Northern NY Agricultural Development Program
2019 Final Report

Continued Use of RIMpro Apple Disease Models on Apple Farms in NNY's Lake Champlain Valley for Prediction of Fire Blight and Apple Scab in 2019 to Time & Reduce Pesticide Sprays

Project Leaders:

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Collaborators:

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• Zeljko Radenovic, Student Intern, Acimovic Lab, HVRL

Cooperating Producers: Seven apple farms in NNY (only 4 listed, but others were targeted and impacted too):

1. Chazy Orchards Inc.
Mr. Jay Toohill
chazyorchards@westelcom.com,
customerservice@chazyorchards.com
9486 U.S. 9, Chazy NY 12921

2. Northern Orchards
Jesse and Jenna Mulbury
jam623@cornell.edu, Cell: 518 572 5740
537 Union Rd, Peru NY 12972

3. Everett Orchards
Kyle Everett
Cell: 518 335 5465
675 Calkins Rd, Peru NY 12972

4. Forrence Orchards - Valcour
Seth, McIntosh and Mason Forrence
forrencemac@aol.com
753 Telegraph Rd, Peru NY 12972

Background:

Fire blight infects apple flowers, shoots, and wood, and can kill entire trees. Unusually hot and humid weather with rains and hail at the end of apple bloom in 2016, favored serious fire blight epidemic in Northern New York (NNY), causing severe losses to apple industry in this region with ca. 30,600 acres of apples (western NY: 27,500 acres; Lake Champlain Valley: 3,100 acres). Losses in yield, trees, ineffective spray applications, and fruit budwood were estimated at more than $16 million.

Overwintering fire blight cankers remaining after this epidemic on infected trees will serve as infection sources for years to come. Considering climate change predictions by climatologists and meteorologists, we predict that years with unusually warm and humid weather favoring fire blight will become more frequent in NNY. Hence, it is essential to support NY's apple industry in using new fire blight prediction models in NEWA (Network for Environment and Weather Applications) and RIMpro cloud services. Additionally, if left unmanaged, apple scab fungus (*Venturia inaequalis*) whose infection periods are also accurately predicted by these online-available predictive model services, can cause 70–100% reduction in marketable fruit yield in each year.

Project Goal:

The goals of this Northern New York Agricultural Development Program-funded project in 2019 were:

- to outsource RIMpro's apple scab model and NEWA's new EIP (fire blight model (Maryblyt, originally developed by Dr. Paul W. Steiner, University of Maryland, and Gary Lightner, USDA) as currently the best options allowing excellent to good accuracy in prediction of these diseases based on 5- to 10-day weather forecast,
  (1) through continued extension, promotion and grower education in using the new disease prediction models,
  (2) providing model calibration and technical support in setting on-farm RIMpro systems up, and
  (3) sending model interpretations and disease recommendations to RIMpro subscribers and users of free NEWA EIP model; and
- to continue research on comparing basic outputs of RIMpro and NEWA models for accuracy so growers can avoid unnecessary bactericide/fungicide sprays based on these models; and
- to present project results to NY apple growers at extension meetings to increase their knowledge on the necessity for using models to better prevent and manage infections.

Under the climate change conditions, it is and will be essential for growers to use these models to predict outbreaks and thus accurately time protective antibiotic sprays. In previous years, weather conditions were extremely favorable for fire blight and apple scab in the Hudson River Valley and Lake Champlain Valley. Depending on an orchard location, there were 2-6 severe infection events recorded by fire blight prediction models such as RIMpro and NEWA. Besides fire blight, the fungus *Venturua inaequalis* infects orchards every year, with 2-9 recorded infection periods per year. These infections can cause fruit losses if spray applications are not timed well by using models. In the humid climate of NY that favors both apple scab and fire

blight diseases, intensive fungicide spray programs must be applied every year to produce high quality fruit that can be marketed for top price.

RIMpro's apple scab model and NEWA's new EIP (Epiphytic Infection Potential) fire blight model are currently the best options allowing excellent to good accuracy in prediction of these diseases based on 5- to 10-day weather forecast. These models are also essential to address the numerous challenges that burden the apple industry and stem from intense application of fungicides on a calendar or weekly basis and application of antibiotics unguided by models:

(1) plant-based agriculture is scrutinized by the public and legislature due to fears of antibiotic resistance development, while at the same time alternative fire blight control products have so far shown mediocre efficacy under heavy disease pressure,
(2) effective bactericides for fire blight are getting harder to label by the EPA,
(3) risk of fungicide resistance development in *V. inaequalis* populations and loss of their efficacy,
(4) public concern for accumulation of pesticide residues in fruit,
(5) scab-susceptible cultivars favored by fresh fruit buyers grown under reduced-spray management programs, and
(6) increasing pressure on apple growers to reduce pesticide use, while maintaining a high level of fruit quality.

If growers do not use models to potentially reduce use of pesticides in apple protection programs, it will be increasingly difficult to control fire blight and apple scab in the future under extreme weather patterns favoring infections. The new fire blight model equips growers to effectively prevent disease epidemics and to reduce the number of total spray applications per season depending on year-specific weather conditions.

Methods:

In fall of 2018, after apple leaf drop, we selected and collected the most scab-infected leaf litter on the orchard floor from a single source (experimental orchard in Highland, NY) and placed it at three different locations in NY, including the northernmost location in NNY at Peru in Clinton County. We monitored apple scab fungus maturity late in winter of 2019, from 20 March onward on a weekly basis. Leaf litter from an orchard in Peru and two other locations (Highland and Rexford, NY) was collected 1-2 times/week and shipped for examination in the laboratory at the Hudson Valley Research Laboratory using vacuum scab tower spore trap (Fig. 1) to detect and quantify the first apple scab ascospores ejected from leaf litter and thus to determine and issue to growers the date of their first detection.

This date is a necessary Biofix point in RIMpro to calibrate the model for more accurate infection periods predictions. By working in the lab on 18 April, we detected the first mature ascospores in the leaf litter collected on 16 April in Peru (Table 1; http://blogs.cornell.edu/acimoviclab/2019/04/18/apple-scab-ascospores-mature-in-leaf-litter-near-peru-ny-champlain-lake-valley-set-venturia-biofix/), which allowed correct calibration of RIMpro in Champlain Lake Valley (in Rexford ascospores were first detected on 17 April; in Highland on 28 March).

Figure 1. Left to right: Collected, selected and evenly distributed leaf litter infected with apple scab fungus *Venturia inaequalus* in previous growing season (left); Vacuum tower spore trap for collecting *V. inaeqialus* ascospores (middle); Apple scab ascospores collected in the vacuum tower visible and counted for this project under the microscope (right).

Table 1. Dates and abundance of first detected mature Venturia inaequalis ascopores in Northern and Eastern New York during 2017, 2018, and 2019 using vacuum tower spore trap, with dates of green tip (50% of fruit buds at green tip) and the backward-adjusted RIMpro biofixes based on ascospore numbers. A level of 50 to 60 trapped ascospores are considered as an economic threshold.

Locations in East New York	2017			2018			2019		
	Date of ascospore detection and their number range	*RIMpro Biofix adjusted to caught ascospore number	Apple green tip date for Zestar!	Date of ascospore detection and their number range	*RIMpro Biofix adjusted to ascospore number	Apple green tip date for Zestar!	Date of ascospore detection and their number range	*RIMpro Biofix adjusted to caught ascospore number	Apple green tip date for Zestar!
Peru/Chazy	11 April (50-127)	6 April	16 April	22 April (7-15)	13 April	3 May	16 April (7-19)	12-14 April	21-25** April
Rexford/ Altamont	7 April (25-30)	31 March	6 April	5 April (1-2)	3 April	17 April	17 April (121-188)	1-5 April	9 April
Highland	29 March (9-15)	26 March	30 March	31 March (6-16)	29 March	7 April	28 March (5-10)	26 March	7 April

**As described in the text, the Biofix date was adjusted backward after the first spore detection to adjust for the fact that leaf litter was tested for ascospore release only at 7- to 13-day intervals.*

*** Peru – Northern Orchard 22 April; Peru – Dimock Farm GT: 22 April; Chazy – Chazy Orchards GT: 25 April.*

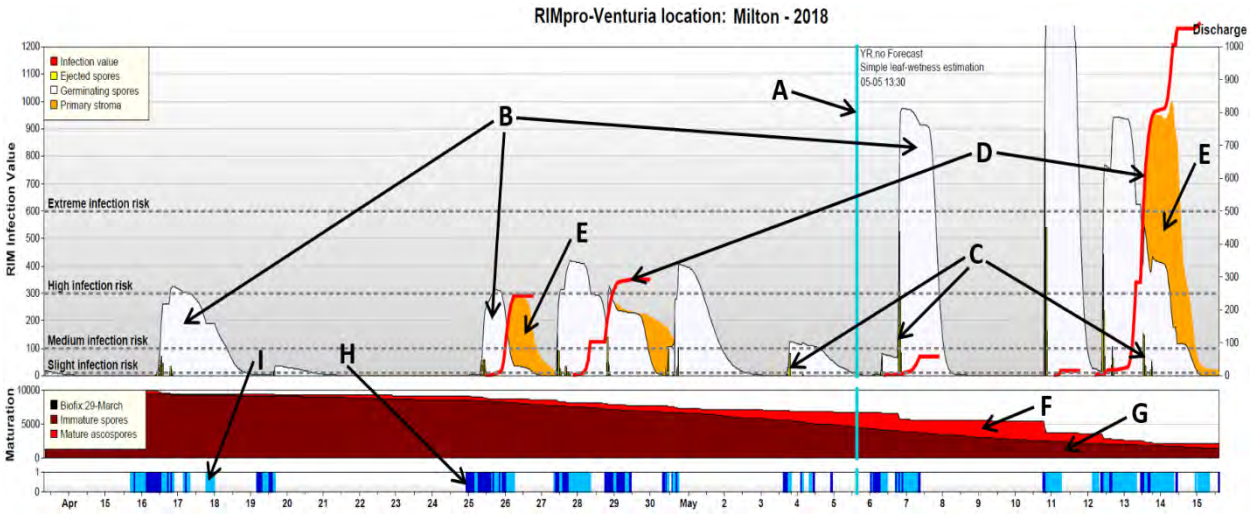


Figure 2. Example of RIMpro apple scab model output on 5 May 2019 for Milton, NY, (location unrelated to the project).

(A) Vertical light blue line marks the current date and time within that the day.

(B) White camel hump-like areas labelled "Germinating spores" designate cumulative number of *Venturia inaequalis* ascospores that germinate over time and are read using the right-side vertical Y-axis scale that is labelled "Discharge".

(C) Small yellow-black bars, seen better by using the zoom-in tool on the RIMpro screen, show the number of spores ejected from leaf litter in the orchard during each one-hour interval.

(D) The red curved line is the RIM infection value which, when divided by 100, is roughly the percentage of the total season's ascospores that are likely to cause infection in any given infection period. Read each curve's peak RIM infection value/s using the vertical Y-axis scale on the left-hand side of the graph labelled "RIM Infection Value".

(E) Orange area is called "Primary stroma" and represents scab lesions that were initiated by infection from germinating spores and that are incubating in the leaf after which scab lesions will become visible. Incubating infections are worth noting because, if no fungicide was in place before the infection event began, some or all of the incubating infections can still be eliminated by using fungicides with post-infection activity.

(F, G) The light red at the top of the middle "Maturation" graph is the proportion of mature scab ascospores that are ready for discharge with wetting events whereas the dark red (G) shows the proportion of immature ascospores remaining in leaf litter.

(H) Dark blue bars in the wetting graph with dates, at the bottom, are the actual or predicted rain periods.

(I) Light blue bars are actual or predicted wetting periods when no rain is falling but trees continue to be wet after rain. *Used by permission of RIMpro B.V., Netherlands*

We used a two-prong approach to help the NY apple industry by delivering critical apple disease prediction information and management recommendations in advance of infection risks:

- delivering e-mails (14 in 2019) to RIMpro subscribers with date-precise data on apple scab infection predictions for their farm location (23 farms); and
- delivering short blog posts (45 in 2017, 44 in 2018, 43 in 2019) on tree fruit disease management, available to the entire NY apple industry via Acimovic Lab website: http://blogs.cornell.edu/acimoviclab/.

In both cases, the key goal was quick information delivery timed to assist NY growers in planning their disease management efforts 5-7 days in advance of potentially major infection

events.

The e-mails sent to the RIMpro user group delivered screenshot images of the RIMpro apple scab model outputs containing 10-day predictions for pathogen infection periods and potential disease outbreaks for the subscribed farms and provided

(1) updates on apple growth development stages and pathogen monitoring in northern and eastern NY,
(2) interpretations and commentary of predicted scab infection periods as shown in the RIMpro output, and
(3) disease management recommendations for three regions: NNY's Lake Champlain Valley, the Lower Hudson Valley, and the NY Capital Region/Upper Hudson Valley.

We also published blog posts two or more times per week, depending on predicted weather conditions: http://blogs.cornell.edu/acimoviclab/category/12019-growing-season/. These posts allowed growers in the northern NY on a weekly basis to:

(1) know when major infection risks for tree fruit diseases were expected in relation to tree growth stages and pathogen maturity,
(2) plan and decide when to apply protective spray applications for disease management ahead of infection risks,
(3) be aware of when the first symptoms of apple scab occurred in their region, and
(4) be aware of predicted severe thunderstorms or other unusual weather events that could contribute to scab problems.

Before publishing blog posts, we analyzed and compared outputs from RIMpro and NEWA apple disease models to determine any differences in dates when infection risks were predicted. However, in the published blog posts we did not provide location-specific dates of predicted scab infection periods (i.e., risks from RIMpro's model) as this data is owned by the RIMpro subscriber and is protected by copyright laws. Instead, we used publicly available weather forecasts, NEWA's apple scab model for each region and revised Mills' table data to determine scab infection period date ranges and deliver them in blog posts.

When severe disease infection risks were predicted, growers in NY would receive e-mail alerts and emergency phone calls as necessary.

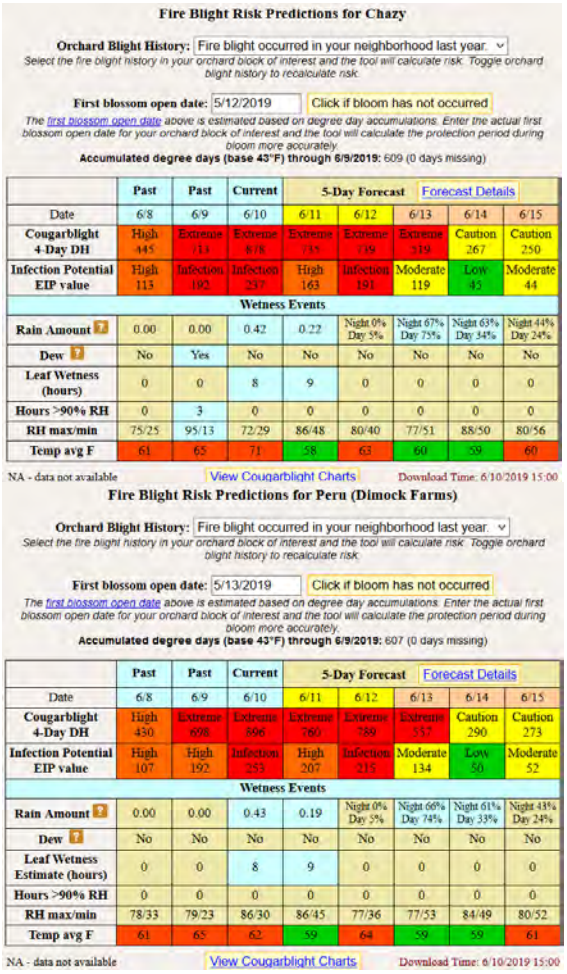
Based on the number of detected ascospores in the tower on the date when spores were first detected (Table 1) and using historical data and experience from the squash mount examinations of *V. inaequalis* pseudothecia made in prior years, we adjusted RIMpro Biofix dates to a certain number of days before the green tip date for the earliest apple cultivar on the farm to increase accuracy of the RIMpro forecasts (Table 1).

This adjustment of the first spore release Biofix was necessary because leaf litter was sampled only at roughly weekly intervals and large spore numbers on the date of first detection implied that the first mature spores may have appeared soon after the previous assessment was completed, whereas lower spore counts on the first assessment suggested that the actual date of first spore maturity was closer to the date when the testing was conducted.

We reported the dates listed in Table 1 to NY apple industry via e-mails and Acimovic Lab blog posts. To increase the accuracy of infection prediction in NEWA's apple scab model using ascospore data in Table 1, we recommended to growers that had not subscribed to RIMpro that they might also wish to set their green tip date in NEWA apple scab model to the same date when first mature spores were estimated to have been available for release, since that provides a more accurate biofix for the NEWA model as well as for the RIMpro model.

Results: Fire Blight (Make this the first Results section)

The first apple/pear flowers in Peru, NY, opened on 13, 14 and 18 May 2019 (Zestar!, Duchess of Oldenburg) and on 12 May in Chazy (SweeTango). In the Lake Champlain Valley the first fire blight predicted infection periods were on 9, 10 and 12 June according to the NEWA EIP model which we trust more than RIMpro. Based on Fig. 4 below, infections happened at the end of bloom or after bloom, depending on cultivar, as in 2016. The first fire blight symptoms on shoots were seen in Peru on Honeycrisp in early July, following a 19 June hailstorm, indicating that infections did start on very few open flowers at the end of bloom. According to RIMpro's fire blight prediction model, orchards in Peru required one streptomycin application on 4 May to cover only late blooming cultivars that were at the end of bloom. However, NEWA EIP model did not report infection on 4-5 May, while RIMpro did.



Fire Blight Risk Predictions for Chazy

Orchard Blight History: Fire blight occurred in your neighborhood last year.

Select the fire blight history in your orchard block of interest and the tool will calculate risk. Toggle orchard blight history to recalculate risk.

First blossom open date: 5/12/2019 Click if bloom has not occurred

The first blossom open date above is estimated based on degree day accumulations. Enter the actual first blossom open date for your orchard block of interest and the tool will calculate the protection period during bloom more accurately.

Accumulated degree days (base 43°F) through 6/9/2019: 609 (0 days missing)

	Past	Past	Current	5-Day Forecast				Forecast Details
Date	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
Cougarblight 4-Day DH	High 445	Extreme 713	Extreme 878	Extreme 735	Extreme 739	Extreme 519	Caution 267	Caution 250
Infection Potential EIP value	High 113	Infection 192	Infection 237	High 163	Infection 191	Moderate 119	Low 45	Moderate 44
Wetness Events								
Rain Amount	0.00	0.00	0.42	0.22	Night 0% Day 5%	Night 67% Day 75%	Night 63% Day 34%	Night 44% Day 24%
Dew	No	Yes	No	No	No	No	No	No
Leaf Wetness (hours)	0	0	8	9	0	0	0	0
Hours >90% RH	0	3	0	0	0	0	0	0
RH max/min	75/25	95/13	72/29	86/48	80/40	77/51	88/50	80/56
Temp avg F	61	65	71	58	63	60	59	60

NA - data not available View Cougarblight Charts Download Time: 6/10/2019 15:00

Fire Blight Risk Predictions for Peru (Dimock Farms)

Orchard Blight History: Fire blight occurred in your neighborhood last year.

Select the fire blight history in your orchard block of interest and the tool will calculate risk. Toggle orchard blight history to recalculate risk.

First blossom open date: 5/13/2019 Click if bloom has not occurred

The first blossom open date above is estimated based on degree day accumulations. Enter the actual first blossom open date for your orchard block of interest and the tool will calculate the protection period during bloom more accurately.

Accumulated degree days (base 43°F) through 6/9/2019: 607 (0 days missing)

	Past	Past	Current	5-Day Forecast				Forecast Details
Date	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
Cougarblight 4-Day DH	High 430	Extreme 698	Extreme 896	Extreme 760	Extreme 789	Extreme 557	Caution 290	Caution 273
Infection Potential EIP value	High 107	High 192	Infection 253	High 207	Infection 215	Moderate 134	Low 50	Moderate 52
Wetness Events								
Rain Amount	0.00	0.00	0.43	0.19	Night 0% Day 5%	Night 66% Day 74%	Night 61% Day 33%	Night 43% Day 24%
Dew	No	No	No	No	No	No	No	No
Leaf Wetness Estimate (hours)	0	0	8	9	0	0	0	0
Hours >90% RH	0	0	0	0	0	0	0	0
RH max/min	78/33	79/23	86/30	86/45	77/36	77/53	84/49	80/52
Temp avg F	61	65	62	59	64	59	59	61

NA - data not available View Cougarblight Charts Download Time: 6/10/2019 15:00

Figure 4. Critical NEWA outputs of fire blight predictions and historical fire blight infection data for Chazy and Peru, NY in 2019. Whenever EIP increases above 100 and wetting event is predicted to occur (dew, rain, ≥RH 90%) ,streptomycin in mix with surfactant should be applied preventively or up to 24 hours after the wetting event that triggered the infection.

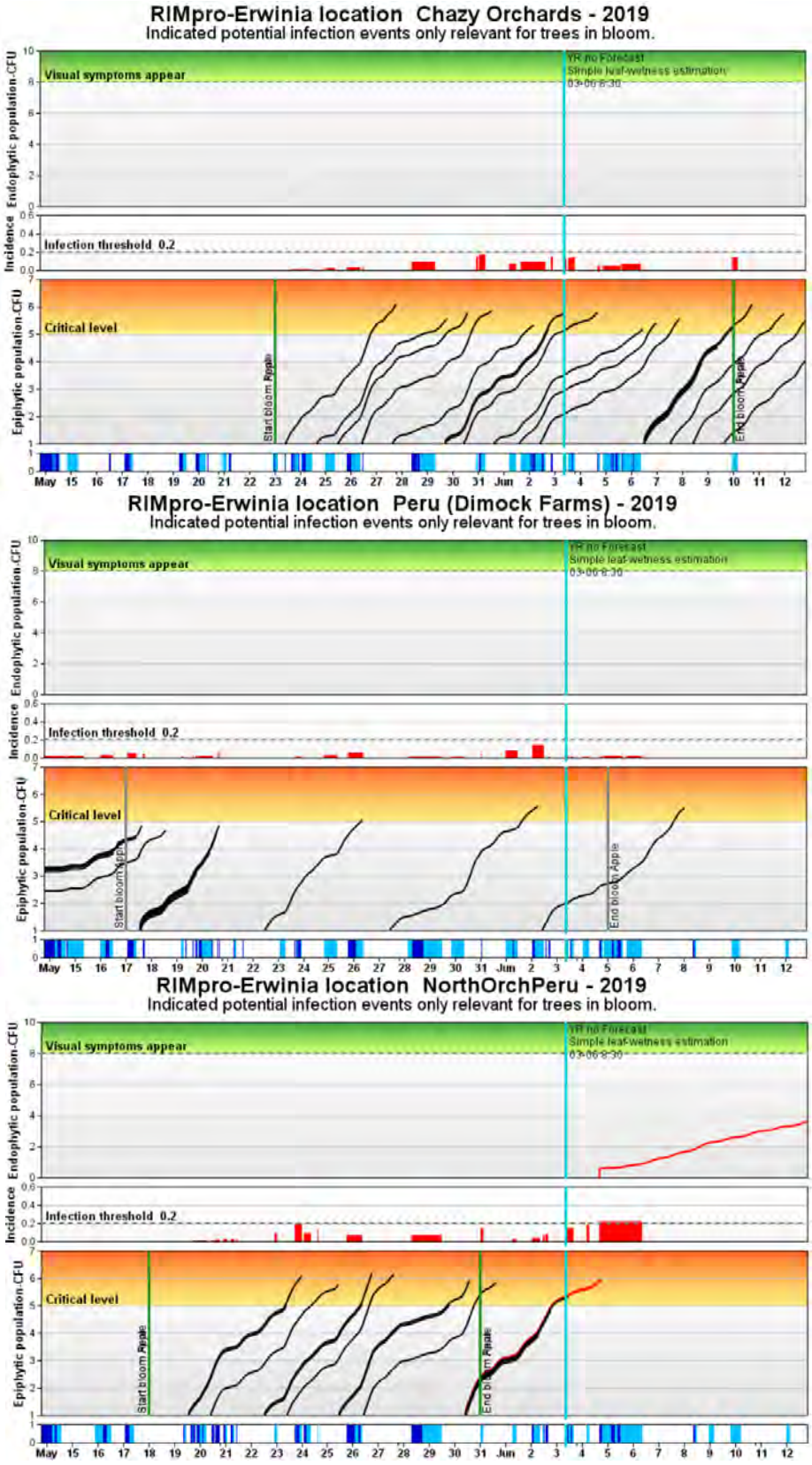


Figure 5. Critical RIMpro outputs of fire blight predictions and historical fire blight infection data for Chazy and Peru, NY, in 2019. Explanation of the data in these graphs is on pg. 9.

Figure 5 is an example of RIMpro fire blight graphing showing fire blight predictions for the

bloom period at northern NY orchards in 2019. Blossom blight infections are predicted to occur when the red bars in the small center graph go through the dashed/dotted line indicating an infection threshold of 0.2 (e. g., May 3, 4, 6, 10, 15 and 22 on the middle graph). The top graph red curved lines indicate incubation of the infections and the time that visual symptoms should be expected after infection took place as per the middle graph. This is important historical data information that would allow you to apply one spray application of Apogee at 12 oz/100 gal to prevent progress of fire blight from the infected flowers and shoots into the wood (limbs, trunk, rootstock) and, in that way, prevent formation of deadly cankers that can kill young and small apple trees in high-density orchards.

The black and red curved lines on the bottom graph indicate how bacterial populations multiply on the flowers. Any wetting that occurs after the black lines reach the orange area can trigger an infection. The red curved lines are populations that successfully led to infection due to a wetting event. Each separate black or red thread (curved line/s) that starts from the base of the graph represents a new batch of apple/pear flowers that open on that day and are carrying fire blight bacteria that grow their populations on these flowers. When the bacterial population is high enough to cause infection, the black or red thread enters the yellow-orange area labeled "Critical level" in the bottom graph and will cause infection if wetting occurs before those flowers age out. When one applies streptomycin plus surfactant (Regulaid or LI 700), then all of the flowers represented by different black or red curved threads that would be intersected by a spray on that spray date will be protected, including anything sprayed up to 24 hours from the actual infection event (red rectangle bar/s in the middle graph). Black or red threads not yet initiated at the time of the spray will be new flowers opening that are not protected by that spray application.

Looking at this discrepancy between the RIMpro and NEWA EIP fire blight models, in relation to 4 May infection, we trust that NEWA's EIP model is more accurate than RIMpro, and the infection on 4 May did not happen. Based on the weather data, it seems that marginal fire blight infections occurred on rattail flowers during 8-12 June period, and then these limited-in-number infections led to infection spreading by hailstorm on 19 June (only one orchard in Peru). In both Peru and Chazy, one to two streptomycin sprays would have been needed on 9 and 11 June, according to NEWA's EIP model, as some late cultivars were still in bloom at that time.

We are not certain why RIMpro disagreed with NEWA EIP model. We assume that input of the date for the end of bloom in RIMpro limits grower's view on what infections can happen on rattail flowers. We advised growers to put this date as late as possible to unlock the view on predictions. Once bloom was completely done, they would change the date to actual day when no flowers were anymore present in orchard at all.

CONCLUSION: FIRE BLIGHT PREDICTION

In conclusion, for this project, we collected, stored, and shared with growers daily print screens from RIMpro's apple scab and fire blight models in for Peru and Chazy, NY, and provided model interpretations to all growers in northern NY. All this activity allowed essential support to the apple production agricultural sector of the NNY counties of Clinton, Essex, Franklin, Jefferson, Lewis, and St. Lawrence to reduce the number of pesticide sprays. We presented the results to NY apple growers and agricultural consultants at the following meetings and in the following publications to increase their knowledge on the opportunity to and necessity for using

models to better prevent and manage infections:

1. Champlain Valley Thinning Meeting, Rulf's Orchard, Peru, NY, *Current Status of Fruit Tree Diseases and Future Disease Model Predictions*. 28 May 2019.
2. S. G. Aćimović. *"New Options for Apple Scab and Fire Blight Management-From Efficacy Trials to Research."* 39th Annual Long Island Agricultural Forum, Long Island, Riverhead, NY, January 8-9, 2019.
3. *"From Research to Orchard and Back: Solutions for Fire Blight, Apple Scab, Bitter Rot, Marssonina Leaf and Fruit Blotch and Blister Spot*." 2019 Apple Forum at Hudson Valley Research Laboratory, Highland, NY, 18 December 2019.

Project-Related Instruction Tutorials on Disease Prediction Models

Aćimović, S. G. (2017):

Tutorial #1. How to create account in RIMpro and join ENY Apple Farm User Group. Acimovic Lab. Vol. 2017 Growing Season, pg. 1-10.

Tutorial #2. BIOFIX Parameters You Have to Set in RIMpro. Acimovic Lab. Vol. 2017 Growing Season, pg. 1-2.

Tutorial #3. Find Your and Other NEWA Stations in ENY Apple Farm User Group and Their Apple Scab Predictions in RIMpro. Acimovic Lab. Vol. 2017 Growing Season, pg. 1-2.

Tutorial #4. Accessing fire blight RIMpro graphs on other NEWA stations than your own in ENY apple farm user group in RIMpro. Acimovic Lab. Vol. 2017 Growing Season, pg. 1-6.

Aćimović, S. G. (2017): Tutorial #5. What is What in an Example Output Graph from RIMpro Apple Scab Model. Acimovic Lab. Vol. 2017 Growing Season, pg. 1.

Project-Related Handouts on Disease Forecast, Occurrence, and Management

Aćimović, S. G. (2019): Handout for thinning meeting 2019 – Champlain Lake Valley. Acimovic Lab. Vol. 2019 Growing Season, pg. 1-2.

Project-Related Extension Journal Articles

S. G. Aćimović, C. L. Meredith (2019): Effective Post-Infection Programs of Prohexadione-calcium for Reducing Shoot Blight and Preventing Fire Blight Canker Initiation on Apple Wood with Cost-Benefit Analysis. *Fruit Quarterly, Summer issue, Vol 27 (2), pg. 25-31.*

S. G. Aćimović, A. E. Wallis, M. R. Basedow (2018): Two Years of Experience with RIMpro Apple Scab Prediction Model on Commercial Apple Farms in Eastern New York. *Fruit Quarterly, Winter issue, Vol 26 (4), pg. 21-27.*

Results: Apple Scab

Using the vacuum scab tower trap, we found first mature ascospores in leaf litter on 28 March 2019 in Highland, NY, on 17 April in Rexford, and on 18 April in Peru, NY. On 4 June in the Hudson Valley and on 21 June in the Lake Champlain Valley, all ascospores were discharged from pseudothecia according to RIMpro's maturation model and primary scab season was over. In Highland we found the first apple leaf scab symptoms on 10 May in untreated control plot with Jersey Mac trees in Highland and on 16 May on Honeycrisp leaves in one commercial orchard in Wallkill. These infections were probably initiated on the first major scab infection

periods of 26 April (Highland) and on 12 April (commercial orchard), respectively. All this information was reported to growers.

The directly related project blog posts to growers containing disease predictions, interpretations, and management recommendations for 2019 and project reporting meetings, workshops, and presentations were as follow and posted at http://blogs.cornell.edu/acimoviclab/category/12019-growing-season/:

1. Call Today to Fix Your Existing or Buy a New Weather Station: RainWise Weather Stations Need to Work Accurately for Disease Models to Predict Infections Correctly in 2019, January 29, 2019
2. Workshop Announcement: Pre-Bloom Decision Making for Your Orchard, Friday March 8th, 2019, 2-5PM, Cornell's HVRL, February 23, 2019
3. Act Now: Renew or Start RIMpro Subscription and Use NEWA's EIP Fire Blight Model in 2019, March 5, 2019
4. Acimovic Power Point for Workshop: Pre-Bloom Decision Making for Your Orchard, from Friday March 8th, 2019, 2-5 PM, March 9, 2019
5. Reduce Overwintering Inoculum of Fungi in Apple Leaf Litter, March 12, 2019
6. Get Ready to Apply Delayed Dormant Copper with Oil in 2019, March 17, 2019
7. 3/28/2019: First Apple Scab Ascospores Detected in Vacuum Spore Trap in Leaf Litter from Highland NY – Farms in Lower Hudson Valley Set your Scab Biofix!, March 28, 2019
8. First Predicted Scab Infection Possible at GT in Lower Hudson Valley & South NY, April 4, 2019
9. No Ascospores Detected Yet in Scab Leaf Litter from Rexford & Peru NY, April 6, 2019
10. If the Weather Forecast Remains the Same: Two Apple Scab Infections Coming on 11-14 April, April 9, 2019
11. Scab Infection Occurred 4/12–13 in Lower Hudson Valley; Next Coming 4/14; Rust Infections Possible, April 13, 2019
12. Lower and Mid-Hudson Valley: Scab Infections Predicted for 19 and/or 20 April, April 16, 2019
13. Apple Scab Ascospores Mature & Abundant in Leaf Litter from Rexford NY: Set Venturia Biofix!, April 17, 2019
14. Apple Scab Ascospores Mature in Leaf Litter Near Peru NY: Champlain Lake Valley Set Venturia Biofix!, April 18, 2019
15. Apple Scab Infections 23–26 April; First Pear and Apple Flowers Opened in Marlboro NY, April 23, 2019
16. First Apple King-Flowers Opened at HVRL: Start Using Fire Blight Models, April 24, 2019.
17. More Apple Scab Infections Predicted 4/30 – 5/3; Fire Blight Not Risk Yet but Stay Tuned, April 29, 2019.
18. What-is-What in RIMpro Prediction Model for Fire Blight (Example), May 1, 2019
19. Fire Blight Is of Low Concern; Severe Scab Infections: 6 and 9 May; Rust is Very Active. May 5, 2019
20. First Rust Symptoms Visible 6 May 2019 at HVRL; Scab Infections: 9-10, 12-13 May; Fire Blight a Minor Concern, May 8, 2019.
21. First Apple Scab Lesions Visible on Leaves at HVRL, 10 May 2019, May 10, 2019
22. Check Your Apple Leaves to Determine If First Scab Symptoms Are Visible (Hudson Valley), May 16, 2019
23. Danger: Fire Blight Infection Predicted for 19 or 20 May – Apply Streptomycin + Surfactant on Any Open Apple Flowers, May 17, 2019
24. Champlain Lake Valley: Earliest Apple Cultivars Start Bloom; Watch Fire Blight Models! May 18, 2019
25. NY Capital Farms Still in Bloom: Fire Blight Infection 23 May (Few Farms), Next on 26 May (All Farms), May 22, 2019
26. Don't Mix *Nectria* Twig Blight with Fire Blight; Brown Rot on Stone Fruit Visible, May 24, 2019
27. Start Using Sooty Blotch & Flyspeck NEWA Model in 2019 for Your Location, May 24, 2019
28. Fire Blight Potential Infections Ahead If Forecast Stays Same; Continue Scab Protection, May 26, 2019
29. 1-2 June: Fire Blight Infection in NY Capital Region if Flowers Open; Champlain Lake Valley – No Risk, May 31, 2019
30. If Hail Hit with Tonight's Storm in South Central Ulster, Potential Fire Blight Risk, June 1, 2019
31. Lower Hudson Valley: Primary Scab Season Over; Fire Blight Risk 5–6 June Only on Young Trees in Bloom, June 4, 2019

32. Champlain Lake Valley: Fire Blight Infection Risks 5-11 June Depending on a Location and Flowering, June 7, 2019
33. SB&FS 190 h Accumulated Wetting Fulfilled on 16, 19 or 21 June Depending on a Location; Marssonina Leaf Blotch Favored by Intense Rains, June 16, 2019
34. Primary Scab Season Over on 21 June 2019 in Champlain Lake Valley Region; SB&FS, Marssonina Leaf Blotch Problems with Excessive Rains, June 22, 2019
35. If Hail Occurs with Today's Storm in East Central NY: Potential Risk For Fire Blight Trauma Development, June 30, 2019
36. Upcoming Hudson Valley Research and Extension Tour: July 26th 2019, July 12, 2019
37. First Marssonina Leaf Blotch Symptoms Visible on 19 July, Highland, NY, July 19, 2019
38. First SB&FS and Bitter Rot Symptoms Visible in Lower Hudson Valley (7/22/2019), July 22, 2019
39. Hail in Highland NY, If Hit Apply Protection from Fire Blight up to 24 h After July 29, 2019
40. Webinar: Fire Blight IPM Using Non-Antibiotic Control Methods, October 5, 2019
41. Mark Your Calendar: Apple Forum at Cornell's Hudson Valley Research Laboratory on Dec 18, 2019, November 12, 2019
42. Preliminary Report on Fungicide and Bactericide Efficacy Trials at HVRL in 2019, November 25, 2019
43. Apple IPM Intensive Workshop at Empire State Expo, December 12, 2019
44. Agenda for Apple Forum at Cornell's Hudson Valley Research Laboratory on Dec 18, 2019, December 17, 2019
45. Read on Scab Resistance Testing of Apple cv. Kalei at Cornell's HVRL and Fill Out Variety Survey, January 7, 2020.

The same blog posts were summarized in short and advertised through the weekly E-alerts by the ENY Commercial Horticultural Program's Dan Donahue and Michael Basedow (Cornell Cooperative Extension) throughout the growing season. In Table 1, we compiled date comparison chart from RIMpro and NEWA on when first ascospores were detected in 2017, 2018, and 2019 and which biofixes were recommended to growers for use in RIMpro.

Two to three false or unwarranted infection periods, when ascospore release and germinate only, did not require two early season fungicide applications in the Lake Champlain Valley

There were 7 and 8 major infection periods in Chazy and Peru, NY, respectively, based on the RIMpro apple scab prediction model, spanning from Green Tip to Petal Fall growth stages (Fig. 3).

On 26 April, 2019, in Chazy, NY (Fig. 3A), there was one very weak infection period whose red line did not go over both the 100 and 300 RIM threshold values, meaning that in both the high-inoculum and inoculum-free orchards fungicide spray application was not needed and money could be saved. In contrast, in Peru, NY (Fig. 3B), this infection of 26 April had the red line going over the 100 RIM threshold value but not over the 300 RIM, meaning that fungicide protection was needed in the high-inoculum orchards, which had infections in 2018, but not in the inoculum-free orchards, that had no infections last year. Therefore, in commercial orchards in Peru that did not have apple scab in 2018 expressing on both leaves and fruit, fungicide spray application was not needed to protect against the 26 April 2019 event, and money could be saved.

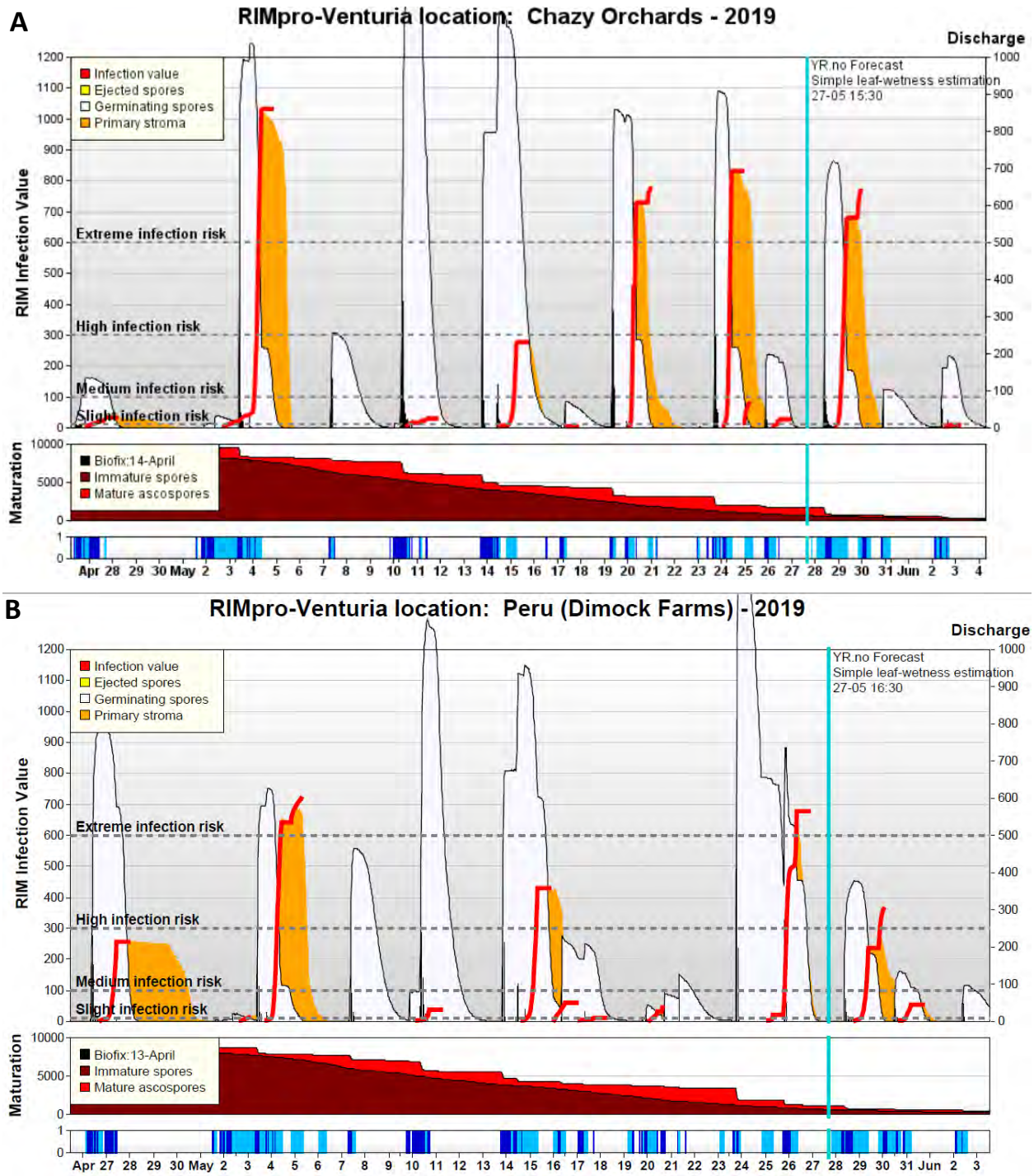


Figure 3. RIMpro apple scab model outputs for Chazy (A) and Peru (B) on 27 May 2019 showing 8 infection major periods in 2019. The vertical light blue line marks the current date and time within that the day.

Before the first major infection on the 26 April at ½-inch green flower bud stage in the Lake Champlain Valley, there were no "false infection" periods, i.e. ascospore releases and germination only periods visible as standalone white humps that did not lead to significant infections (significant infections would be white humps with red line after white hump rising

above 100 RIM value in the high-inoculum orchards or 300 RIM value in the inoculum-free orchards). White humps without red lines going above these thresholds indicate that conditions after rainfall were cold and unfavorable for germinating spores to establish an infection. Therefore, earlier in the season there were no opportunities to save fungicide application/s in commercial orchards.

However, on 7 May in both Chazy and Peru, when trees were in TC (tight cluster flower bud growth stage), there was one "false infection" period, i.e., ascospore release and germination only, visible as standalone white hump without red line, and one very weak infection period on 10 May. Since the 10 May infection did not go over both the 100 and 300 RIM threshold values for high-inoculum and inoculum-free orchards, fungicide spray applications were not needed, and money could be saved.

Pink bud stage started sometime between 12 to 14 May onward. First open flowers were reported on Duchess of Oldenburg on 18 May (Peru, NY). Therefore, depending on what the carryover inoculum load was in the commercial orchards based on last-year infections, by using the RIMpro model there was an opportunity to save money by not applying at least two fungicide applications on 3,100 acres in the Lake Champlain Valley (Table 2). The false infections on 26 April, 7 and 10 May 2019 did not warrant fungicide application/s in commercial orchards that did not have scab last year since conditions after rainfall were too cold and unfavorable for germinating spores to establish an (significant) infection (Table 2).

In 2019, the RIMpro and NEWA models for *V. inaequalis* ascospore maturity showed a discrepancy of 19 days between dates when primary scab season was declared over (Table 3). In RIMpro's ascospore maturity model, the primary scab season is over when predicted infection events fail to reach RIM threshold values of 300 for clean orchards or 100 for high-inoculum orchards and petal fall has passed. This usually occurs after ascospores remaining to be discharged are less than 5% of the season total (Fig. 2 and 3, middle graph). In NEWA, the ascospore maturity model predicts that after 95% of ascospores have been discharged or are ready for release, the primary scab season will end after next daytime rain of more than 0.1 inch with temperatures above 50ºF.

CONCLUSION: APPLE SCAB PREDICTION

Our basic comparison of RIMpro and NEWA apple scab models in 2019 indicated that RIMpro's model called to omit two early season fungicide sprays (Table 2). After the end of primary scab season, RIMpro's model allowed growers to better protect their crop from scab than NEWA by requiring two additional fungicide applications necessary to control primary scab. Therefore, it seems that in 2019, there would be more-less an equal number of spray applications needed if using both NEWA and RIMpro, but due to discrepancy in fungicide initiation and timing, scab stood chance to infect and express if NEWA's model was used thus reducing profit gains from fresh fruit sales. By comparing the RIMpro's and NEWA's primary scab season end dates, we found that in Peru there were two infection periods recorded in NEWA that still required fungicide protection according to RIMpro but not according to NEWA (Table 3). Hence, the overestimation in the NEWA's ascospore maturity model reporting earlier end of primary scab season might lead growers to miss applying two fungicide applications that would still be essential for controlling primary scab.

Table 1. Total disorder development of the 21 study blocks following four months of storage. Prediction of Bitter Pit in 'Honeycrisp' Apples Before Storage project, NNYADP.

Orchard Block	Initial Storage Temperature (°F)	Predicted Fruit with Bitter Pit (%)	Actual Fruit with Bitter Pit (%)	Difference Between Predicted and Actual (%)	Soft Scald (%)	Soggy Breakdown (%)	Blotch (%)	Wrinkly Skin (%)	Shrivel (%)	Rot (%)	Senescent Breakdown (%)	Flesh Browning (%)	Core Browning (%)	Vascular Browning (%)	Internal CO2 Injury (%)	Total Disorders (%)
1	50	2	15	13	0	0	0	0	0	0	0	0	0	5	0	21
2	50	1	11	10	0	0	0	0	0	2	0	0	0	0	0	13
3	38	10	10	0	8	9	0	0	0	9	8	0	1	0	0	45
4	38	7	1	-6	0	2	0	0	0	7	0	2	0	0	0	12
5	33	17	20	3	7	0	6	0	0	8	0	0	0	0	0	41
6	50	1	2	1	0	0	0	0	0	2	0	0	0	0	0	4
7	50	3	8	5	0	0	0	0	0	0	0	0	0	0	0	8
8	33	18	9	-9	6	18	4	0	0	9	2	0	0	0	0	48
9	50	2	5	3	0	0	0	0	0	5	3	1	1	0	0	15
10	38	5	16	11	3	2	0	0	0	6	3	2	1	0	0	34
11	50	0	2	2	0	0	0	0	0	0	0	0	0	0	0	2
12	50	2	1	-1	0	0	0	0	0	0	3	0	0	0	0	4
13	50	3	33	30	0	1	1	0	0	3	0	0	0	0	0	39
14	33	12	2	-10	2	2	1	0	0	17	2	0	0	1	0	28
15	38	8	16	8	2	0	1	0	0	8	2	1	0	1	0	31
16	50	0	1	1	0	4	0	0	0	2	0	0	0	0	0	7
17	50	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5
18	50	0	4	4	0	0	0	0	0	1	0	0	0	0	0	5
19	50	1	3	2	0	0	0	0	0	0	0	0	0	1	0	4
20	50	0	3	3	0	0	1	0	0	13	0	0	0	1	0	18
21	50	0	1	1	0	0	0	0	0	1	0	0	0	0	0	2

FOR MORE INFORMATION

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