2023 Annual Winter Meeting of the American Cranberry Growers Association

AMERICAN CRANBERRY GROWERS association

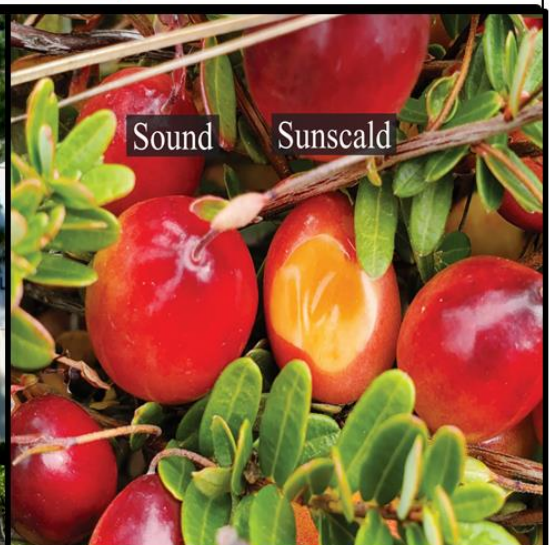
Rutgers University EcoComplex

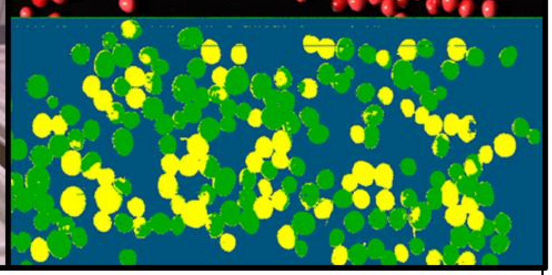
Bordentown, NJ

Thursday January 19, 2023

RUTGERS

New Jersey Agricultural Experiment Station





Presentation Summaries

ACGA Winter Meeting Program

Thursday, January 19, 2023
Rutgers EcoComplex, Bordentown, NJ

8:00-8:30 Registration and Coffee

8:30-8:50 Welcoming Remarks– ***Shawn Cutts*, President, ACGA**
Treasurer's Report **– *Shawn Cutts***

8:50-9:00 **New Jersey Cranberry Statistics**
Bruce Eklund, National Agricultural Statistics Service, Trenton, NJ

9:00-9:20 **Research Addressing Current and Future Solutions for Cranberry Fruit Rot**
Peter Oudemans, Professor, Department of Plant Biology, P.E. Marucci Center for Blueberry & Cranberry Research & Extension, Rutgers University, Chatsworth, NJ

9:20-9:40 **Latest Advances in Entomological Research**
Cesar Rodriguez-Saona, Professor and Extension Specialist, *Yahel Ben-Zvi*, PhD Student, Department of Entomology, and *Robert Holdcraft*, P.E. Marucci Center, Chatsworth, NJ

9:40-9:55 **Refining a Degree-Model for Sparganothis Fruitworm**
James Shope, Research Associate, Department of Environmental Sciences, Rutgers University, and *Cesar Rodriguez-Saona*, Professor and Extension Specialist, P.E. Marucci Center, Chatsworth, NJ

9:55-10:20 **Cranberry Institute Update**
Katherine Ghantous and *William Frantz*, Cranberry Institute, Carver, MA

10:20-10:40 **Break**

10:40-11:00 **Multistate Evaluation of Cranberry Tolerance and Weed Control with Newly Labeled Pendimethalin Herbicide**
Thierry Besancon, Associate Professor and Extension Specialist, Department of Plant Biology, Rutgers University, P.E. Marucci Center, Chatsworth, NJ

11:00-11:20 **Update on Cranberry Breeding Projects**
Jennifer Johnson-Cicalese, Research Associate, *Nicholi Vorsa*, Professor, *Sara Knowles*, Laboratory Technician, and *Thomas Spain*, Sr. Fld. & Grhs. Technician, Rutgers University, P.E. Marucci Center, Chatsworth, NJ

11:20-11:40 **Updating Approaches to Fruit Rot Resistance Research**
Joseph Kawash, Bioinformaticist, USDA-ARS, and *James Polashock*, Research Plant Pathologist, USDA-ARS

11:40-12:00 **Cranberry Fruit Epicuticular Wax Benefits and Identification of a Wax-Associated Molecular Marker**
Lindsay Erndwein, ORISE Postdoctoral Scholar, *Joseph Kawash*, Bioinformaticist, USDA-ARS, and *James Polashock*, Research Plant Pathologist, USDA-ARS

12:00-1:00 **Lunch**

1:00-1:20 **Gene Functional Analysis in Cranberry**
James Polashock, Research Plant Pathologist, and *Sujon Sarowar,* ORISE Established Scientist Fellow

1:20-1:40 **Application of Drone Technology in Cranberry Production**
Giverson Mupambi, Extension Assistant Professor, UMass Cranberry Station, East Wareham, MA

1:40-2:10 **Pesticide Safety Update: Exposure, Recordkeeping, and Storage**
Kate Brown, Program Associate—Commercial Agriculture, and William Bamka, Rutgers Cooperative Extension of Burlington County

2:10-2:30 **Grower Forum**

2:30 **Adjournment**- *ACGA Board of Directors Meeting*

New Jersey Agricultural Statistics

Bruce Eklund, State Statistician
NJ Field Office, National Agricultural Statistics Service
Phone: 503.308.0404
E-mail: bruce.eklund@nass.usda.gov

USDA's National Agricultural Statistics will release the 2022 Non-citrus Fruit and Nut Final Summary noon May 8, 2023 at 3 PM eastern: https://www.nass.usda.gov/Publications/Reports_By_Date/index.php We want to work with you to get the best data to accurately represent New Jersey cranberries.

Thank you in advance for your help.

Until May 8, I do not have new NASS cranberry data. NASS released the production forecast for the 2022 crop August 12, 2022.

You can get e-mail alerts for New Jersey and Regional customized reports:

https://www.nass.usda.gov/Statistics_by_State/New_Jersey/index.php

Look under 'I want to' on the left.

Please respond the Census of Agriculture. It is important to show the importance of New Jersey Cranberries.

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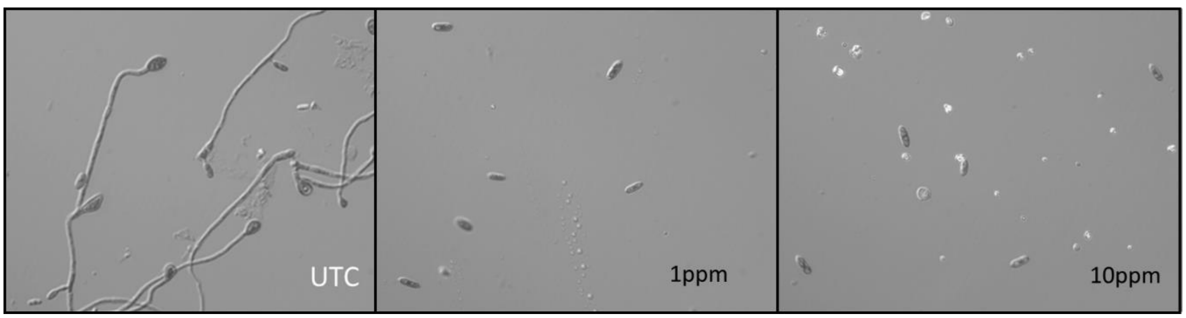
Research Addressing Current and Future Solutions for Cranberry Fruit Rot

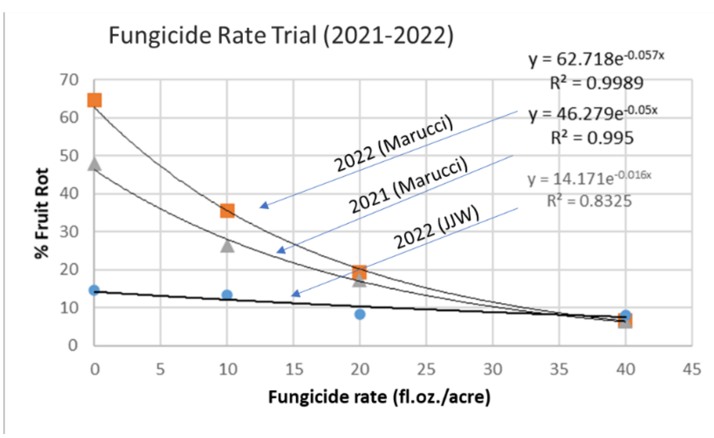
Peter Oudemans, Professor, Department of Plant Biology, P.E. Marucci Center for Blueberry & Cranberry Research & Extension, Rutgers University, Chatsworth, NJ

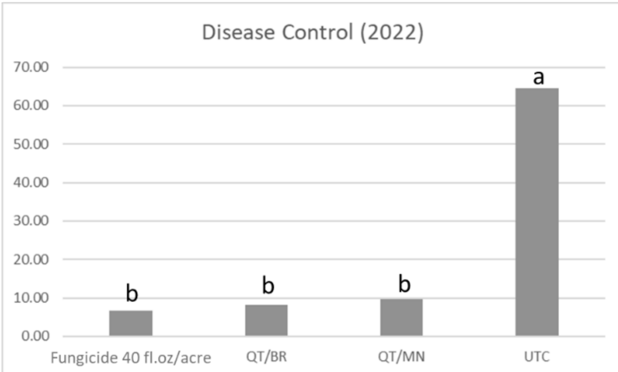
In today's presentation I will discuss a multipronged research program aimed at developing short-, medium- and long-term strategies for addressing fruit quality. The presentation is divided into 3 topics that, although interrelated require different approaches.

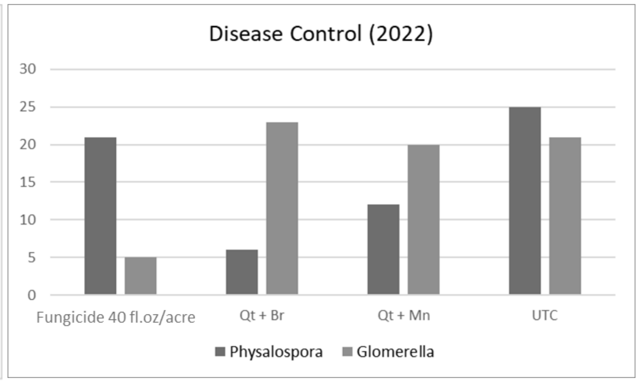
1. **Fungicide toolbox**. Testing new fungicides can be a time consuming process if field trials are the primary approach. We have adopted a Flower Extract (FLEX) bioassay that increases throughput in the lab and provides guidance for improved field trials. Last year I described a finding using a combination of two fungicides that provided excellent control of Fruit Rot (FR) and those materials are going through the registration process. This year I am presenting work with a novel fungicide (FRAC 29) that has given poor results in field trials. The fungicide was highly active in the FLEX Bioasssay and for that reason it was re-tested in field conditions. As you can see in the figure below the spore germination was completely shut down at the lowest



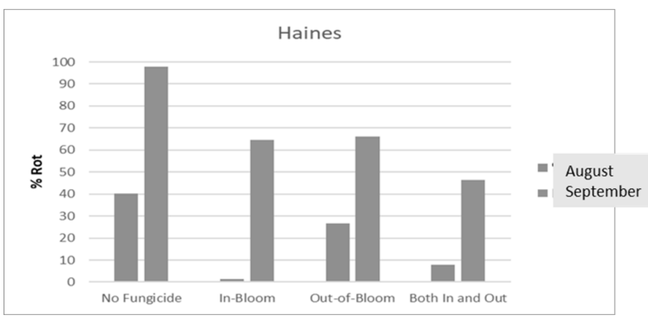
concentration tested. Three field trials were conducted with the fungicide and a significant rate response was observed. The problem in earlier field trials was that too low a rate was used (10 fl.oz/acre) and the response was unimpressive. At 20 and 40 fl.oz./acre better results were obtained. Further work is necessary to develop a strong recommendation for this fungicide and it will have to be registered through EPA. In comparison with other fungicides it performs well and is expected to compliment other modes of action already registered. In field trials from 2022 (similar results were obtained in 2021) control was comparable to the Quadris Top/Bravo program used by many growers in New Jersey. A unique property of this fungicide is the strong activity against one of the fruit rotting species (*Colletotrichum fructivorum*) that is increasingly important and notoriously prevalent in New Jersey and other states.

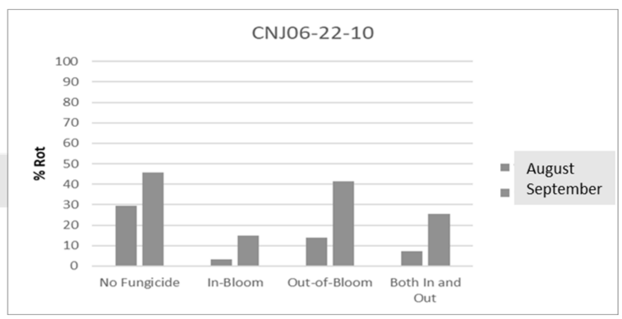




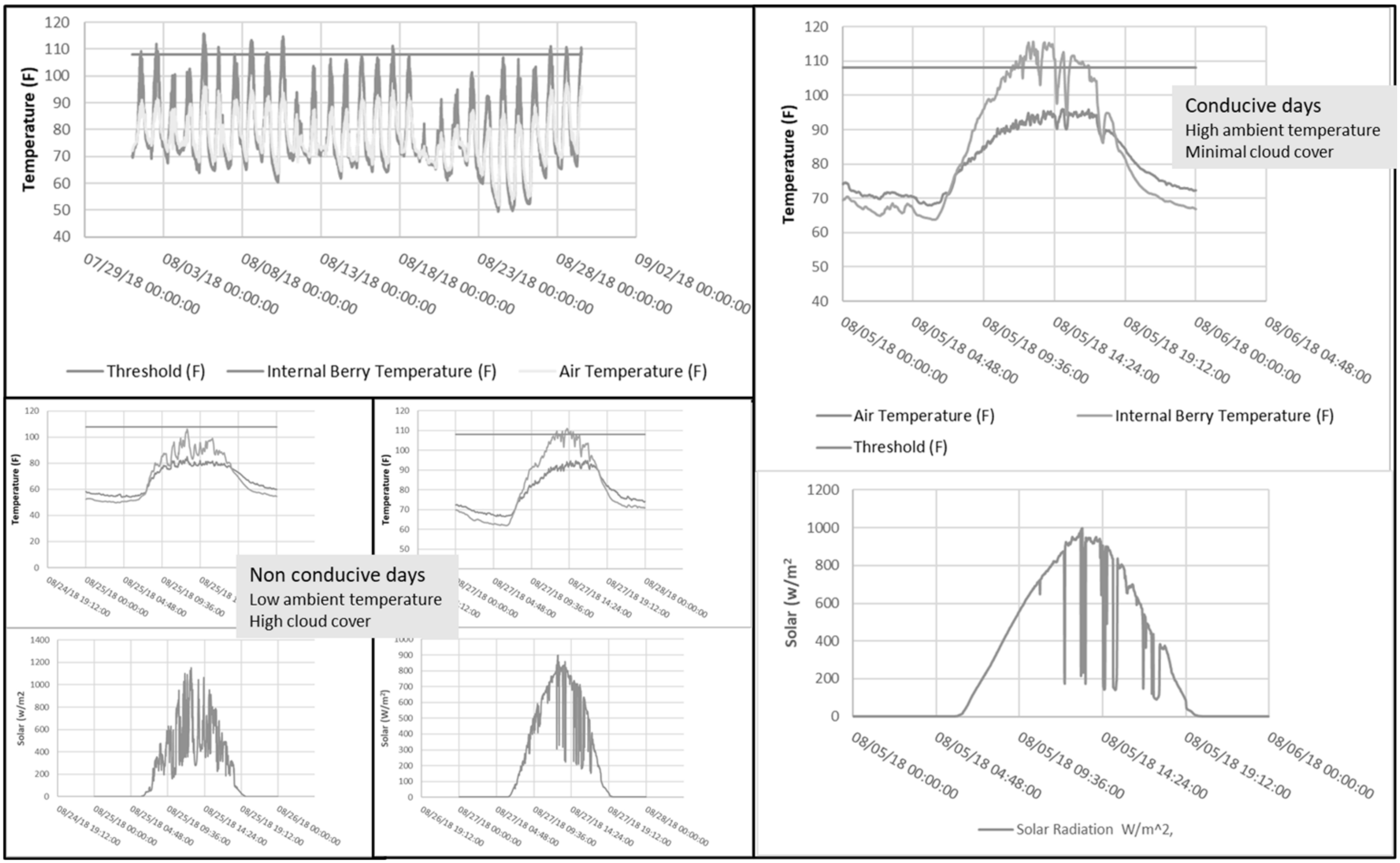


2. **Fruit rot resistant (FRR) selections**. The Rutgers cranberry breeding program (Nick Vorsa and Jennifer Johnson Cicalese) have been investigating the use of Budds Blues and Cumberland as parents to combine with higher yielding genotypes. This work has resulted in selections made in 2006, 2012 and 2014 that are significantly more resistant that any of the current varieties. The selections still require the use of fungicides but in field trials work from my group is showing reduced fungicide inputs. This is significant because as the fungicide toolbox is diminished use patterns become more restricted. In the results below you will see that a 2-spray in-bloom regime provides excellent control in the selected FRR genotype as opposed to the standard (in this case Haines). Adoption of these selections will require more research with larger plots. Many of these are sensitive to Bravo and develop significant scarring from its use.





3. **Overheating and Canopy Management**. Research with overheating is focused on characterizing conditions leading to overheating and cultural methods for mitigation. Work thus far points to intense solar radiation after berries have started turning red. Berries located at the top of the canopy are most vulnerable because they do not benefit from shading. Cloud cover is another major factor because the cranberry fruit will cool almost immediately when shaded. Ambient temperature is also a factor and generally air temperatures above 90 degrees should be considered at risk days. Irrigation will promote cooling of the fruit on typical heat stress days through evaporative cooling. Wet bulb temperatures are a good indication of the cooling potential of any particular day. With irrigation it is necessary to minimize the time to avoid creating conditions conducive to rot. A good rule of thumb is to irrigate the top 1-2” of canopy (15-30 min). The canopy structure is also very important and beds with shaded fruit require much less attention for overheating. I am working with a group to develop risk assessment for cranberry overheating.



Temperature (F)
Threshold (F)
Internal Berry Temperature (F)
Air Temperature (F)
Conducive days
High ambient temperature
Minimal cloud cover
Air Temperature (F)
Internal Berry Temperature (F)
Threshold (F)
Solar (w/m2
Solar Radiation W/m^2,
Non conducive days
Low ambient temperature
High cloud cover

Latest Advances in Entomological Research

Cesar Rodriguez-Saona, *Yahel Ben-Zvi*, and *Robert Holdcraft*, P.E. Marucci Center, Chatsworth, NJ

Insecticide Trials

In 2022, an experiment was conducted to test the efficacy of two insecticides for controlling blunt-nosed leafhoppers in cranberries. Treatments were an unregistered insecticide, Danitol 2.4EC (fenpropathrin) at 16 fl oz/acre, and an untreated control. The experiment was conducted in a cranberry bed, cv. 'Haines,' located at the Rutgers P.E. Marucci Center in Chatsworth, New Jersey (USA). Plots were 91 × 91 cm each, replicated five times in a CRB design. Applications were made with R&D CO_2 backpack sprayer, using a 1-liter plastic bottle. The sprayer was calibrated to deliver 50 gal of volume per acre at 30 psi, using a single Teejet VS 110015 nozzle, yielding 39.1 ml per plot. Treatments were applied in the morning of 6 June 2022. Control plots received no insecticide.

Four hours after treatment, four cranberry uprights (i.e., stems with leaves) were randomly collected from the central portion of each plot, avoiding a 15-cm buffer zone from the plot's edges. Uprights were inserted in florists' water picks and the tops containing the leaves were enclosed in a ventilated 32-oz plastic deli container (Figure 1). The water picks were placed on top of water-filled trays so that the bottoms of the uprights (stems) were submerged in water. Ten containers were setup for each treatment on 6 June, and five blunt-nosed leafhopper nymphs were placed in each container. Blunt-nosed leafhopper nymphs were collected via sweep net sampling from an infested cranberry bed in commercial farm in Chatsworth, New Jersey, on the same day of the experiment. Each container was considered a replicate. Plants and insects were placed on a bench in the laboratory at approx. 25°C and a 15:9 L:D cycle. Mortality was assessed by recording the number of leafhoppers (alive or dead) at 1, 3, and 7 days after exposure (DAE).

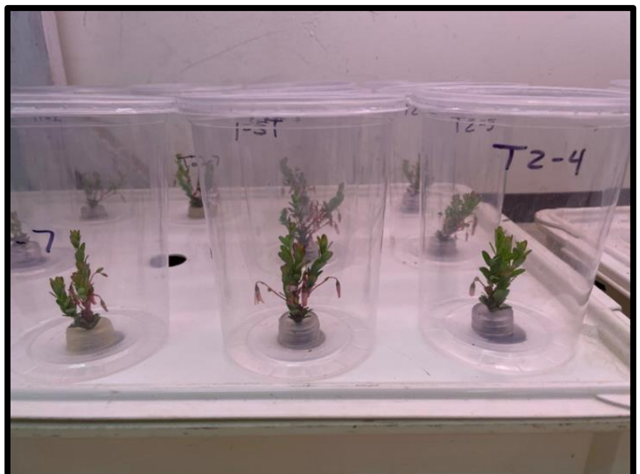
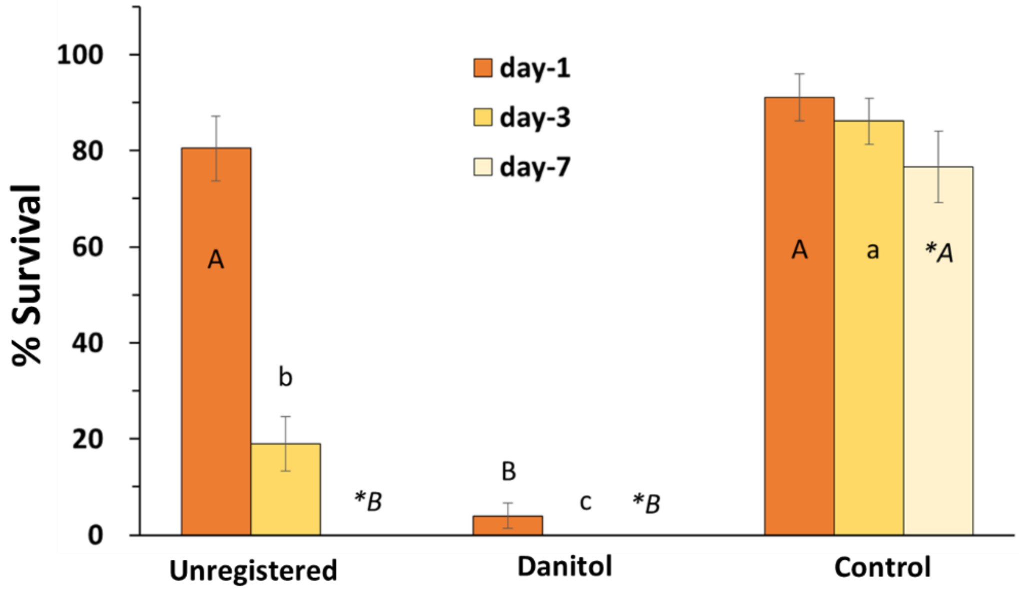


Figure 1. Experimental setup to test the efficacy of insecticides against blunt-nosed leafhoppers.

At 1 DAE, only Danitol significantly reduced the number of live nymphs when compared with controls (Figure 2). At 3 DAE, both Danitol and the unregistered insecticide reduced the number of live nymphs when compared with controls; however, Danitol provided greater control than the unregistered insecticide (Figure 2). At 7 DAE, both insecticides provided 100% control (Figure 2). Control mortality was < 25%.

Figure 2. Toxicity of insecticides against blunt-nosed leafhoppers.



Abundance and Distribution of Insect Pests and their Natural Enemies in Cranberries

Insect abundance and distribution are likely influenced by landscape composition in agroecosystems, which in turn can affect pest pressure, predation, and pollination in crops such as cranberries. In fact, natural habitats surrounding cranberry farms can provide alternative resources and nesting sites for pests, natural enemies of pests, and pollinators. In 2022, the abundance and distribution of insect pests and natural enemies (predators and parasitoids) was assessed in 50 beds across three commercial cranberry farms in New Jersey. Each bed was geo-referenced to assess the landscape composition surrounding them and to characterize the type of landscape (forest, crop, other) surrounding each bed. Of the 50 beds, 10 beds are Stevens, 10 Early Black, 10 Ben Lear, 10 Mullica Queen, and 10 Crimson Queen. In each bed, we placed two yellow sticky traps, one of the traps was baited with a commercial natural enemy attractant called PredaLure (AgBio Inc.), while the other trap was unbaited. Traps were placed once a month in May, June, July, and August, and left in the field for 1 week. Trapped insects, including blunt-nosed leafhoppers and natural enemies, were counted. To assess the natural enemy function, we measured predation of sentinel eggs (using fall armyworm egg masses) in each of the beds. Sentinel eggs (N = 6 egg masses per bed) were placed in the field for 2 days (Figure 3), and the number of eggs was counted before and after field exposure to assess the level of predation. In addition, we will collect insecticide use in each bed. These data will be used to study, for the first time, the relative importance of landscape composition and local management practices on insect communities in cranberries.

Acknowledgements

This research was supported by industry gifts of pesticide and research funding. We thank Vera Kyryczenko-Roth, Sophie Olsen, and Jennifer Frake for their assistance during the experiment.

Refining a Degree-Model for Sparganothis Fruitworm

James Shope, Research Associate, Department of Environmental Sciences, Rutgers University, and *Cesar Rodriguez-Saona*, Professor and Extension Specialist, P.E. Marucci Center, Chatsworth, NJ

Background

The Sparganothis fruitworm (*Sparganothis sulfureana* Clemens) (Figure 1) is a native cranberry pest to North America and can cause significant economic damage to cranberry harvests each year. Overwintered larvae become active in the cranberry bog in the spring (early May) as temperatures warm, and adult moths lay eggs in late-June/early-July on cranberry leaves. This second generation soon hatches and continues to damage the crop and burrows into the fruit, where it is protected from insecticide application. The timing of spray applications in New Jersey bogs utilizes the projected peak flight of the adult moth as an indicator of when to apply insecticide, typically 10–14 days after peak flight, to target these second-generation larvae before they can burrow into the fruit and reduce yield (De Lange and Rodriguez-Saona 2015).

Figure 1. Sparganothis fruitworm adults.

To help predict the timing moth peak flight, and following insecticide application, a degree day model developed by Deutsch et al. (2014), using data from Wisconsin and New Jersey cranberry bogs, is typically used. The timings of moth peak flight, however, was only calibrated using Wisconsin data, not New Jersey's. Similarly, the biofix to start degree day accrual was listed as March 1st each year, which again was based on Wisconsin climate and growing practices and thus differs from the climate and cranberry growing practices in New Jersey. For example, New Jersey's spring (March–May) temperatures tend to average about 51 °F while Wisconsin's average 43 °F. Additionally, New Jersey drains its cranberry bogs later in the season, which further affects the emergence of the adult moth. To account for some of these differences, prior predictions of peak flight and spray timings within New Jersey instead have used a biofix of April 15th (about the time when water is drawn off most bogs). Despite this change, we have heard from growers that there is a disconnect between the predictions and what they are experiencing in their bogs.

Data

To address these concerns, we have refined the degree day model of Sparganothis fruitworm peak flight to specifically address New Jersey's needs. We have also tested if the exact date of bog water draw and the variety of cranberry affect the peak flight date. We collected trap capture and bog-specific data from a commercial cranberry farm to improve the model. The specific data were the dates and number of adult moth captures per trap, the variety of cranberry in that bog, and when the water was drained for the years 2016 to 2021.

Daily temperature data were for the same period were collected from the Lake Oswego weather station in Chatsworth, NJ, which is operated by the Office of the New Jersey State Climatologist and who provided these data to us. We calculated degree days using a lower development threshold of 50 °F and an upper threshold of 86 °F. We tested two biofixes for the degree days, April 15th (which has been typically used) and the date of water draw per bog.
Peak flight is considered when the cumulative captures for a specific trap reached 50% of its total captures for the year. The peak was calculated for each bog for both biofixes: April 15th and when the water is drawn. Additionally, we calculated peak flight by cranberry variety to detail specific differences.

Model Updates and Findings

Table 1. Degree days accumulated by variety using the April 15th biofix and the water draw biofix. The absolute difference between the two methods is listed for comparison. The "ALL" variety is an aggregate measure of all cranberry bog traps, regardless of variety.

Variety	Biofix		Difference
	April 15	Water Draw	
BenLear	954.0 ± 6.6	952.8 ± 5.7	1.2
Crimson Queen	950.2 ± 12.1	925.9 ± 10.8	24.3
Demoranville	972.5 ± 14.1	937.2 ± 12.4	35.2
Early Black	968.9 ± 7.1	954.7 ± 7.3	14.1
Haines	929.8 ± 25.3	906.8 ± 20.5	23.0
Mullica Queen	908.5 ± 15.3	881.8 ± 13.6	26.7
Stevens	913.9 ± 6.7	921.3 ± 6.3	7.3
ALL	945.8 ± 3.6	937.9 ± 3.3	7.9

The prior model estimated that peak flight occurred at 884.1 degree days, but the New Jersey specific values presented in Table 1 shows that across all varieties, the typical number of degree days for peak flight is 938 to 946, depending on the biofix. Over the 2016–2022 period, this difference is on the scale of 2-3 days. For example, in 2022, 884 degree days were achieved on June 15th, while 938–945 degree days was on June 18th. The updated model typically predicts peak flight 3 days later in the season compared to the older model, which can affect spray timings where even a few days difference can result in significant damage to the crop. The difference between the two biofix dates was about 8 degree days, less than one day difference, so the April 15th biofix is an easier-to-use and valid benchmark.

The average day of water draw per year for each bog occurred later in the year between 2016 and 2021: about April 7th in 2016 to April 27th in 2021. Across all years, the average date of water draw was April 17th, which is close to the prior usage of the April 15th biofix, and well within the margin of error of the averaging.

There are differences between peak flight dates recorded at each cranberry variety. The maximum difference in degree days using the April 15th biofix is between Demoranville and Mullica Queen at 64 degree days, and between Early Black to Mullica Queen at 73 days for the water draw biofix. This range constitutes about 3 to 4 days, indicating up to a half week offset depending on variety may be considered in starting spray cycles. The difference in biofix dates for individual varieties was generally offset less than one day, with the difference for Demoranville being closer to one day, and not enough to warrant the extra effort to calculate degree days based on water draw.

Finally, one caution is that there can be much difference in peak flight timings from year-to-year and from cranberry bog to cranberry bog. The lowest peak flight degree day was about 724 degree days and the highest was 1252 for individual traps. Most were closer to the estimate of 945.8 degree days on average and this is the best metric to use when timing spray cycles. However, the range in peak flights indicates that while the updated model is useful and better, it is not perfect and there will be instances where it fails to project an accurate peak flight timing.

Takeaways

We have updated the Sparganothis fruitworm peak flight estimates to consider New Jersey specific data and found:

- Peak flight should be (in general) considered 946 degree days from April 15th.
- There was not enough difference in comparing the April 15th biofix to a water draw biofix to warrant the extra calculations for the grower.
- Peak flight by variety can differ by up to half a week, indicating that offsetting sprays between varieties may be a valid strategy for farms with multiple varieties with significantly different peak flight estimates.
- There can be wide year-to-year and bog-to-bog differences in peak flight timings. While the model is better, there will be times where it fails because there are many other factors that affect the exact timing of peak flight.

Moving forward, we will refine the model further by incorporating trapping data from multiple growers. Also, in future usage, it would likely be best to shift the biofix from April 15th to April 17th, to coincide with the average date of water removal.

Reference

De Lange E and Rodriguez-Saona C. 2015. Sparganothis Fruitworm: A Pest of Cranberry in New Jersey. New Jersey Agricultural Experiment Station. Cooperative Extension Fact Sheet FS1249.

Deutsch AE, Rodriguez-Saona CR, Kyryczenko-Roth V, Sojka J, Zalapa JE, Steffan SA. 2014. Degree-Day Benchmarks for *Sparganothis sulfureana* (Lepidoptera: Tortricidae) Development in Cranberries. J Econ Entomol. 107(6):2130-6. doi: 10.1603/EC14261. PMID: 26470078.

Multistate Evaluation of Cranberry Tolerance and Weed Control with Newly Labeled Pendimethalin Herbicide

Thierry E. Besançon, Associate Professor and Extension Weed Science Specialist, Rutgers; *Katherine Ghantous*, Extension Educator IV, UMass Cranberry Station; *Marcelo L. Moretti*, Weed Science Assistant Professor, Oregon State University

Pendimethalin is a WSSA group 3 herbicide that provide excellent preemergence control of various annual grasses as well as small seeded annual broadleaf weeds. An encapsulated pendimethalin formulation (Satellite HydroCap) has recently added cranberry to its label. In 2017, the use of a similar pendimethalin formulation was associated with widespread highbush blueberry phytotoxicity in New Jersey. High use rate, blueberry shallow root system, sandy soil with low organic matter content, and applications timed around or after budbreak increased the risk of pendimethalin injury. Given the genetic proximity of blueberry and cranberry, and the lack of reference regarding, multistate field studies were conducted in 2022 to assess cranberry tolerance to chemigated (400 GPA) or boom applied (30 GPA) pendimethalin at different growth stages and rates.

In NJ, MA, and WI, pendimethalin was applied at 800 (½X or 1.5 pt/A) or 1,600 (1X or 3 pt/A) g ha^{-1} on cranberry vines at the spring dormant (SD) or cabbage head (CH) phenological stages. Applications were either chemigated (MA) or boom-applied (NJ, WI). Additional NJ treatments included 1/2X and 1X applications at the rough neck (RN) stage and split-application at ½X at CH and RN stage. In OR, pendimethalin was chemigated or boom-applied at 1,600 (1X) or 3,200 (2X or 6 pt/A) g ha^{-1} on cranberry vines at SD or CH stage.

In NJ, pendimethalin applied at SD or CH stage (regardless of rate) provided ≥ 96% control of large crabgrass 8 weeks after treatment as compared to < 30% with the napropamide standard. However, pendimethalin did not control bog violet (≤ 16%), little bluestem (0%) and American burnweed (≤ 25%).

In MA and NJ, pendimethalin did not affect development of cranberry uprights but decreased yield by 25% when applied at the 1X rate at the CH stage, as compared to untreated control or applications at the SD stage (Fig. 1). Lower cranberry tolerance at later growth stage was shown in NJ with 56% and 70% yield reduction following pendimethalin applied at the RN stage at the ½X and 1X rate. Cranberry vine stunting was 12% 28 DAT with RN application at the 1X rate.

In OR, all applications at the CH stage reduced fruit yield 66% to 99%, regardless of pendimethalin rate or spray volume. The 1X rate chemigated at the SD stage was the only treatment not affected by yield reduction (Fig. 2). Greater injury 70 DAT was noted with applications made at the CH (34%) than at the SD (6%) stage, and at the 2X (27% than at the 1X (13%) rate. To a lesser extent, similar effect of rate and timing of application was noted again 100 DAT when boom-applied pendimethalin showed greater injury (16%) than chemigation (8%).

Figure 1. Commercial berry yield following pendimethalin applied at two different rates (1.5 and 3 pt/A) and timings (Spring dormant and Cabbagehead) and averaged over trials conducted in MA and NJ in 2022.

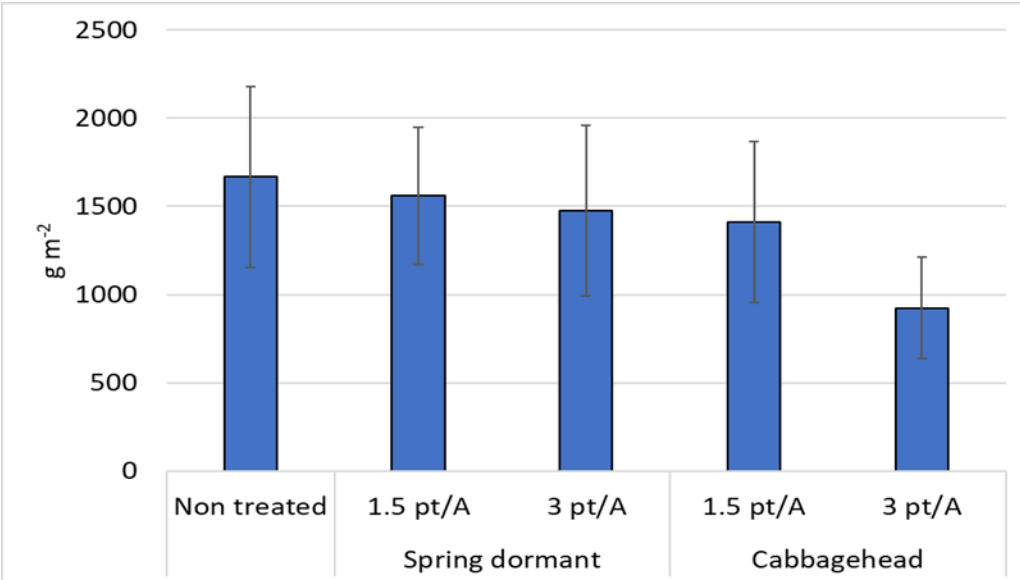
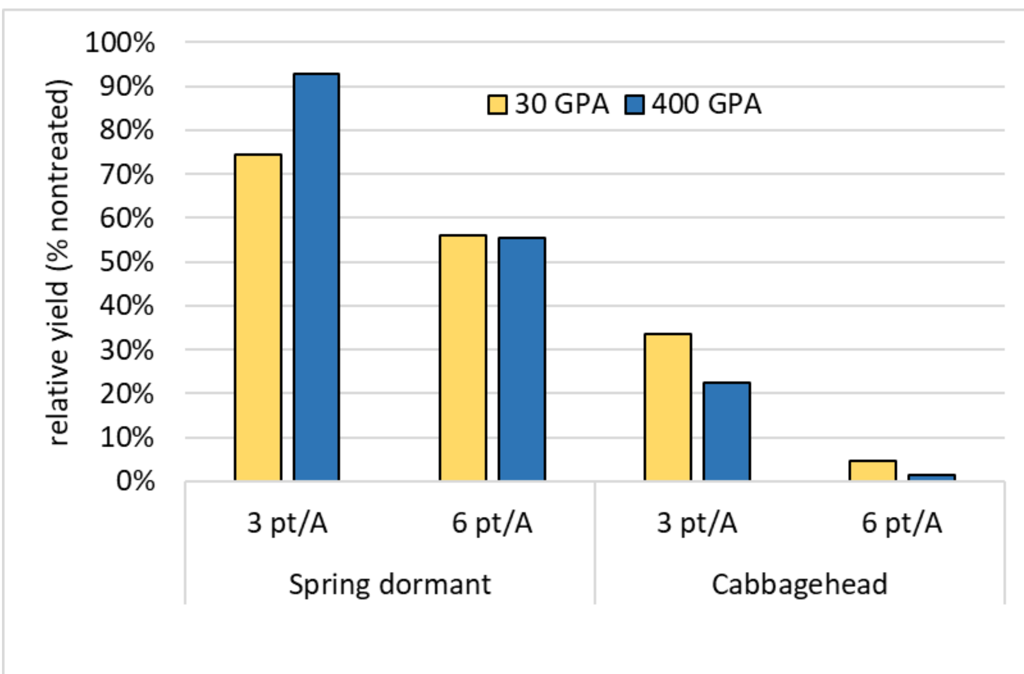


Figure 2. Relative commercial yield following pendimethalin applied at two different rates (3 and 6 pt/A), timings (Spring dormant and Cabbagehead), and spray volume (30 and 400 GPA) in a trial conducted in OR in 2022.



Update on Cranberry Breeding Projects

Jennifer Johnson-Cicalese, Research Associate, *Sara Knowles*, Laboratory Technician, *Thomas Spain*, Sr. Fld. & Grhs. Technician, *James Polashock*, Research Plant Pathologist, USDA-ARS, *Nicholi Vorsa*, Professor, Rutgers University, P.E. Marucci Center, Chatsworth, NJ

Before discussing current breeding projects, let's look back at the past 30 years of Dr. Nicholi Vorsa's work and see how far we've come. From 1992 to 2022, 3180 crosses were made, over 100,000 seedlings were transplanted, and approximately half of these progeny were evaluated in field plots and in the greenhouse. Breeding and evaluation techniques were developed and continue to evolve. Countless fruit samples were collected and evaluated for yield, fruit size, percent rot, TAcy, brix, and titratable acidity. Analytical techniques were developed to quantify flavonoids and organic acids in cranberry breeding material, and collaborative research conducted to learn about the effects of these compounds on human health. We have developed techniques to identify varieties with DNA fingerprinting, map the cranberry genome and identify genetic markers. Seven new varieties have been released from the program in which yield, fruit size, and TAcy have all increased. For example, in the original NJ trial, 'Haines' 3yr-average yield was 475g/ft^2 and TAcy of 21, in comparison to 'Stevens', with yield of 278 g/ft^2 and TAcy of 10. Additional new varieties are in the pipeline.

This work was done with considerable collaboration with colleagues and by students at the Marucci Center and elsewhere, and collaboration with cranberry growers. Bill Haines Sr. offered Dr. Vorsa acreage for his first progeny evaluation plots, approx. 2300 plots, and growers around the country have planted numerous advanced selection trials over the years. And the work continues… Currently the focus of the program is breeding for: 1) resistance to fruit rot, 2) reduced fruit acidity, 3) compounds associated with human health, 4) heat stress tolerance, and 5) fruit quality. When the new breeder starts this year, I'm sure they will have some ideas of their own!

Resistance to Fruit Rot - As you are well aware, fruit rot is a serious concern to cranberry growers, and continues to get worse due to fungicide restrictions and climate change. A concerted effort to breed for resistance to fruit rot began in 2003, with identification of several sources of resistance. Multiple generations of crosses have been made, along with field evaluations of 1000's of progeny. Progress has been made and advanced selections with both improved fruit rot resistance and good yield are being tested in large grower plots at JJ White and Pine Island, and in replicated fungicide trials (in collaboration with Peter Oudemans) with promising results.

We are currently evaluating 2400 progeny from 2nd generation crosses, with some crosses between FRR selections and lower acidity selections. The latest set of progeny that were field planted in 2021 and 2022 are 3rd generation crosses for fruit rot resistance (FRR), 36 crosses and almost 2000 progeny, including some crosses with newly identified selections with superior yield and unique fruit chemistry.

Another population of particular interest is **CNJ14-31**, a 2nd generation FRR x FRR cross, with 219 progeny replicated 4 times. These progeny have been genotyped and extensively phenotyped for yield, fruit size, FRR, leaf disease, fruit chemistry, organic acids, epicuticular wax, bloom date, #flowers and fruit/upright, fruit firmness and quality. Because the population is so large and replicated, making the data more reliable, we hope to be able to identify genetic markers for numerous traits and be able to test our current markers. This mapping project is being done as part of a collaborative grant (VacCAP) with multiple researchers including James Polashock's team. In addition, we have identified one individual with potential for varietal release!

Flavonol - Flavonoid compounds have been attributed to a multitude of human health benefits, including urinary tract and cardiovascular health, as well as neuroprotective activity. Within the flavonoids, the flavonol class is found in especially high levels in cranberry fruit and has been shown to have higher bioavailability in mammals. Eight principal flavonols are present in cranberry fruit. When we screened our germplasm collection, plants with significantly higher flavonol profiles were identified in wild accessions, both for total and individual flavonols (Fong et al, in prep.). To determine if flavonol content is heritable, 24 breeding populations were analyzed using a mid-parent offspring regression and gave a narrow-sense heritability (h^2) of 0.47. Analysis of seven varieties in four growing regions (NJ, WI, WA, OR) indicated significant regional variation in the fruit size and flavonol content in the different regions, but no genotype by environment interaction. In addition, genetic markers for individual flavonols have been identified. Because these findings suggest potential for genetic enhancement of flavonol content in cranberry, we began making crosses in 2020 among accessions with the highest flavonol components and will evaluate fruit as it becomes available.

Reduced Fruit Acidity - Organic acids (OAs) are important compounds for both the consumer and the plant. Fruit acidity affects overall fruit flavor as well as experiences of aroma and sweetness. Commercial cranberry cultivars are high in titratable acidity (2.0-3.0%) compared to fresh market apples (0.3- 1.0%), and other fresh market fruits. Reducing cranberry acids through breeding will lessen their aggressively tart flavor, which may allow the reduction of added sugars required for palatability of cranberry products. OAs are essential to plant development and stress response, for example, they help maintain membrane function (Mignard *et al* 2022). Fruit acids (particularly malic) have bacteriostatic properties, preventing growth of bacteria (and therefore delaying fruit spoilage) due to reduced pH (Baker and Grant 2022). Benzoic and quinic acids were found to reduce fruit rot fungal growth and reactive oxygen species levels in *Vaccinium macrocarpon* (Tadych *et al* 2015).

In 1998, our germplasm collection was screened for OAs and variability was found. In particular, one accession with very low citric acid and one with very low malic acid were identified, and in 2004, we began using them in crosses. Genetic markers for low citric and malic acid identified through Stephanie Fong *et al*'s research (2020, 2021), were used to evaluate 76 populations and thousands of seedlings in the breeding program so far, aiding in selection of plants with TA as low as 0.6%. One concern addressed by Fong *et al* includes a dwarf-like vegetative phenotype associated with homozygous low-malic acid genotype, increased seedling mortality, and decreased vigor in the field. This phenotype tends to be associated with the lowest TA among progeny (Figure 1). However, a range of TA exists within these populations, including progeny with low TA and good vigor. In the coming months, we will have updated results from the germplasm collection for concentrations of the organic acids, citric, malic, quinic, and benzoic. Efforts are underway to identify additional sources of low acidity and associated genetic markers. We have begun planting low TA individuals in the field to evaluate their yield and potential (Figure 2).

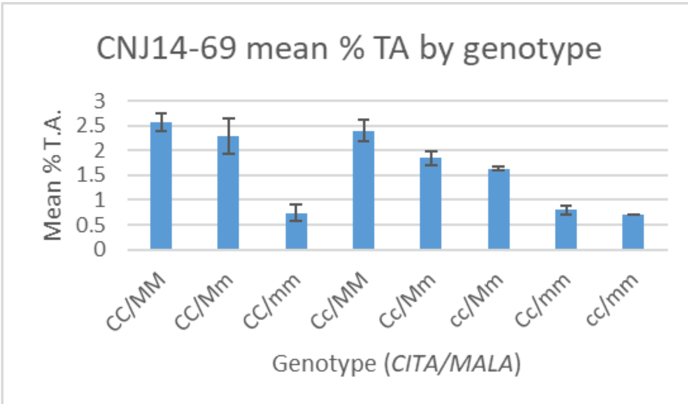


Figure 1. Mean TA based on citric/malic acid genotypes in a low TA breeding population. 1st pair of letters is the citric acid genotype (CC, Cc, cc), 2nd pair of letters is malic acid genotype (MM, Mm, mm). Note the homozygous low malic acid genotype (_ _/mm) groups have the lowest mean TA.

Figure 2. Homozygous low malic acid plant with associated dwarf-like vegetative phenology and a TA of 0.7%. However, this plant has larger, more “normal” sized fruits.

Other Breeding Activities - We are compiling the data we’ve collected over the last decade from several regional trials (WI, OR, BC, NJ) to better understand the performance of new varieties and the effect of environment, using new statistical methods in collaboration with Jeff Neyhardt. High throughput phenotyping methods are being developed to speed up the screening process, such as various imaging techniques. Work is underway to identify and test genetic markers (with Joseph Kawash), and as they become more reliable, will be used to screen for traits at the seedling stage.

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Updating Approaches to Fruit Rot Resistance Research

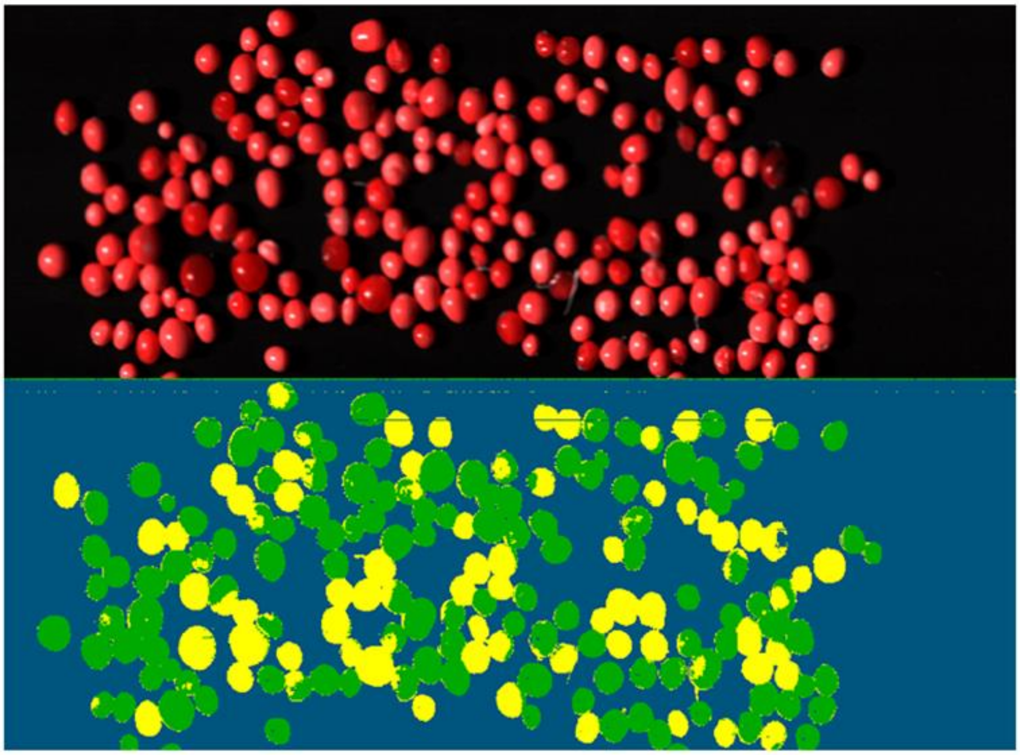
Joseph Kawash, Bioinformaticist, USDA-ARS, and *James Polashock*, Research Plant Pathologist, USDA-ARS

Breeding and selection of woody perennial crops such as cranberry is time consuming and labor intensive. Selection for fruit rot resistance is especially resource intensive; genotypically consisting of multiple interacting, non-additive genetic components and phenotyping that requires manual collection and sorting. However, due to the complex nature of fruit rot, the development of rot resistant lines will ultimately require several rounds of selection to identify causative genetic factors of desired phenotypic traits.

We are working towards streamlining both the genotypic and phenotypic aspects of marker assisted selection (MAS), to reduce the amount of time, labor, and resources required for successful rounds of selection in cranberry. We have developed marker identification methods utilizing machine learning (ML) that effectively follow phenotypic traits of interest, even considering complex marker interactions. This approach will potentially reduce the number of rounds of breeding and selection cycles. Additionally, we are developing new methods of high throughput phenotypic methods that utilize machine vision and hyperspectral imaging. Using machine vision, we would be able to sort fruit at a higher rate that requires less time and manual assessment than currently needed, while maintaining a high level of accuracy.

Our ML approach to marker development offers a more comprehensive means of MAS, with an increased ability to identify interacting and non-additive markers compared to traditional studies. Methods were validated in several populations of cranberry previously studied for low acid traits, where highly associated markers were identified using a conventional software package. We then utilized the ML methods to study the polygenic trait of fruit rot resistance in several populations of cranberry that were not well characterized using conventional analysis software. Four genetic locations on four different chromosomes were identified in these populations with three locations contributing to an estimated 23% of phenotypic variance in one population and two loci contributing to an estimated 27% of the variance in the remaining population. SNPs at the locations identified facilitated the creation of markers for genotyping and used to screen a population not utilized in the ML development. These markers were successful in identifying rot resistant individuals and separation by genotypic group identified a potential 17% difference in phenotypic variance.

Our approach to improving phenotyping methods also utilizes ML. Using hyperspectral imaging, including light wavelengths beyond the visible light spectrum, pre-sorted fruit (rotten, sound) were assayed in small batches to develop training sets. The resulting information was passed into ML best fit models to determine the spectral information of each classification group. Further assessment of fruit pulled from the field does not require manual separation or identification, only imaging of bulk fruit at single layer depth. Using these methods we are able to assay fruit samples at a rate of approximately 500 fruit per minute with batch accuracy greater than 90%. However, this current method is limited to only batch information as it relates to the total viewed fruit space. Currently we are improving on these methods, using convolutional neural networks for the automated identification and assessment of individual fruit within a bulk sample.

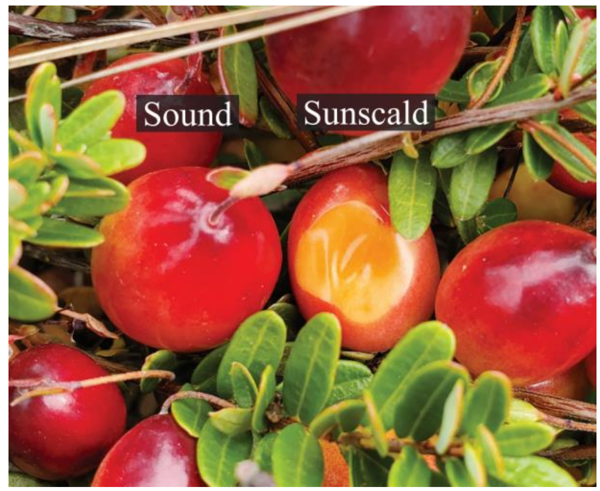


Top: Unclassified cranberry fruit, sound and rotten, mixed in bulk.
Bottom: After ML analysis fruit is classified as sound (green) or rotten (yellow).

Cranberry Fruit Epicuticular Wax Benefits and Identification of a Wax-associated Molecular Marker

Lindsay Erndwein, *Joseph Kawash*, *Sara Knowles*, *Nicholi Vorsa*, and *James Polashock*

As the global climate changes, periods of abiotic stress throughout the North American cranberry growing regions will become more common. One consequence of high temperature extremes and drought conditions is sunscald. Scalding damages the developing berry and reduces yields through fruit tissue damage and/or secondary pathogen infection. Irrigation to cool the fruit is the primary approach to controlling sunscald. However, it is water intensive and can increase fungal-incited fruit rot. Epicuticular wax functions as a barrier to various environmental stresses in other fruit crops and may be a promising plant feature to mitigate sunscald.



In this study we assessed the function of epicuticular wax in cranberries to mitigate stresses associated with sunscald by subjecting high and low epicuticular wax cranberries to controlled drying and light/heat exposure. A cranberry population that segregates for epicuticular wax was phenotyped for epicuticular fruit wax levels and DNA sequences were generated using genotyping by sequencing (GBS). Quantitative trait loci (QTL) were then used to identify regions of the genome that influence the high epicuticular wax phenotype. A molecular marker identified on the QTL region was then genotyped to assess how this molecular marker influences epicuticular wax.

Results: Cranberries with high epicuticular wax lost less mass and maintained a lower surface temperature following heat/light and drying experiments as compared to fruit with low wax. QTL analysis identified a marker with the epicuticular wax phenotype. Genotyping assays revealed that cranberry selections homozygous for the molecular marker have consistently high epicuticular wax ratings. A gene associated with epicuticular wax synthesis was also identified near this QTL region.

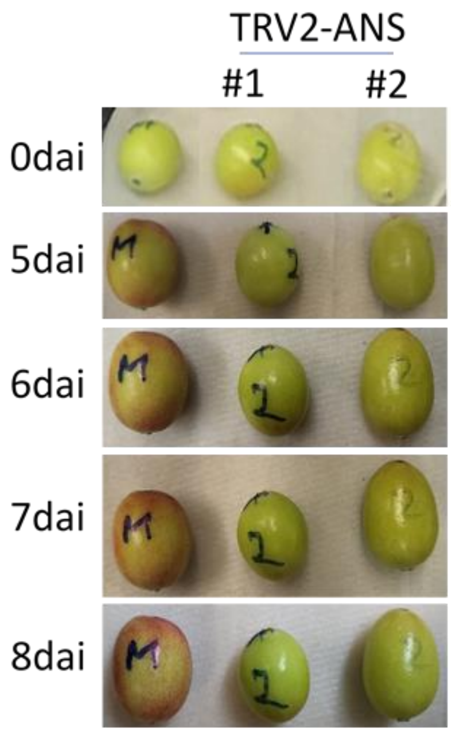
Conclusions: Our results suggest that increased cranberry epicuticular wax load may help reduce the effects of heat/light and water stress: two primary contributors to sunscald. Further, the molecular marker identified in this study can be used in marker assisted selection to screen cranberry seedlings for epicuticular wax. This work serves to improve yields and fruit quality of cranberry crops in the face of global climate change.

Gene Functional Analysis in Cranberry

James Polashock, Research Plant Pathologist, and *Sujon Sarowar,* ORISE Established Scientist Fellow

Our advances in the molecular biology of American cranberry (*Vaccinium macrocarpon*) have allowed us to identify important regions of the cranberry genome and to generate markers for those regions to be used in marker assisted selection. In addition to generating markers, we seek to identify the genes associated with important phenotypic characteristics. However, biotechnological approaches to cranberry research and improvement are still nascent due to challenges in developing a reliable method for gene transfer and genetic integration into the cranberry genome. Virus-induced gene silencing (VIGS) has proven to be an efficient tool to study gene function in various model and crop plant species in a high throughput fashion. We have developed an efficient method for virus-induced gene silencing assays in cranberry using a Tobacco Rattle Virus (TRV)-based VIGS system. We demonstrated effectiveness in cranberry fruit by silencing a gene in the anthocyanin biosynthetic pathway, anthocyanin synthase (ANS), which is required for fruit colorization during ripening. Silencing of ANS using this approach resulted in delayed colorization as compared to mock infiltrated control fruit, and fruit remained green at least 12-15 dpi. Quantification of anthocyanin content and detection of anthocyanin transcripts by real-time quantitative polymerase-chain reaction (qPCR) confirmed target gene silencing. Our success Targeting ANS suggests that this system will work for other target genes.

Mock inoculated berries (first column) begin to ripen (turn red) as normal, but those inoculated with the VIGS vectors (TRV-2ANS, #1 and #2) remain green due to silencing of ANS.



Application of Drone Technology in Cranberry Production

Giverson Mupambi, UMass Cranberry Station

Introduction

Recent technological improvements in drones or unmanned aerial systems offer new opportunities for cranberry growers to improve precision agriculture. Drones can potentially be used for frost monitoring, irrigation monitoring, insect scouting, disease detection, fertilizer, and pesticide application. The main objective of the research is to explore various ways in which drones can aid in cranberry production.

Approach

The research is divided into two main areas (1) remote sensing and (2) application of inputs (fertilizer and pesticides). In terms of remote sensing, the research is focused on testing different cameras (RGB, multispectral and hyperspectral) and evaluating different photogrammetry packages for creating high-quality orthomosaic maps. With regard to inputs, we are still working on regulations with partners at the state level to develop rules for the aerial application of fertilizer and pesticides using drones.

Frost monitoring

We investigated the use of long-wave infrared (thermal) imaging for mapping cold spots on a multiple cranberry bog system that is controlled by one frost temperature sensor. The experiments aimed to improve the placement of the temperature sensor used for frost protection. Data was collected using a ZENMUSE XT1 thermal camera mounted on a Matrice M100 Drone. Thermal calibration was done using a clear sun background. We constructed an orthomosaic and digital elevation model from raw images using Pix4D mapper photogrammetry software (**Figure 1).**

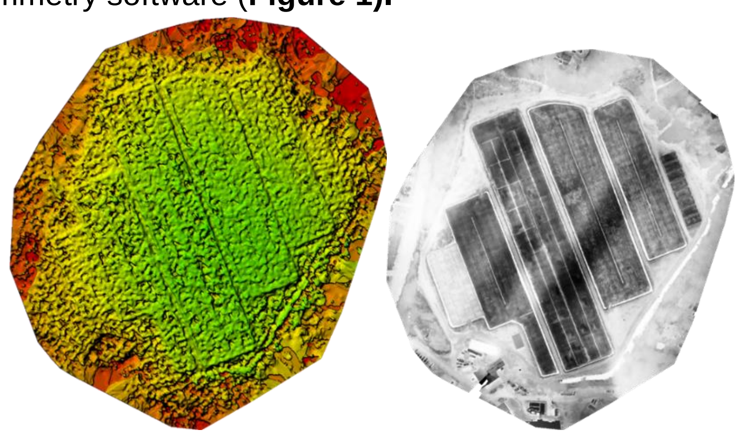


Figure 1: Digital elevation model (left) and thermal image orthomosaic (right) in greyscale of a cranberry bog system. The dark spots on the thermal image represent the coldest spots.

From the results, we could pinpoint the coldest spot on the bog to within inches of precision. The results were then used for the precision placement of the frost temperature sensor. This is particularly useful in a bog system that comprises many cultivars. In this case, the grower can protect the bog to the threshold temperature of the most sensitive cultivar. Subsequent flights on different dates confirmed the coordinates of the cold spot on the bog sytem. Future experiments will conduct thermal flights during a frost irrigation cycle to determine the uniformity of protection.

Insect damage

We explored the use of visible (RGB) and multispectral imaging to map and detect inset damage from Putnam scale and golden casebearer. Data was collected using a DJI P4 Multispectral Agriculture Drone with D-RTK 2 Mobile Base Station. We constructed orthomosaics from raw images using Pix4Dfields photogrammetry software. The camera was calibrated with a Parrot Sequoia calibration target using images acquired before and after the flight. The orthomosaics from the RGB and multispectral cameras showed the extent of Putnam scale damage (**Figure 2**). A grower can use this image to decide a threshold for applying insecticides to control the scale. Growers can also use orthomosaics to develop a database for each bog over several growing seasons that can help them understand the patterns of insect damage and the efficacy of their sprays.

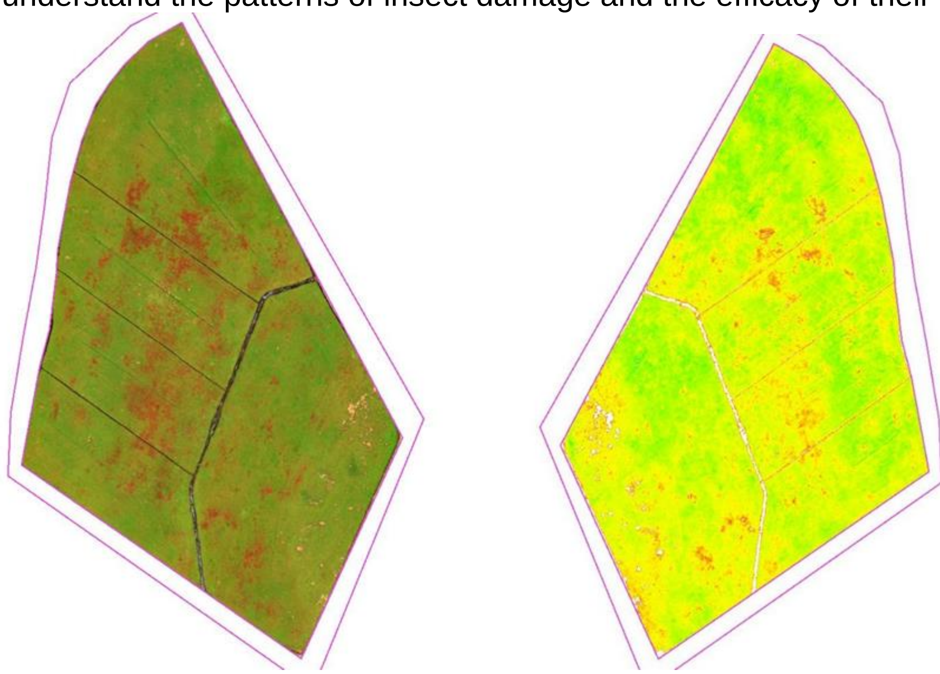


Figure 2: Visible (RGB) (left) and normalized difference vegetation index (NDVI) (right) image orthomosaic of a cranberry bog showing Putnam scale damage (reddish brown areas). The data was acquired using a multispectral camera.

Plant nutrition

The use of a multispectral camera for detecting the efficiency of rotary spreader fertilizer application was explored. Data was collected using a DJI P4 Multispectral Agriculture Drone with D-RTK 2 Mobile Base Station. We constructed orthomosaics from raw images using Pix4Dfields photogrammetry software. The camera was calibrated with a Parrot Sequoia calibration target using images acquired before and after the flight. Tissue samples were also collected for nutrient analysis at a lab. Based on both visible and NDVI images, the rotary spreader fertilizer application on this particular bog was shown to be uneven (**Figure 3**). The results from the tissue sampling confirmed this. The grower will be advised to take remedial action for the upcoming bog season for a more uniform application. In the future, the orthomosaics will be used for creating maps for variable-rate fertilizer applications to achieve bog uniformity.

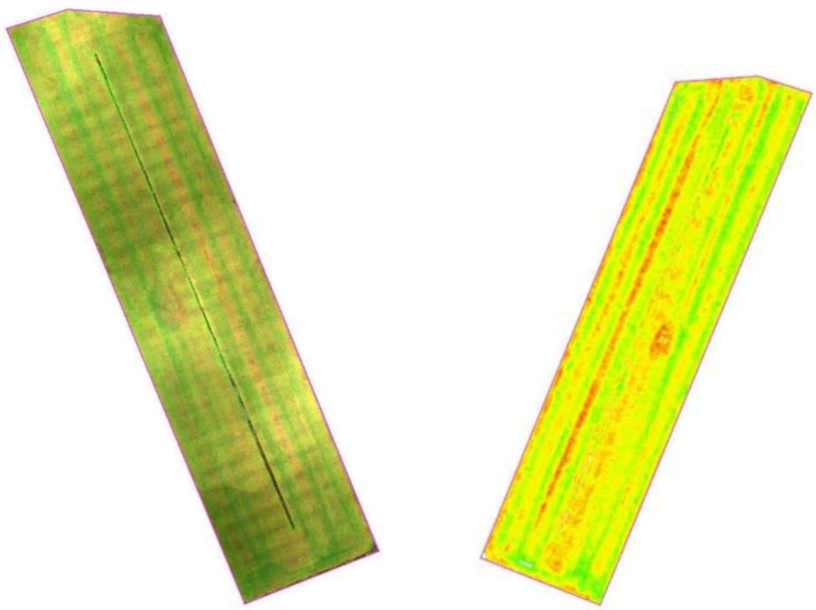


Figure 3: Visible (RGB) (left) and normalized difference vegetation index (NDVI) (right) image orthomosaic of a cranberry bog showing inefficiency of rotary spreader fertilizer application. The green stripes represent areas that received optimal fertilizer, and the brown stripes represent under-fertilized areas.