2017 Annual Winter Meeting of the American Cranberry Growers Association
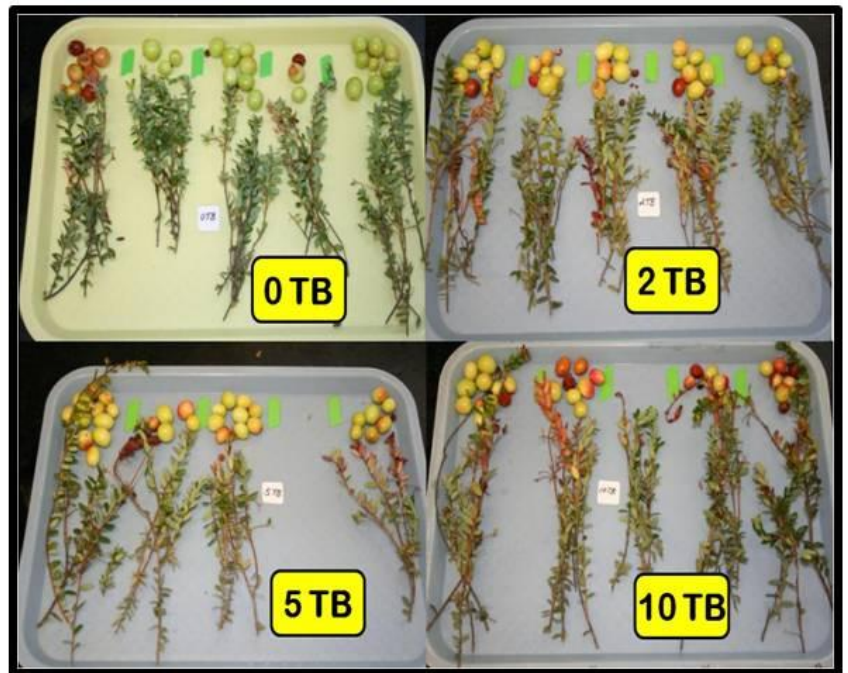
AMERICAN CRANBERRY GROWERS
association

Rutgers University EcoComplex

Bordentown, NJ

Thursday January 19, 2017

RUTGERS
New Jersey Agricultural Experiment Station

ACGA Winter Meeting Program

Thursday, January 19, 2017

Rutgers EcoComplex, Bordentown, NJ

8:00-8:30 Registration and Coffee

8:30-8:45 Welcoming Remarks– *Shawn Cutts*, **President, ACGA**
          Treasurer's Report *– Shawn Cutts*

8:45-9:00 C**ranberry Statistics**
          Bruce Eklund, National Agricultural Statistics Service, Trenton, NJ

9:00-9:20 C**ranberry Institute – An Update**
          John Wilson, Cranberry Institute, Carver, MA

9:20-9:40 **Overview of Weed Management Program in Cranberry: New Challenges**
          Thierry Besancon, Weed Science Extension Specialist, Rutgers University, P.E. Marucci
Center, Chatsworth, NJ

9:40-10:05 **What do We Know and Don't Know about Leafhoppers and Toadbugs?**
          Cesar Rodriguez-Saona, Extension Specialist, Department of Entomology, Rutgers
University, New Brunswick, NJ; *Vera Kyryczenko-Roth*, and *Robert Holdcraft*, P.E.
Marucci Center, Chatsworth, NJ

10:05-10:20 **Break**

10:20-10:40 **Grower Survey: USDA SCRI – *Vaccinium* research**
          Cesar Rodriguez-Saona, N. Vorsa, and J. Polashock, Rutgers University

10:40-11:05 **The Quest for Fruit Rot Resistance**
          James Polashock, Research Plant Pathologist, USDA-ARS, *G. Daverdin, J. Johnson-
Cicalese, and N. Vorsa*, P.E. Marucci Center, Chatsworth, NJ

11:05-11:30 **Urinary Clearance of Cranberry Flavonol Glycosides in Humans**
          *Yifei Wang, A.P. Singh, H.N. Nelson, A.J. Kaiser, N.C. Reker, T.L. Hooks, T. Wilson, N.
Vorsa,* Department of Plant Biology and Pathology, Rutgers University, New Brunswick,
NJ

11:30-11:55 **Managing and Measuring Fruit Quality**
          Peter Oudemans, Professor, Department of Plant Biology and Pathology, Rutgers
University, New Brunswick, NJ; P.E. Marruci Center, Chatsworth, NJ

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

1:00-1:45 **Irrigation and Drainage Management Strategies for Enhancing Crop Production in Cranberry Farms**
Casey Kennedy, USDA-ARS/UMass Cranberry Station, East Wareham, MA

1:45-2:15 **Farm Safety with Pesticides**
Ray Samulis, Burlington County Agricultural Agent, Rutgers University, Mt. Holly, NJ

2:15 **Adjournment**- *ACGA Board of Directors Meeting*

NEW JERSEY AGRICULTURAL STATISTICS
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USDA's National Agricultural Statistics will release the 2016 Noncitrus Fruits and Nuts Final Summary noon June 27 2017. There is no Preliminary Noncitrus Fruits and Nuts release for this January. The 2017 production forecast for the five major states is August 10.

 For 2015, New Jersey growers were third nationally in acres harvested, yield, utilized production, price received, and value of utilized production.

https://www.nass.usda.gov/Publications/Reports_By_Date/index.php

Please always feel free to contact me by phone or e-mail with questions or to help find data.

CRANBERRY INSTITUTE – AN UPDATE
John Wilson
Cranberry Institute, Carver, MA

The CI will provide updates on research funding, regulatory and MRL activities. The CI continued to help coordinate research funding of grower associations and a few cranberry handlers. In 2016, growers and handlers provided a little more than $800,000 for horticulture research which is down 12% from 2015 and about even with 2014. New this year are the funding figures from growers in Quebec. Contributions from NJ growers continues to be among the top of all grower and handler organizations.

This past year found the CI providing comments on several possible regulatory actions. These include: the possible loss of chlorpyrifos (Lorsban) in the US and chlorothalonil (Bravo) in Canada; the possible loss of diazinon due to its effect on endangered species; the availability of Closer (sulfoxaflor) to cranberry growers. We will report on possible new materials that might become available in 2017. During the 2016 Minor Use Workshops in Canada and US, two new fungicides and one new herbicide will be investigated for future registrations. After a visit to EPA last February with several industry people, we learned about a Cranberry Water Model that is being used to evaluate how new chemicals behave in harvest water. This has not been helpful to the cranberry industry causing some chemical registrants to step away from supporting new cranberry registrations. Several options for dealing with this issue will be presented.

On the MRL front, there has been some progress to report. A total of 80 new MRLs were acquired last year, although most were because we started tracking 5 new chemicals and their associated MRLs. However, the one MRL we wanted and not able to get is for quinclorac in the EU – progress is slow. We will report on several other high profile MRL updates.

OVERVIEW OF WEED MANAGEMENT PROGRAM IN CRANBERRY AND NEW CHALLENGES.

Thierry Besançon
Rutgers University

Callisto 4 SC (mesotrione) has been labeled for use in newly planted or bearing cranberries in New Jersey since 2008 to suppress or control rushes, sedges, or annual broadleaf weeds such as yellow loosestrife (*Lysimachia terrestris*) or St. Johnswort (*Hypericum* ssp.). Callisto belongs to the bleacher herbicide family and will affect the biosynthesis of carotenoids. It can be used both pre and postemergence as a systemic herbicide and can penetrate plants through the root system or through the foliage. Currently, Callisto is mostly broadcast through the irrigation system (chemigation) at a rate of 8 fl oz/acre delivered in 400+ gallons of water. Excessive dilution will decrease the amount of herbicide absorbed through the roots or foliage of weeds and may decrease herbicide efficiency on hard to control weeds such as dodder or poison ivy. Spot application of Callisto on cranberries is labelled in Massachusetts under a Section 24(c) Special Local Need. Spot application of Callisto at 1.5 fl oz/gal + COC at 1.5 fl oz/gal prior to dodder flowering effectively reduces dodder seed production whereas similar treatments applied after dodder flowering were less efficient. Similar spot applications of Callisto and COC applied early (late May to mid-June) or late in the season (mid-June to early July) were efficient to reduce poison ivy cover and increase cranberry cover when treatments were repeated over the course of 2 years. Advantages of spot application of Callisto in cranberry bogs include: a more concentrated application of herbicide for effective control of hard-to-control weeds, a lesser overall amount of herbicide applied, a lower risk of off-target application, improved yield, and reduced chance of vine injury since cranberries are very tolerant of Callisto. Obtaining a 24(c) Special Local Need label for spot application of Callisto in New Jersey is currently under discussion with Syngenta and the New Jersey Department of Environmental Protection.

Two weed management concerns affecting cranberry production in New Jersey have been identified and will be the focus of greenhouse and field research over the next 3 years. Carolina redroot (*Lachnanthes caroliniana*) is a monocotyledonous herb found in wet acidic habitats in eastern North America. It has been shown to dominate areas previously occupied by native plant species after disturbance of animal origin. In cranberry bogs, redroot will rapidly colonize and establish dense populations in areas that have been opened up following the development and spread of fairy ring disease, preventing cranberry vine recolonization of these areas. Additionally, wintering swans and geese are known to feed on redroot fleshy rhizomes, creating more disturbance in cranberry bogs. Little is known about the influence of different environmental factors on redroot seed germination or resprouting ability of the rhizome. Therefore, future research will focus on assessing the effect of temperature, burial depth, solution pH, water stress, rhizome size on Carolina redroot development. Information on redroot control is limited, only recent studies from North Carolina have documented the efficiency of some herbicides used in blueberry production to control redroot. Distribution of redroot in cranberry bogs is often patchy and prevents researchers from obtaining consistent results with on-farm studies. Greenhouse studies will therefore be conducted in spring 2017 to compare the efficacy of herbicide already labelled for use on cranberry as well as potentially interesting compounds to control Carolina redroot through preemergence and postemergence

treatments. If sufficiently large and homogeneous redroot infested area for conducting on-farm research are identified, field experiments will be conducted with the same herbicides.

Fruit produced by cranberry vines during the first years that follow crop establishment are generally not harvested for commercial production. These fruit are left on site and can therefore release seeds that will germinate and produce new cranberry seedlings (volunteer seedlings) or contribute to the seedbank. As crop canopy closure will occur after a few years following bed renovation, space and light availability are not factors limiting the development and growth of volunteer seedlings that can compete for light, water or nutrients with planted seedlings. In addition, volunteer seedlings may often be considered off-types varieties resulting from cross-pollination with wild cranberry. These off-types are generally lower yielding plants that will produce more vegetative structures than commercial varieties and can therefore outcompete them by occupying the available space more rapidly thanks to the spread of more competitive stolons. Ultimately, the contamination of planted cranberry beds by volunteer cranberry seedlings will result in decreased productivity. The proposed research will foster collaboration between qualified scientists, at Rutgers University, University of Massachusetts and USDA-ARS. With limited knowledge on possibilities to control volunteer cranberry seedlings, producers will benefit from assessing and understanding the impact of different environmental factors on seed germination and seed longevity, and are supportive of research efforts that may increase cranberry productivity while meeting societal demand for more sustainable agriculture. Therefore, future weed science research on volunteer cranberry seedlings may address the following topics:

1. Understand the contribution of different environmental factors (solution pH, temperature, water stress, burial depth…) on volunteer cranberry seed germination.
2. Investigate the longevity of cranberry seedlings preserved under various edaphic and environmental conditions encountered in areas of cranberry production in North America.
3. Develop management strategies to prevent the production of fruits during bed establishment, control the emergence of volunteer seedlings and avoid the propagation of undesirable genetic plant materials
   a. Inhibit pollination by damaging flowers (short-term flooding, nontoxic biodegradable household products, sanding, plant growth regulators…).
   b. Induce fruit drop from uprights before cranberry seeds reach reproductive maturity (mechanical control, plant growth regulators…).
   c. Suppress the germination of seeds (sanding, preemergence herbicides…).
4. Genetic fingerprint of cranberry seedlings that germinate from the longevity study.

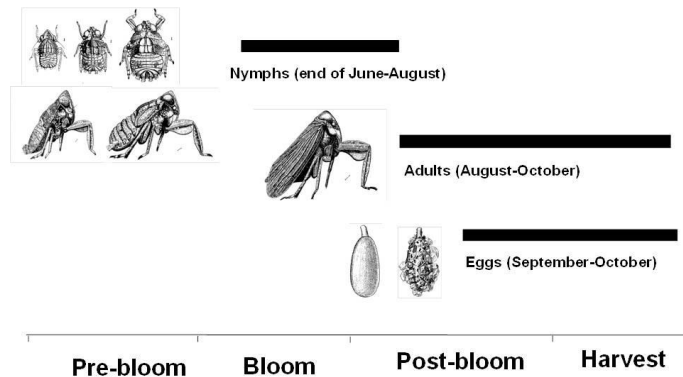**WHAT DO WE KNOW AND DON'T KNOW ABOUT LEAFHOPPERS AND TOADBUGS?**
Cesar Rodriguez-Saona, Department of Entomology, Rutgers University, New Brunswick, NJ;
Vera Kyryczenko-Roth, and *Robert Holdcraft*, P.E. Marucci Center, Chatsworth, NJ

The Cranberry Toad Bug

Toad bugs are hemipteran insects (similar to blunt-nosed leafhoppers) but belong to the Family Dictyopharidae (planthoppers) (as opposed to leafhoppers, which belong to the family Cicadellidae). The cranberry toad bug, *Phylloscelis atra*, feeds only on cranberries. This insect has a single generation per year. It overwinters as eggs. The nymphs appear by mid-June through August, and the adults from mid-July through October. Eggs are laid

The cranberry toad bug life cycle

Nymphs (end of June-August)

Adults (August-October)

Eggs (September-October)

Pre-bloom Bloom Post-bloom Harvest

from mid-August through October. Feeding damage can be noticed in two stages. First stage feeding damage on vines causes closing in (towards the branch) of the leaves on the new growth. Second stage feeding causes changed in color (reddish to brown) of new growth. The damage can be seen from July until harvest. This damage will cause dying of the branch and the berries to shrivel up. Heavy infestation will result in dwarfed berries. Little information is currently available on the ecology, impact, monitoring, and management of cranberry toad bugs.

Field trial for Leafhoppers & Toad bug control

Many of the newer selective insecticides have no or little control over piercing-sucking insects such as leafhoppers, toad bugs, mirids, etc. There is concern of a potential increase in secondary pests, such as the cranberry toad bug, because of recent changes in pest management strategies (e.g., adoption of new reduced-risk products and decreased applications of broad-spectrum insecticides). Using a semi-field/lab assay in 2014 we tested a range of new chemicals in comparison with broad spectrum chemicals currently in use. To evaluate the effectiveness of those same chemicals in an actual field setting, we ran a medium-size plot trial in 2016.

In 2016 we evaluated the efficacy of a late season application of 9 insecticides (plus an untreated control) against leafhoppers [blunt-nosed leafhoppers (BNLH) and sharp-nosed leafhoppers (SNLH)] and Toad bugs. A cranberry bog (var. Early Black) located at the Rutgers Blueberry & Cranberry Research Center was divided into 40 plots (10 treatments x 4 reps), Plots were 20 ft x 15 ft. The research plots were sprayed using a customized 8 ft boom sprayer on 5 August, chemicals were applied in 50 gal water/acre. Vacuumed samples were taken from meter-squares in each plot on 3 August (pre-treatment) and 12 August (post-treatment) with a 2-Cycle Backpack Aspirator (John W. Hock Co., Gainesville, Florida), yielding samples similar to those acquired by sweep-netting.

Table of treatments and rates used in 2014 & 2016							
Treatment	Rate per Acre	BNLH		Toad bug		Status	Class
		2014 Assay	2016 Field	2014 Assay	2016 Field		
Beleaf 50SG	2.8 oz	.	Y	.	Y	Registered	Pyridinecarboxamide
Chem A	13.5 floz	Y	Y	.	Y	Unregistered, IR4	Diamide
Closer SC	4.25 floz	Y	Y	Y	Y	Reassessing Registration	Sulfoximine
Assail 30SG	6.9 oz	.	Y	Y	Y	Registered	Neonicotinoid
Agri-Mek SC	3.5 floz	.	Y	.	Y	Registered	Miticide
Chem B	4.25 oz	Y	.	Y	.	Unregistered	Mixture
Chem C	6.4 floz	Y	Y	Y	Y	Unregistered, IR4	Pyrethroid
Lorsban 4E	3 pt	Y	Y	Y	Y	Registered	OP
Sevin XLR	3 L	.	Y	Y	Y	Registered	Carbamate
Diazinon AG500	3 qt	.	Y	Y	Y	Registered	OP
Imidan 70WP	4 lb	.	.	Y	.	Registered	OP
Actara 25WG	4 oz	.	.	Y	.	Registered	Nicotinoid

Results:

- **Lorsban, Sevin, Diazinon, and the unregistered pyrethroid** worked well against all three pests but killed the spiders.
- **Beleaf** was not effective. **Chem A and Closer** had variable results against leafhoppers but didn't affect toad bugs.
- **Agri-Mek and Assail** seem to work well against toad bugs and BNLH, but Agri-Mek didn't seem to work against SNLH.
- Assail and Agri-Mek had little effect on spiders.

Impact of Toad Bug Damage on Cranberry Upright Health & Fruit

Little is known on the impact of damage by toad bugs on cranberry yield. This information is important for the development of treatment thresholds. We conducted a study to determine whether toad bug feeding impacts cranberry fruit quality and health by characterizing feeding damage. Treatments consisted of 0, 10, 25 or 50 toad bug nymphs, replicated 5 times. Nymphs were used as they are the main target of insecticide applications and the cause of most of the early damage to the vines. Toad bug damage to uprights differed among treatments. There were no differences in number of damaged uprights between the control and 10 toadbugs; however, there were 3 times more damaged uprights at densities equal or greater than 25 toadbugs. No differences were found on number of damaged fruit or fruit weight.

THE QUEST FOR ENHANCING FRUIT ROT RESISTANCE IN CRANBERRY

James Polashock, Research Plant Pathologist, USDA-ARS, *G. Daverdin, J. Johnson-Cicalese, and N. Vorsa*, P.E. Marucci Center, Chatsworth, NJ

BACKGROUND

Fruit rot is the number one problem facing cranberry growers in the Northeast and is an increasing problem in other growing regions. Although carefully selected, timed and properly applied fungicides can be partially effective, the loss of some fungicide registrations, stricter MRLs, development of pathogen resistance and other factors underscore the need to breed resistant varieties.

To be successful, the breeding program requires 1) multiple sources (genes) for resistance as single-gene resistance tends to be short-lived, 2) resistance to be heritable , i.e. resistance is passed on to progeny, 3) broad spectrum resistance since fruit rot is caused by a complex of many different species of fungi, and 4) resistance that is independent of deleterious traits. Development of genetic markers associated with resistance and other desirable traits will allow marker assisted selection (MAS) at the seedling stage and will speed the breeding process.

RESULTS and CONCLUSIONS

Years of collaborative work has resulted in the demonstration that there are at least four different varietal sources of resistance in our germplasm collection. We have evidence that each of these sources harbors one or more genes for resistance. Since these sources are distantly related, they may harbor different genes for resistance. Multiple crosses and extensive evaluation of the progeny demonstrated that the resistance is heritable and the progeny from crosses segregate for resistance/susceptibility. We have isolated fungi from fruit of resistant and susceptible progeny and found that the fungal species and the relative amounts of each are generally the same regardless of the level of resistance to fruit rot. This suggests that the resistance is broad-spectrum since multiple fruit-rotting fungal species are present, but fruit rot is inhibited. The varietal sources of resistance lack many of the qualities needed to be a successful variety, such as high yield, good color, uniform fruit size, etc. Thus, the resistance genes must be dissociable from the deleterious genes. We have developed populations that show a wide range of segregation for all phenotypic traits tested, suggesting that inheritance of these traits is independent, i.e. genetically not linked. This will allow for combining resistance with other desirable horticultural traits. We have genotyped the segregating populations and together with the phenotypic data, e.g. percent fruit rot, we were able to generate genetic maps for cranberry and have identified 60 quantitative trait loci (QTL), or markers, associated with fruit rot resistance, yield, berry weight and other traits.

ACKNOWLEDGMENTS

URINARY CLEARANCE OF CRANBERRY FLAVONOL GLYCOSIDES IN HUMANS

Yifei Wang[1], Ajay P. Singh[1], Heather N. Nelson[2], Amanda J. Kaiser[2], Nicolette C. Reker[2], Tisha L. Hooks[3], Ted Wilson[2] and Nicholi Vorsa[1, 4]

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[2]Biology Department, Winona State University, Winona, MN, USA
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[4]Philip E. Marucci Center for Blueberry and Cranberry Research and Extension, Rutgers University, Chatsworth, NJ, USA

Flavonoids are polyphenolic secondary metabolites which occur widely in different plant species and plant derived foods, such as vegetables, fruits, tea and wine (1). They have been shown to be associated with various health-beneficial properties, such as antioxidant, anti-inflammatory and anti-cancer activities, as well as cardiovascular benefits (2). American cranberry (*Vaccinium macrocarpon*) is rich in flavonoids, including anthocyanins, proanthocyanidins and flavonols. These flavonoids contribute to many of the cranberry's health-beneficial properties.

The potential benefits of cranberry flavonoids largely depend on their human bioavailability, which can greatly differ between individual compounds (3). Cranberry anthocyanins have been recovered in human plasma and urine following consumption of cranberry juice or other cranberry products (4-5). Cranberry proanthocyanidins, due to their large, polymeric structures, are poorly absorbed in the human body, as most *in vivo* studies only detected proanthocyanidin monomers (epicatechin, catechin) in human or animal (6-7).

The third category of flavonoids is the flavonols. They occur in cranberry and other plants mostly as conjugates of an aglycone (such as quercetin and myricetin) and a sugar (such as galactoside or arabinoside) (8). Although flavonol aglycones have been recovered in human plasma and urine after consumption of flavonol-containing foods (9-10), bioavailability of flavonol glycosides (the conjugated form of the molecule) is still poorly understood, in part because of the enzyme/acid hydrolysis employed by previous studies in their sample preparation. Since the bioactivity of flavonol aglycones can be different from their conjugated derivatives, which are the primary flavonol forms in cranberry, an improved understanding of flavonol glycosides bioavailability is needed to evaluate cranberry's health benefits for human.

In this study, we evaluated the urine clearance of cranberry flavonols of ten healthy female subjects (19.5 ± 1.1 years) after consumption of 27% cranberry juice. The consumed cranberry juice contained six major flavonol glycosides, including quercetin-3-galactoside (1.83 mg), quercetin-3-arabioside (0.53 mg), myricetin-3-galactoside (0.46 mg), quercetin-3-rhamnoside (0.31 mg), myricetin-3-arabinoside (0.23 mg) and quercetin-3-xyloside (0.19 mg). To avoid flavonol deglycosylation and degradation, a protocol without hydrolysis was used for sample extraction. A sensitive HPLC-ESI-MS-MS method was developed to maximize the detection of flavonols in urine samples. Following ingestion of 240 ml (8 oz.) of cranberry juice, urine samples were collected at 0, 90, 225 and 360 minutes post-ingestion. Five major cranberry flavonol glycosides were recovered in urine samples collected between 90 and 360 min post-

ingestion: quercetin-3-galactoside, quercetin-3-rhamnoside, quercetin-3-arabinoside, myricetin-3-galactoside, and myricetin-3-arabinoside.

Quercetin-3-galactoside, the most abundant cranberry flavonol, exhibited highest peak urine concentration (C_{max}) of 1315 pg/mg creatinine, significantly higher than the other four flavonol glycosides. Most subjects had highest urine quercetin-3-galactoside levels at 90 min post-ingestion, and the time to reach peak concentration (T_{max}) was 115 min on average, indicating a rapid absorption and clearance of such compound in humans.

Quercetin-3-rhamnoside had the second highest C_{max} (671 pg/mg creatinine) among detected cranberry flavonols. Average urine quercetin-3-rhamnoside levels slightly reduced from 90 to 225 min, resulted in an average T_{max} of 151 min, longer than quercetin-3-galactoside and the two myricetin glycosides.

Although cranberry juice contained more quercetin-3-arabinoside than quercetin-3-rhamnoside, the opposite was found in the urine samples, the former showed lower C_{max} (343 pg/mg creatinine) than the latter. Quercetin-3-arabinoside also exhibited delayed urine clearance compared to other compounds, with average T_{max} of 237 min, which is significantly longer than the other four flavonols.

The two myricetin glycosides, myricetin-3-galactoside and myricetin-3-arabinoside showed similar excretion patterns. With average T_{max} at 104 and 90 min respectively, they exhibited fastest urine clearance among the five flavonol glycosides. Interestingly, although the cranberry juice contained only half as much myricetin-3-arabinoside as myricetin-3-galactoside, the former had higher C_{max} in urine samples.

Previously reported major onion quercetin metabolites in human, such as quercetin-glucuronide, quercetin-sulfate and 3-methylquercetin-glucuronide, were not found in the study. The different flavonol profiles between onion and cranberry may result in differential human metabolic patterns, as the former mainly contains quercetin-glucosides which only present at very low concentrations in cranberry.

In summary, this is the first study that identified and quantified major cranberry flavonol glycosides in human urine. It demonstrated that cranberry flavonol glycosides can be absorbed into the human circulatory system and excreted though urine in their intact conjugated forms, which may contribute to the health benefits of cranberry. The different pharmacokinetic parameters of individual flavonol glycosides indicate that both the aglycone and conjugated sugar moiety structure mediates the flavonol's bioavailability. These results will add insights to a better understanding of cranberry's nutritional values, as well as future studies on the bioavailability, absorption mechanism or clearance efficiency of various dietary flavonoids.

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MANAGING AND MEASURING FRUIT QUALITY

Peter Oudemans, Rutgers PE Marucci Center

My program is aimed at investigating plant diseases however; this has become a moving target with issues such as chemical phytotoxicity, berry heating and increased stringency in the definition of fruit quality. Specifically, we (as an industry) are challenged with color, firmness, and size as well as total soluble solids and in some cases storage of fresh fruit and many of these characteristics overlap with plant disease management. In addition, changing fungal populations and increasing challenges with climate extremes create new challenges for cranberry production. In this talk I will discuss some of the most critical issues I believe we are facing and provide research updates where we have made progress. The presentation is broken down into three basic sections.

1. Manage fruit rot using both cultural and chemical approaches.

    i. **Chemical controls:** Identify either synergistic or new treatments for the control of cranberry fruit rot. This will include testing mixtures of commercial fungicides that do not work alone as well as investigating the use of unique compounds such as waxes, phospholipids and certain biological control agents to replace broad spectrum fungicides targeted for cancellation.
    ii. **Fungicide resistance:** The fungicide azoxystrobin (Abound) is a high risk fungicide that has anecdotally weakened in effect over the past few years. We are currently investigating fruit rot populations of the predominant fungal species to determine if resistance is occurring.
    iii. **Estimating risk:** Fruit rot levels are tied to the environment within the canopy. We are collecting data of the microclimate within the canopy to guide the use of cultural practices.

2. Develop methods to protect the crop from heat damage or treatments to increase heat tolerance.
    i. **Identifying Risk:** Overheating in cranberry fruit is likely tied to several variables including crop characteristics such as fruit position in the canopy , fruit color and surface features (albedo), fruit biochemical characteristics (i.e. the capacity of stress-protective metabolite accumulation and antioxidant capacity), and cultivar variations in whole-plant heat tolerance, as well as climatological factors including humidity, radiation, convection and transpiration. We are developing a crop model that will identify risk factors for fruit overheating as well as a climatological model to predict conditions that lead to overheating.
    ii. **Treatment:** The capacity of fruit to tolerate high temperatures may be enhanced by boosting fruit's stress defense mechanisms. In 2017 we plan to screen various organic compounds and identify the most effective compounds that can prevent and alleviate heat damages in fruits, particularly for enhancing fruit antioxidant capacity and suppress heat-accelerated fruit maturation or ripening.

iii. **Protection:** Shading, use of sunscreens, evaporative cooling and misting are all possible physical approaches to protecting fruit. We will determine the most effective timing and levels of shading or cooling practices during fruit formation and maturation and investigate the use approaches on an experimental scale and evaluate how they could be implemented on a commercial scale.

3. Utilize state of the art crop sensors to optimize management of overheating and minimize conditions that promote fruit rot.

i. **Parameters:** In order to evaluate fruit quality the methodology must be standardized. Under this objective we will utilize standardized methods for estimating color, size, titratable acidity and soluble solids. We will investigate the utility of firmness measurements through all of the objectives listed above.

ii. **Storage:** The capacity of fruit to survive in storage is related to the in-season production methods and post-harvest handling. Under this objective we will establish standardized methods for evaluating shelf life of fruit that can be used in the objectives listed above.

iii. **Berry heating:** The temperature of cranberry fruit is not strongly linked to canopy temperature and typical measurements using shaded sensors provide erroneous data. We will utilize different types of thermal sensors including thermal cameras and artificial fruit to measure berry heating within the cranberry canopy.

iv. **Canopy microclimate:** Although standard sensors are readily available for measuring solar radiation, temperature, relative humidity, soil moisture and rainfall proper use of these sensors for cranberry canopy monitoring has not been optimized.
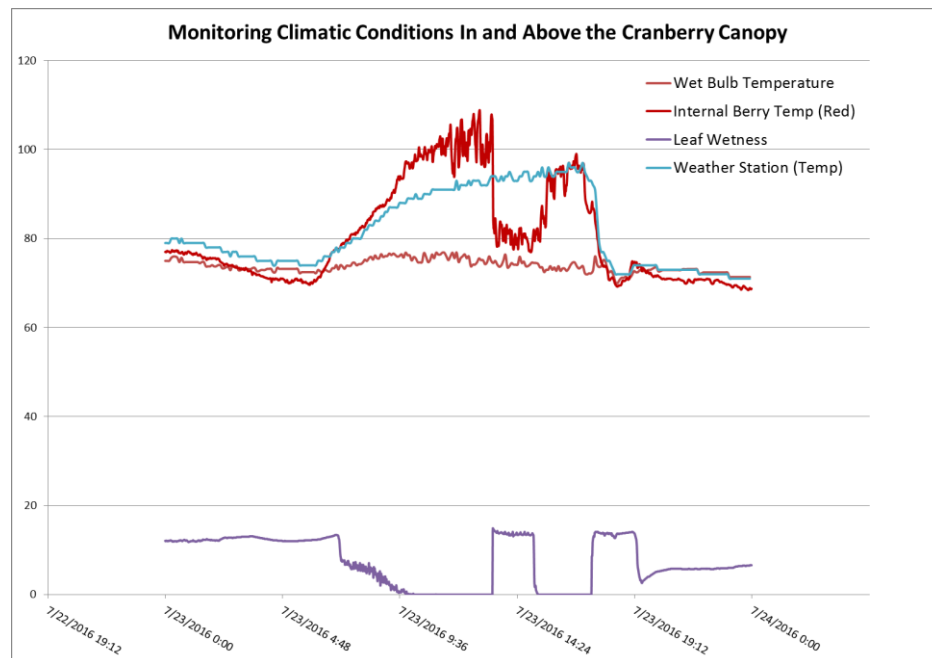
WATER MANAGEMENT STRATEGIES TO ENHANCE CRANBERRY PRODUCTION

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Introduction. Cranberries are an integral part of the economy of the North American continent, where ~98% of the world's cranberries are produced. Despite its status as a wetland plant, the American cranberry flourishes in relatively dry soil moisture conditions. Indeed, one of the very first cranberry researchers, Dr. H. J. Franklin of the Massachusetts Cranberry Station, observed that cranberry soils are "too wet oftener than too dry" (Franklin, 1948). Despite decades of research to advance irrigation management, wet soils that manifest from poor drainage or excessive irrigation still exist in many cranberry farms across North America.

In my talk, I will discuss irrigation and drainage management strategies to improve crop production in cranberry farms. The presentation is divided into four separate but related parts, each focusing on a specific water management practice. First, I will discuss the hydrologic and horticultural benefits of cycled frost irrigation. Second, I will review the current literature on summer irrigation thresholds for cranberries, based on four studies from Wisconsin, Massachusetts, and Quebec, Canada (Sandler et al., 2004; Pelletier et al., 2013; Caron et al. 2015; Jeranyama et al., in review). Third, I will discuss the principles of subsurface tile drainage and its performance in a poorly drained farm in Massachusetts. Finally, I will present new research on a low-cost, field-scale method for improving irrigation water quality in cranberry farms.

Automated cycled irrigation for spring frost protection. Overhead (sprinkler) irrigation is commonly used for spring frost protection of cranberries. However, a general paucity of information exists on the horticultural and hydrological effects of on-off "cycling" of irrigation pumps based on pre-programmed temperature setpoints during frost protection. In my talk, I will discuss the relative effects of cycled and conventional frost irrigation on crop yield and water use (Ndulov et al., in review). Based on three years of monitoring, data show that cycled frost irrigation reduces seasonal water use from 33-80% compared to conventional frost irrigation. Values of cranberry yield were similar between the two methods or slightly higher for cycled frost irrigation. The conventional frost irrigation method always applied more irrigation water, possibly causing soil saturation and anaerobic conditions that are known to limit cranberry production. Based on these results, I will show that cycled frost irrigation can enhance yield and save water in cranberry production.

Summer irrigation setpoints to maximize crop production. Irrigation scheduling continues to be a major challenge in cranberry production. Here, I will review the current literature on irrigation thresholds for cranberry production (Sandler et al. 2004; Caron et al. 2015; Jeranyama et al. in review). Collectively, these studies point to irrigation thresholds between -4 and -6 kPa (Table 1).

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Table 1. Irrigation setpoints for cranberry production. Studies were conducted on cranberry farms located in Massachusetts, Wisconsin, and Quebec, Canada.

Reference	Soil Water Tension
Sandler et al., 2004	-2 to -5 kPa
Caron et al., 2015	-4 to -7 kPa
Jeranyama et al., in review	-4 to -6 kPa

The modeling, lab, and field results of Caron et al. (2015) provide strong evidence of soil water tension as a determinant of physiological activity and crop yield in cranberry. The work of Jeranyama et al. (in review) generally corroborates these findings, suggesting lower soil tension values compared to Sandler et al. (2004). In my talk, I will discuss the significant improvements in crop production that can be achieved through close monitoring of soil water tension during the growing season.

Principles and performance of subsurface tile drainage. I will discuss the causes and effects of poor drainage in a Massachusetts cranberry farm called "Poor Farm Bog." Measurements of soil water tension (SWT), fruit yield and rot, and ground penetrating radar were conducted on two fields: PF1, where tile drains were installed at 8 and 12 in, and PF7, where tile drains were installed at 12 in. In PF1, values of SWT (-1.1 kPa), crop yield (135-158 bbl acre-1) and fruit rot (13-24%) did not vary with tile drain depth. By comparison, crop yield was twice as high in PF7 (363 bbl acre-1) due to lower SWT (-3.2 kPa). Increased crop yield could be related to physiological effects (i.e., enhanced root-zone oxygen) or to decreased fruit rot (~4%) associated with enhanced drainage in site PF7. The lower values of SWT were not related to differences in subsurface geology, which consisted mostly of mineral deposits of silt (not organic sediments). Instead, a strong gradient caused by a 13-ft elevation decrease probably facilitated drainage from PF7 to PF1. These results illustrate the significance of landscape features on the relationship between subsurface drainage and crop production in cranberry farms.

Low-cost treatment method to improve irrigation water quality
Irrigation ponds loaded with sediment or contaminated with bacteria could adversely affect crop production. Here, I will present a new method for reducing sediment and phosphorus in irrigation pond water. The method capitalizes on the acidity of bogs soils and the use of barges for winter sanding. I will discuss results from batch experiments and two field studies in Massachusetts.

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