure 1. Add new block information.

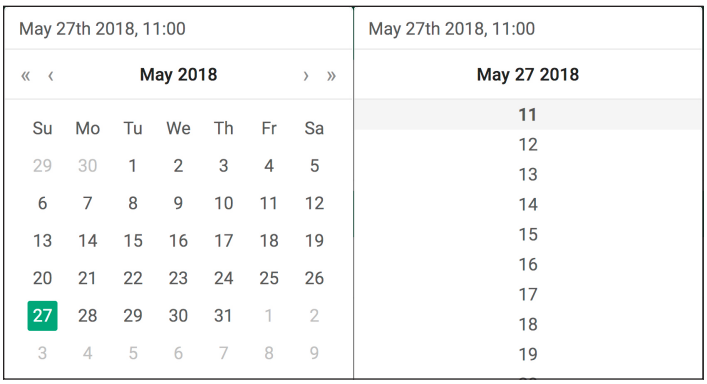


Figure 2. Choose the model start date and time

Conclusions

Having the PTGM incorporated into NEWA will expand available thinning options and methods for apple growers who face increasingly variable growing conditions across the region. The PTGM will bolster the profitability of apple growers by making bloom thinning more reliable and help reduce biennial bearing issues on varieties such as Gala and Honeycrisp. Additionally, using the PTGM for bloom thinning increases the precision that growers are trying to achieve in their crop load management plans.

Acknowledgments

We thank the Apple Research Development Program for funding support. Alex Sinafarosa developed the programming for the PTGM interface on NEWA with oversight from Dr. Art DeGaetano, Director of the NOAA Northeast Regional Climate Center. Dr. Keith Yoder provided a critical review of this manuscript and, who along with his technician Leon Combs, has overseen more than a decade's worth of research to develop the PTGM. A special thanks to Dr. Juliet Carroll, Fruit

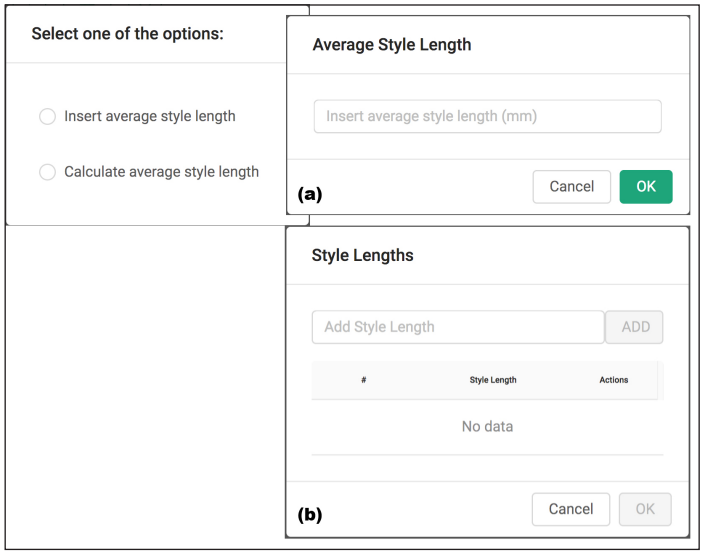


Figure 3. Interface to enter (a) average style length or (b) individual style lengths.

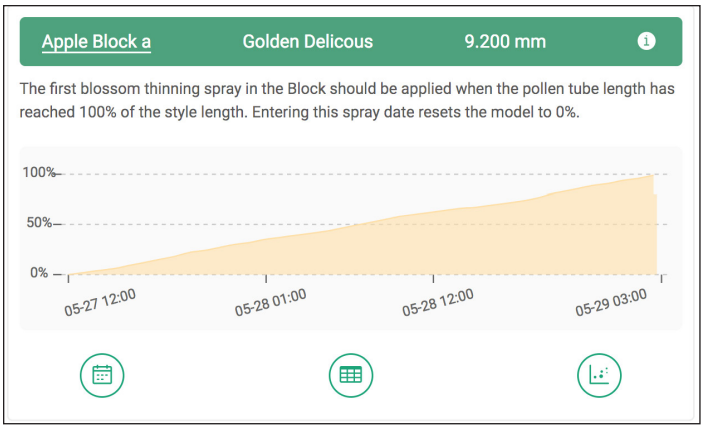
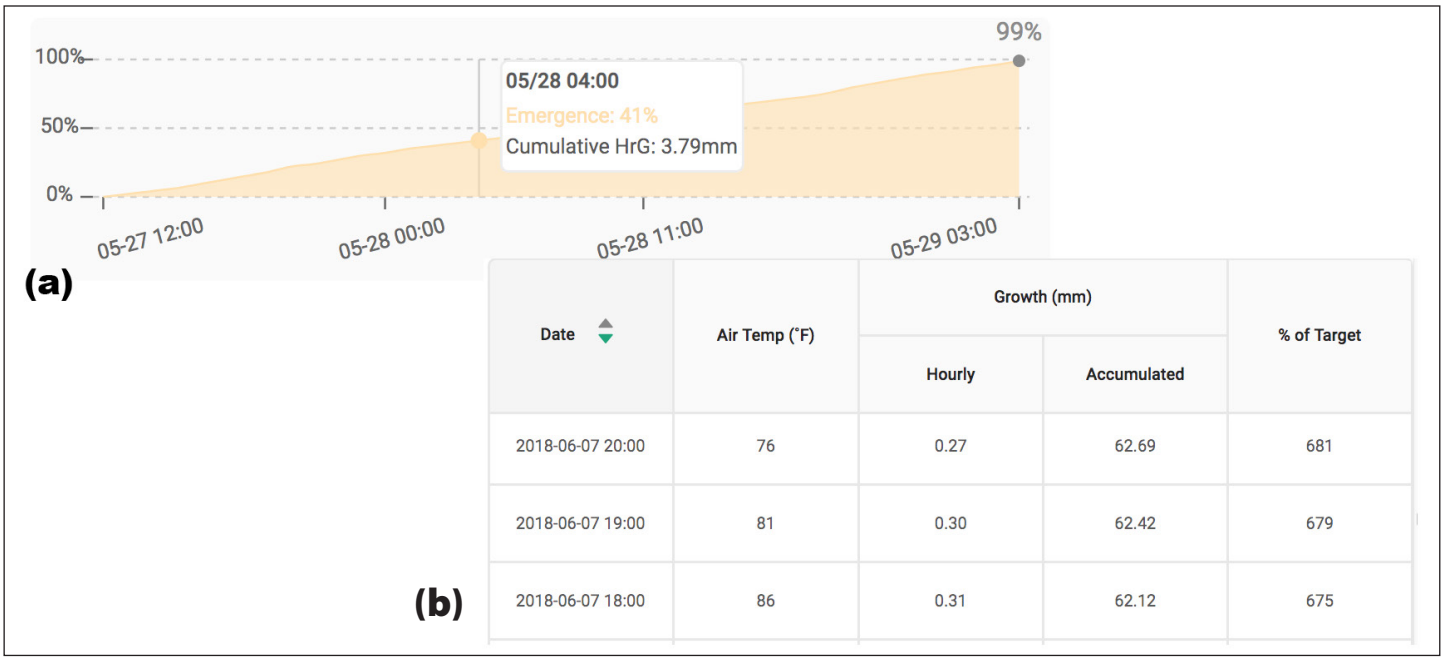


Figure 4. Full model output.



Date	Air Temp (˚F)	Growth (mm)		% of Target
		Hourly	Accumulated	
2018-06-07 20:00	76	0.27	62.69	681
2018-06-07 19:00	81	0.30	62.42	679
2018-06-07 18:00	86	0.31	62.12	675

Figure 5. (a) Model graph pop up and (b) growth table output.

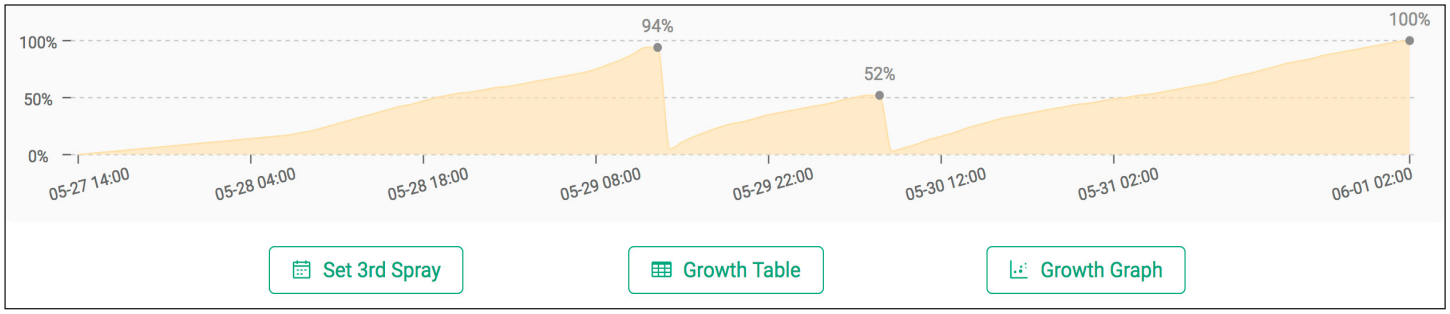


Figure 6. Enter first, second, third spray.

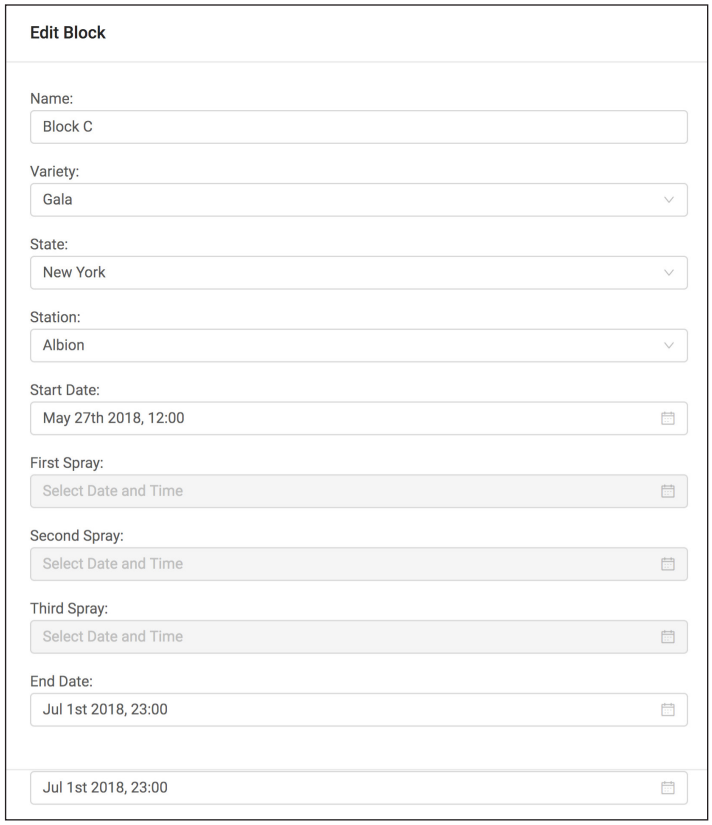


Figure 7. Editing Block information.

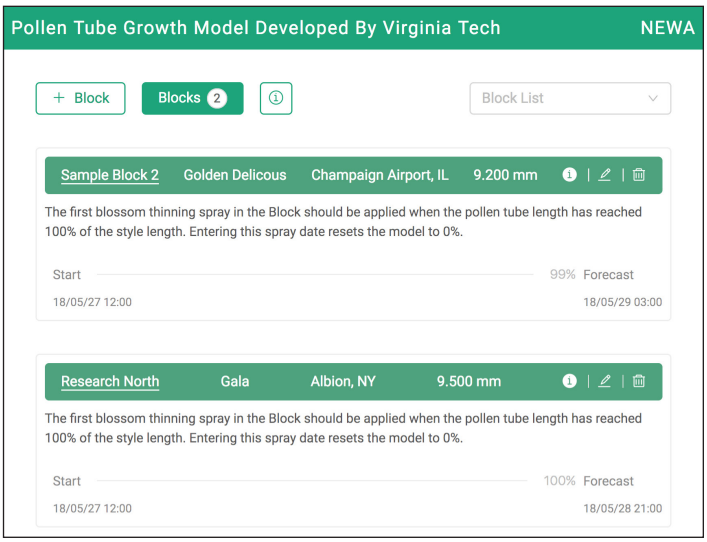


Figure 8. Summary view.

Coordinator for the New York State IPM Program, for getting the ball rolling on the PTGM-NEWA interface.

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