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Guillaume Daverdin, Jennifer Johnson-Cicalese, Juan Zalapa, Nicholi Vorsa, James Polashock. Rutgers University, USDA ARS. Identification and mapping of fruit rot resistance QTL in American cranberry using GBS.

E. E. McMahan, Shawn Steffan, and Christelle Guédot. University of Wisconsin. Population densities of lepidopteran pests in selected cranberry cultivars in Wisconsin.

Sophie Wilderotter and Casey Kennedy. USDA ARS, Cranberry Station. Water and nutrient monitoring in a cranberry bog dominated watershed.

Camilo Villouta, Beth Ann Workmaster, and Jenny Bolivar, Amaya Atucha. University of Wisconsin. Exploring Cranberry Bud Cold Hardiness Using Differential Thermal Analysis.

Baylee L. Carr, Thierry E. Besancon, and Dan Schiffauer. Rutgers Universty and Ocean Spray. Control of Carolina redroot (*Lachnanthes caroliana)* in cranberry with preemergence herbicides.

Liang Xue, Andrew Milstead, Kim Colson, Catherine Neto. UMass Dartmouth, Bruker BioSpin. Metabolomic analysis and variation in phytochemical composition among North American cranberry cultivars.

John Turbitt, Catherine Neto, Brian Killday, and Kim Colson. UMass Dartmouth, Bruker BioSpin. Metabolomic analysis of commercial cranberry supplements.

Xin Wang, Catherine Neto, Erika Saalau Rojas. UMass Dartmouth, UMass Cranberry Station. Variation in p-coumaric acid and quercetin derivatives in cranberry (*Vaccinium macrocarpon*) leaf and fruit in response to fruit and root rot diseases.

Reza Jamaly, Sebastien Marchand, Serge-Étienne Perent, Silvio Jose Gumiere, Jean-Pierre Deland and Leon-Étienne Parent. Univ. Laval. Impact of fertilization on the firmness of cranberry (*Vaccinium macrocarpon* AIT.)

Peter Jeranyama, Casey Kennedy, Carolyn DeMoranville and Rebecca Brennan. UMass Cranberry Station. Soil Moisture Management and Variability in Cranberry Beds.

Noel Hahn, Andrea C. Couto, Anne L. Averill. UMass. Regional and temporal parasite loads in bumble bees associated with cranberry landscapes.

ABSTRACTS

Identification and mapping of fruit rot resistance QTL in American cranberry using GBS

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Sustainability of the cranberry industry is threatened by widespread and increasing losses due to fruit rot in the field, as well as increasing restrictions on fungicide inputs. Breeding for resistance offers a partial solution, but is challenging because fruit rot is caused by a complex of pathogenic fungi that can vary by location and from year to year. We identified four genetically diverse germplasm accessions that exhibit broad-spectrum fruit rot resistance under field conditions. Three of these accessions were used in biparental crosses to develop four populations segregating for resistance. Genotyping by sequencing was used to generate SNP markers for development of high density genetic maps and QTL analyses. Nineteen QTL associated with fruit rot resistance, distributed on nine linkage groups, were discovered in our populations. Three of these QTL matched previously reported fruit rot resistance QTL. Four newly reported QTL found on linkage group 8 (Vm8), which explain between 21 and 33% of the phenotypic variance for fruit rot, are of particular interest to our breeding program. The populations described herein were also phenotyped for other horticulturally important traits, and QTL associated with yield and berry weight were identified. These QTL provide markers for candidate gene discovery and for future breeding efforts to enhance and pyramid disease resistance and other traits into elite horticultural backgrounds.

Population Densities of Lepidopteran Pests in Selected Cranberry Cultivars in Wisconsin

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Host plant resistance, an important strategy of integrated pest management, was examined in the American cranberry, *Vaccinium macrocarpon* Aiton (Ericaceae). Despite the pressure on cranberry growers to reduce pesticide usage, host plant resistance is not used to help manage insect populations. This study measured field population densities of the three most economically important pest insects in Wisconsin, namely, cranberry fruitworm (*Acrobasis vaccinii* Riley), sparganothis fruitworm (*Sparganothis sulfureana* Clemens), and blackheaded fireworm (*Rhopobota naevana* Hu¨bner), in five different cranberry cultivars, i.e., 'Stevens', 'Ben Lear', 'GH1', 'Mullica Queen', and 'HyRed'.

Population densities of male moths of all three species were assessed using pheromone traps in beds of the different cranberry cultivars in commercial marshes in central Wisconsin. For each cultivar, damaged cranberries were collected, and the number of damaged berries and the number of larvae feeding within berries were compared among cultivars. More than 99% of larvae collected were cranberry fruitworm. Mullica Queen and Ben Lear had more damaged berries than Stevens or GH1, and had more larvae than GH1. Conversely, fewer adult male sparganothis fruitworm were found in Ben Lear and Mullica Queen beds than in beds of Stevens or GH1. Adult populations of cranberry fruitworm and blackheaded fireworm were not different among cultivars. Our findings provide evidence of different levels of resistance in common cranberry cultivars, which should inform future plantings and breeding programs.

Quantifying nitrogen export from a large agricultural watershed to a coastal bay in southeastern Massachusetts

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Mitigating nonpoint pollution is the single greatest challenge to improving coastal waters in the United States. In southeastern Massachusetts, the effects of nonpoint pollution are clearly evident in the degradation of water quality in Buzzards Bay, a large (~600 km^2) coastal bay where nonpoint nitrogen (N) pollution is a matter of the utmost concern. Although septic effluent is considered the largest nonpoint source of N pollution, cranberry agriculture is often implicated as a prominent source of N to the bay. For instance, the heavily agricultural Weweantic River watershed is estimated to export 107,300 kg N yr^{-1}, or 22% of the annual N load to the bay. Although the Wewenatic River is closely connected to water quality in the bay, field-based measurements of N export from the Weweantic River are lacking. To fill this gap, we initiated a 2-yr monitoring study of N export from the Weweantic River in July of 2016. The location of our water quality monitoring station was ~3.5 km upstream of a former milldam, which eliminated the potentially confounding effects of tidal fluctuations. A stage-discharge rating curve was established for continuous measurement of streamflow, and stream water samples were collected 3 d per week to determine concentrations of total N (TN), total dissolved N (TDN), nitrate (NO_3^-), ammonium (NH_4^+), dissolved inorganic N (DIN = $NH_4^+ + NO_3^-$), dissolved organic N (DON = TDN – DIN), and particulate N (PN = TN – TDN). Streamflow exhibited considerable seasonal variation, ranging from 90 L s^{-1} in the summer (August) to 7600 L s^{-1} in the spring (April). Concentrations of TN were highest in the summer (mean = 0.46 N L^{-1}), intermediate between November and February (mean = 0.34 mg N L^{-1}), and lowest from March to April (mean = 0.28 mg N L^{-1}). The majority of N exported by the Weweantic River was in the form of DON, which represented, on average, 77% of TN (per sample basis). Measured TN load of 1.8 kg N ha^{-1} yr^{-1} (1.7 kg N ha^{-1} yr^{-1}as DON) was about half the model predicted mean TN load of 4.8 (±0.8) kg N ha^{-1} yr^{-1} (1 standard deviation in parentheses). Lower observed loading could be due to the 2016 drought, supporting the need for further monitoring, or to uncertainty in model inputs (i.e., model simulations assume N fertilizer use of 84 kg N ha^{-1} for cranberry agriculture, whereas grower records indicate N fertilizer use between 40-50 kg N ha^{-1}). Answers to these questions, as well as inverse modeling to estimate cranberry agriculture N loading rates and in-stream N uptake, will be the focus of the monitoring in year 2 of the study.

Exploring Cranberry Cold Hardiness Using Differential Thermal Analysis

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To date, cranberry terminal bud cold hardiness has been assessed by controlled freezing tests where levels of damage are evaluated from tissue samples exposed to a range of predetermined sub-freezing temperatures. As in many woody plant buds, freezing stress damage in cranberry is variable across different structures of the bud, often making evaluation challenging. The buds of many woody plant species survive freezing stress by the mechanism of supercooling, the maintenance of water in the liquid state in specific tissues to temperatures below 0°C. The eventual freezing of this supercooled water is lethal to the tissue. The exotherm released from this phase change of water is detectable by the technique of differential thermal analysis (DTA). As part of a larger study on cranberry bud cold hardiness changes concurrent with the plant's transitions into and out of endodormancy, our initial objective has been to assess the supercooling capability of cranberry buds and the applicability of DTA to quantify this phenomenon. The study was conducted with samples of 'Stevens' and 'HyRed' collected weekly from two farms in central Wisconsin from ice-off until bud swell in early 2017. Eleven DTA tests were run in custom-built equipment, with controlled freezing tests also performed on the last four sample dates. Low temperature exotherms (LTEs) were detected, supporting the hypothesis that cranberry bud tissue supercools. However, the observed number of LTEs was lower than expected, being detected in only 20 to 40% of the total number of buds tested on a given date (n = 90 to 100). Based on these results, LT_{10}, LT_{50}, and LT_{90} values were calculated. Over the course of the sampling period, the range of LT_{50} values remained stable (from -11.3 to -7.3 °C in 'HyRed' and from -12.7 to -5.8 °C in 'Stevens') and did not fluctuate in response to changes in air temperature or the observed variations in leaf pigments. This is in contrast with the results of our controlled freezing tests and those of Workmaster et al. (2006) where LT_{50} values by showed important shifts from tight bud to bud swell. We are considering technical and physiological explanations for the reduced number of LTEs. Despite efforts to maximize equipment sensitivity, technical challenges may remain. Alternatively, changes in water relations of many woody plant buds occur in response to both endodormancy and prolonged exposure to freezing temperatures. These changes are known to involve the mobilization of water from primordia to other organs, such as bud scales, increasing the ability of primordia to supercool, a process known as extraorgan freezing. Additionally, anatomical observations support this freezing stress survival hypothesis in cranberry buds.

Control of Carolina redroot (*Lachnanthes caroliana*) in cranberry with preemergence herbicides

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New Jersey produced 27 million kg of cranberries in 2015 at a farm value of $22 million (USDA 2017). Cranberry beds in New Jersey are concentrated in the Pine Barrens coastal plain where soil conditions (sandy texture, pH 4.0 to 5.0, good drainage) are optimal for cranberry production. The perennial nature of cranberry production predisposes the crop to a diversity of weed species ranging from herbaceous weeds to woody perennial species. Among perennial weed species, Carolina redroot has been an increasing source of concern for New Jersey cranberry growers regarding the lack of sufficient control from their current management strategies. Carolina redroot is a perennial herbaceous monocotyledonous species member of the *Haemodoraceae* family whose common name is derived from the orange to red coloration of its roots and rhizome. Information regarding herbicidal control of Carolina redroot is extremely limited and mostly restricted to blueberry production (Myers et al. 2013). In order to address the issues of successfully managing Carolina redroot under extremely specific environmental and cropping conditions, a study was initiated in the spring of 2017 to evaluate the efficiency of three herbicides at different rates for preemergence control of Carolina redroot. A complete lack of control in the twelve weeks that followed the application was noted for the plants that were treated with Norflurazon at 560, 1,120, 2,240, and 4,480 g ai ha^{-1}. Control of Carolina redroot with napropamide applied at 6,720 g ai ha^{-1} was 74% 28 days after treatment (DAT) and increased to 78% at 83 DAT. Greater control was achieved early in the season with dichlobenil applied at 2,240 or 4,480 g ai ha^{-1} with 90 and 99% control, respectively, at 28 DAT. However, control with dichlobenil declined between 28 and 83 DAT. Carolina redroot density in the nontreated plots reached 430 plants m^{-2} 56 DAT but was reduced to 275 plants m^{-2} with napropamide, 95 plants m-2 with dichlobenil at 2,240 g ai ha^{-1}, and 70 plants m^{-2} with dichlobenil at 4,480 g ai ha^{-1}. Significant damages to the cranberry crop were noted with dichlobenil at 4,480 g ai ha^{-1}, mostly in the form of chlorosis early in the season (19% at 40 DAT) and stunting later (15% at 83 DAT).

Metabolomic analysis and variation in phytochemical composition among North American cranberry cultivars

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Cranberries, *Vaccinium macrocarpon*, are cultivated across several regions of North America. Reported bioactivities of cranberries include antibacterial and antioxidant, with benefits for urinary tract, cardiovascular and gut health. The content of secondary metabolites in the fruit can vary due to factors such as climate, temperature, humidity, cultivar, and disease-related stress; thus a better understanding of how these factors impact composition is desired. Cranberry fruit of multiple cultivars was collected from Massachusetts and Oregon bogs during the 2011 and 2016 growing seasons. Quantitative ^{1}H NMR (qNMR) methods using Assure-RMS software (Bruker Biospin) were developed to quantify triterpenoids and organic acids not easily detected by absorbance-based methods. These include anti-inflammatory compounds ursolic and oleanolic acid, as well as citric, malic, and quinic acids. Using qNMR, cultivar and seasonal differences in these acids were observed. ^{1}H NMR combined with PCA provided non-targeted analysis of variation in fruit composition among samples, revealing similarities and differences between cultivars. Selected polyphenols were also determined using established methods; DMAC assay for total proanthocyanidins (PACs) and HPLC-DAD for quercetin-3-galactoside. As cranberries are a plentiful source of polyphenol antioxidants, a microplate DPPH assay was developed to measure free-radical scavenging antioxidant activity and investigate correlations with fruit composition. The goal is to establish relationships between the health-promoting properties and phytochemical profiles of cranberry fruit from a variety of sources.

Metabolomic Analysis of Commercial Cranberry Supplements

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The potential health benefits of cranberries *(Vaccinium macrocarpon)* can be attributed to a variety of secondary metabolites, including proanthocyanidins (PACs), flavonoids, organic acids, and triterpenoids. Commercial cranberry supplements can provide a low-sugar alternative to juices and sweetened fruit products, however the phytochemical content can be expected to vary due to widely differing manufacturing processes. Selected commercial cranberry supplements were analyzed for secondary metabolite profile in comparison to a whole cranberry powder reference standard material, using ^{1}H qNMR with Bruker AssureNMR software. HPLC-DAD and the DMAC assay were employed for total anthocyanin and PAC content respectively. Principal component analysis of ^{1}H NMR spectra showed overlap between several supplements and whole cranberry powder, whereas others varied widely from the standard. Total PAC content varied widely, with four supplements ranging 5 - 10 mg PAC/g dry weight, one at 100 mg PAC/g dry weight, and insignificant PAC content in the rest. Several supplements contained only minimal amounts of organic acids and flavonoids. Cranberry peel constituents ursolic acid (8.0-16.3 mg/g) and oleanolic acid (0.3-5.1 mg/g), were detected in the whole cranberry reference standard but only about half of the supplements. Study results suggest significant variation in phytochemical composition among commercial cranberry supplements, reinforcing the need for reliable industry standards.

Variation in p-coumaric acid and quercetin derivatives in cranberry (*Vaccinium macrocarpon*) leaf and fruit in response to fruit and root rot diseases

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Cranberry is a popular fruit due to reported health benefits, but fruit rot and root rot diseases can decrease fruit production and quality. To determine the influence of infections, p-coumaric acid and quercetin derivatives which contribute to fruit quality were used as markers. Several cultivars including Stevens (ST), Mullica Queen (MQ), and Demoranville (DM) were sampled in MA during 2016 growing season. Analytical methods were developed for these markers in leaf and fruit with Waters UPLC-MS/MS system. Exposure to the two types of pathogens produced different responses. ST showed significant higher content in p-coumaric acid and quercetin derivatives when exposed to *Phytophthora* and significant lower content in these compounds when exposed to fruit rot fungi. For cultivars MQ and DM, healthy and infected plants exhibited less differences in phenolic composition, suggesting these cultivars may be less susceptible to fruit rot fungi than ST. Principal component analysis of the mass spectra confirmed several p-coumaric acid and quercetin derivatives as contributors to the variations in composition between the healthy and infected samples.

Impact of fertilization on the firmness of cranberry (*Vaccinium macrocarpon* AIT.)

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Québec is the second cranberry (*Vaccinium macrocarpon* AIT.) producing state in the world. Fertilization is a key management tool to reach high fruit yield and quality. N has the greatest effect on the development, flowering and productivity of the cranberry plant. Fertilizer rates and application methods can affect fruit firmness while mechanical harvesting reduces fruit firmness and market life. The objective of this research was to relate firmness reflectance (TA.TX2 Texture Analyzer) to fertilizer treatments. In 2014, four experimental sites of cv. "Stevens" stands were established at Notre Dame-de-Lourdes and St-Louis-de-Blandford, Québec, on acid sandy soils containing more than 90% sand. The experimental design was a randomized complete block that comprised five N (0-60 kg N ha-1), three P (0-30 kg P ha-1) and four K (0-120 kg K ha-1) doses as well as Mg (12 kg Mg ha-1), Cu (2 kg Cu ha-1) and B (1 kg B ha-1) compared to a control, replaced in part by 4 doses of S (0-1000 kg S ha-1) on some sites since 2016, totalling 144 plots across sites. Berries were hand-harvested on 0.37 m2 areas, 2-3 weeks before commercial harvesting. Berries in the zero N treatment showed the greatest firmness but resulted in lowest yield while berry firmness decreased linearly up till 60 kg N ha-1 treatment. The 45 kg N ha-1 treatment produced high yield but still relatively low firmness.

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Soil Moisture Management and Variability in Cranberry Beds

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Summer irrigation is a major management input in cranberry production, and traditionally, cranberry beds have received 25 mm of water per week from either rain, capillary action from groundwater, irrigation , or some combination of these from late spring through the summer. However, environmental conditions and drainage characteristics can vary from bog to bog, meaning that the 25-mm rule does not always result in ideal soil moisture conditions. Measurement of cranberry soil water status has been based on two technologies; (i) measuring the amount of water in the soil using volumetric water sensors or measuring the depth of the water table in the soil by means of water level floats, and (ii) measuring the energy status of the water (water potential) using a tensiometer. Ideally, irrigation scheduling should consider plant processes in conjunction with the status of the soil water matrix to quantify water stress under different soil conditions. This project assessed various tools of measuring soil water moisture in cranberry beds including a FieldScout TDR 300 Soil Moisture Meter and wireless tensiometers. Six cranberry beds primarily growing cultivar 'Stevens' were monitored throughout the growing season for tension readings; wireless tensiometers reported data to a web portal at 15-min intervals, making it easy to download data. The FieldScout TDR 300 Soil Moisture Meter was used to develop soil moisture maps of monitored beds on a weekly basis during the season. The Moisture Meter was connected to a GPS unit so that generated maps could be overlaid on a satellite image of the bed providing precise locations of soil moisture content at the time of measurement. The FieldScout TDR 300 Soil Moisture Meter maps indicated a great variability in soil moisture throughout monitored cranberry beds. Soil moisture variability demonstrated a 10-20% range of differences. This lack of uniformity in soil moisture content makes it difficult to choose an ideal location for installing a soil moisture monitoring device such as a tensiometer. The relationship between soil moisture content and tension was developed in a previous project and has been reported in MA (Jeranyama et al., 2014) and in Canada (Pelletier et al., 2013).

Regional and temporal parasite loads in bumble bees associated with cranberry landscapes.

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There are concerns that the fitness of bumble bees that provide pollination services to cranberry could suffer within intensively managed agricultural lands. In the cranberry region of Massachusetts, the crop occurs within urbanized coastal and sand plains that generally lack floral resources. Additional stressors that compromise the health of bumble bee colonies could be the reduction of habitat and infections by parasites. In contrast to the lack of floral resources in the region, the mass bloom of managed cranberry provides abundant floral resources around July. We examined the prevalence and intensity of pathogen infection in bumble bees collected across areas of varying cranberry bloom. To determine how the amount of cranberry acreage affects the prevalence of these parasites, bumble bee queens and workers of multiple *Bombus* spp. were assessed for parasite presence and load. The amount of cranberry bog within 2 km of each collected bee was calculated and included in a model testing its effect on parasite prevalence and intensity. Initial investigations appeared to show higher prevalence and intensity of the trypanosome *Crithidia bombi* in areas with little to no acreage of cranberry bog in comparison to areas with higher acreage of cranberry. This did not hold true for *Nosema bombi*, *Apicystis bombi*, and parasitism by conopid flies. We speculate on the reasons behind our findings, including the potential effects of fungicide use and phytochemicals on the health of bumble bees.