# WISCONSIN CRANBERRY SCHOOL

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# CITIZEN SCIENCE: PLANT AND INSECT PHENOLOGY COMBINED & FLEA BEETLE CONTROL

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**Take home points:**

- Plant and insect phenology are correlated
- We can use the highly apparent plant phenology to corroborate *Sparganothis* phenology in order to improve insecticide application timing

Correlating cranberry plant and insect pest life cycles, such as *Sparganothis* fruitworm, will help growers with pest management strategies. In the summer of 2014, we collaborated with Wisconsin cranberry growers to correlate cranberry growing degree-days (GDD) and with plant phenology. This 'citizen science' effort was organized by the USDA Cranberry Entomology Lab but was initiated out of grower interest. A citizen science project means that data is collected by collaborators by means of a standardized protocol. Due to the standardization of data collection, we can combine data from multiple farms of local temperatures and plant phenology and create a more robust data set than if we were limited to only the resources within our lab. A bigger data set allows us to more confidently connect cranberry plant phenology with specific degree day units.

In order to create this data set, grower collaborators placed temperature probes in cranberry beds at plant canopy level and recorded the daily high and low temperatures. A lower temperature threshold of 41˚F and upper threshold of 85˚F, which encompass the range of temperatures under which cranberry plants develop (DeMoranville 1992), were used to calculate the GDD. Collaborators were also asked to walk transects of the beds to monitor percent tight bud, percent cabbage head, percent roughneck, percent hook, percent bloom and percent fruit set.

Figure 1 shows the GDD accumulation for the cranberry plant over the 2014 season.

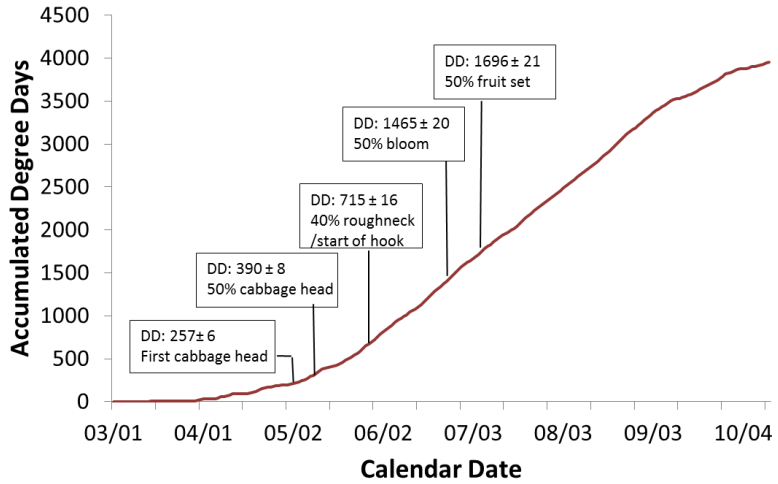


**Figure 1.** Growing degree-days for the cranberry plant and plant phenology in 2014.

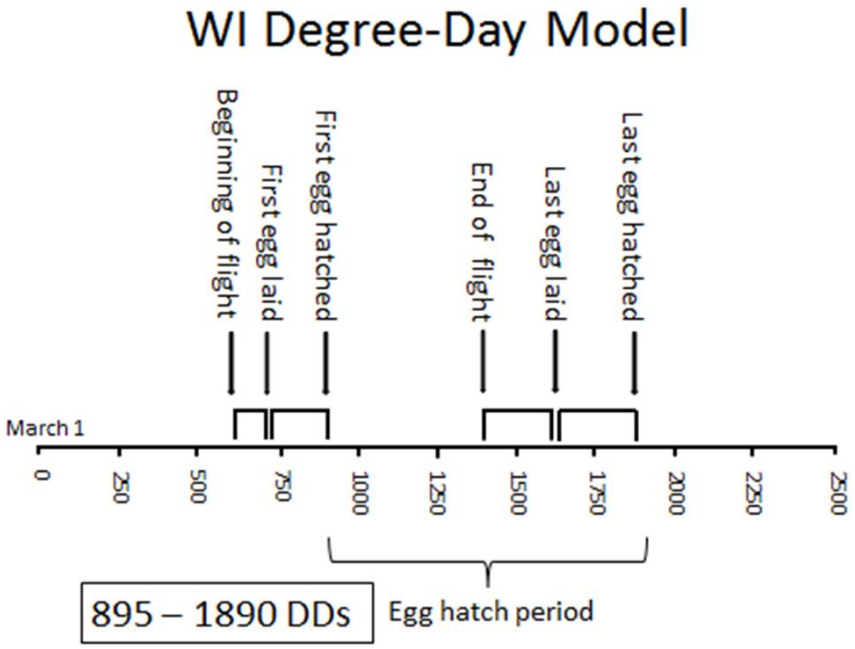


**Figure 2.** *Sparganothis* fruitworm phenology linked to *Sparganothis* specific growing degree-days.

Previous work in the Cranberry Entomology lab has experimentally determined the upper and lower developmental thresholds of *Sparganothis*. We determined that development begins at 50˚F and slows at 86˚F (Deutch et al. 2014). With this information we created a degree-day look up table (Appendix 1). This table allows anyone who is interested to track *Sparganothis* GDD. The DD accumulation for a given day is at the intersection of the daily high and low temperature. By keeping a running total of DD, marsh managers can track *Sparganothis* development. By combining the information on *Sparganothis* GDD with key phonological events from Wisconsin and New Jersey and five additional years of flight data from Wisconsin, we created the model seen in figure 2. When we use the *Sparganothis* upper and lower developmental thresholds to calculate the GDD for 2014, we can visualize both the plant and insect phenology together in figure 3.

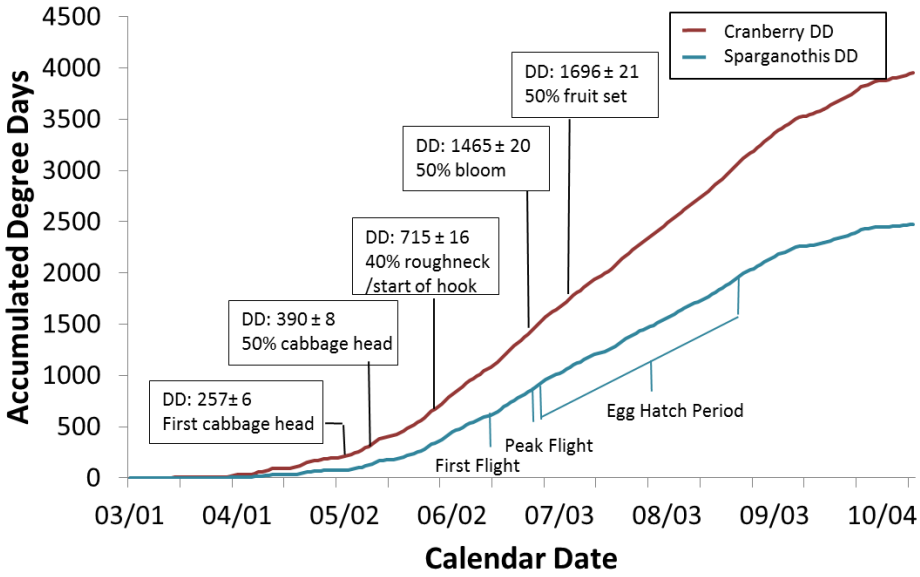


**Figure 3.** Cranberry plant and *Sparganothis* phenologies.

Figure 3 shows us that *Sparganothis* egg hatch period began in 2014 at about the same time as 50% bloom. Over the next couple of growing seasons, we would like to continue collecting data from our citizen science grower collaborators regarding plant GDD and phenology to verify our model.

## FLEA BEETLE BIOLOGY AND CONTROL

**Take home points:**

- Altacor was present in the soil down to at least 8 cm
- Altacor as an insecticidal soil soak post-bloom was not effective at controlling flea beetle.
- Future research may look into action thresholds, and biological controls such as native nematodes.

**Background:** Flea beetles (FB) overwinter as eggs in the soil. Larvae live and feed in the soil until pupation and then the adult beetle emerges, moving up out of the soil and into the plant canopy. Typical FB control on cranberry marshes has consisted of foliar insecticide applications targeted at the adults because it is the only apparent life stage. Because the development of individuals within the population happens throughout a range of time, some adults move out of the soil and into the plant foliage earlier, while others are still underground as larvae and pupa. This means that targeting the adult stage with insecticides often requires 2-3 foliar sprays late in the summer.

Experiments from summer 2012 determined that **FB overwinter almost exclusively within marsh beds** (as opposed to dikes) (fig. 4). Because of this, the Steffan lab has been working to determine an effective insecticide and delivery method to target the larval stage of the population in the soil. In 2012 we found that a post-bloom insecticidal soil soak using Belay was an effective control method. By applying Belay post-bloom, we avoid problems with neonicotinoid use around pollinators. Additionally, residue work on the fruit at time of harvest showed that Belay residues were undetectable.

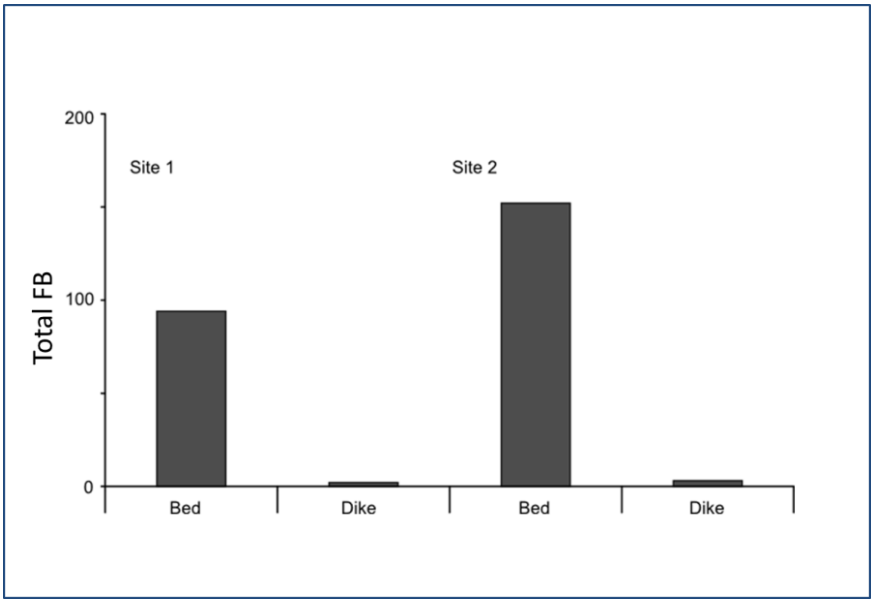


**Figure 4.** Flea beetles found emerging from either the dike or the bed.

**Methods:** Due to concerns with the use of neonicotinoids on cranberries, in 2014 we continued the experiment with Altacor (a.i. chlorantraniliprole), an alternative insecticide class. At 5 marshes, we studied the efficacy of a post-bloom insecticidal soil soak. Experimental procedures began when honey bees on site for pollination were taken off the marsh. Each marsh had two replicates, except one which had only one. Each replicate consisted of two beds: 1 treatment bed (Altacor application + conventional management) and 1 control bed (conventional management). Beds used in the study were chosen based on a history of FB pressure. The determination of which beds would be treated or control was done randomly. Treated beds were pre-irrigated for a half an hour. Following the pre-irrigation, Altacor was applied at 4.5 ounces/acre in 50 gallons $H_2O$/acre along with 2.5% FS Aqualite (Growmark; Bloomington, IL) by volume, a nonionic surfactant. The nonionic surfactant was used to help move the insecticide into and through the soil profile. Immediately after Altacor application, treated beds were irrigated for an additional four hours. Control beds were treated as per the specific grower's management regime. When possible, soil samples were taken within 24 hours of the Altacor application in order to measure Altacor presence throughout the soil horizon and determine the efficacy of the application methods. The 24 hour sample was not possible at two of the marshes due to restricted entry intervals of other pesticides that were applied on the same day. Soil samples were taken to 10" with a probe 1" in diameter. Ten samples were taken per bed. Adult flea beetles were sampled with a sweep net on two dates post treatment. Ten sets of 20 sweeps were conducted in each study bed for a total of 200 sweeps bed$^{-1}$.

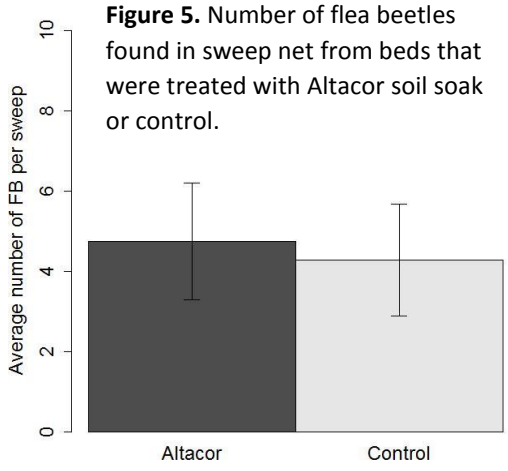


**Figure 5.** Number of flea beetles found in sweep net from beds that were treated with Altacor soil soak or control.

**Results:** There was no difference in adult flea beetle pressure by treatment as seen in figure 5.
Due to cost limitations, we were only able to test soil samples to 8 cm at 2 increments. We found Altacor was present in the soil at depths to 8 cm (fig. 6).

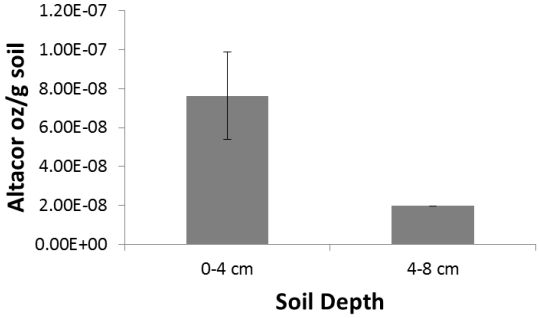


**Figure 6.** Altacor in soil samples taken within 24 hours of Altacor soil soak application.

## References

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**Appendix 1**

# Degree-day Look-up Table for Sparganothis Fruitworm

Lower threshold: 50°F  Upper threshold: 86°F  Intermediate cut-off

Minimum temperature

| Maximum temperature | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 | 51 | 54 | 57 | 60 | 63 | 66 | 69 | 72 | 75 | 78 | 81 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | |
| 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | | | | | | | | | | |
| 55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 5 | | | | | | | | | |
| 58 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 5 | 6 | 8 | | | | | | | | |
| 61 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 6 | 8 | 9 | 11 | | | | | | | |
| 64 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 8 | 9 | 11 | 12 | 14 | | | | | | |
| 67 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 7 | 8 | 9 | 11 | 12 | 14 | 15 | 17 | | | | | |
| 70 | 5 | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 7 | 8 | 8 | 9 | 11 | 12 | 14 | 15 | 17 | 18 | 20 | | | | |
| 73 | 6 | 7 | 7 | 7 | 7 | 8 | 8 | 8 | 9 | 9 | 10 | 11 | 12 | 14 | 15 | 17 | 18 | 20 | 21 | 23 | | | |
| 76 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 10 | 10 | 11 | 11 | 12 | 14 | 15 | 17 | 18 | 20 | 21 | 23 | 24 | 26 | | |
| 79 | 9 | 9 | 9 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 14 | 15 | 17 | 18 | 20 | 21 | 23 | 24 | 26 | 27 | 29 | |
| 82 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 12 | 13 | 14 | 14 | 15 | 17 | 18 | 20 | 21 | 23 | 24 | 26 | 27 | 29 | 30 | 32 |
| 85 | 11 | 11 | 12 | 12 | 12 | 13 | 13 | 14 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 23 | 24 | 26 | 27 | 29 | 30 | 32 | 33 |
| 88 | 12 | 12 | 13 | 13 | 13 | 14 | 14 | 15 | 15 | 16 | 17 | 18 | 19 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 31 | 32 | 34 |
| 91 | 13 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 17 | 17 | 18 | 19 | 21 | 22 | 24 | 25 | 27 | 28 | 29 | 31 | 32 | 33 |
| 94 | 13 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 17 | 17 | 18 | 20 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 30 | 31 | 32 |
| 97 | 13 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 17 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 100 | 13 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 16 | 17 | 18 | 19 | 20 | 21 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 29 |
| 103 | 12 | 13 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 17 | 17 | 18 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 28 |
| 106 | 12 | 12 | 13 | 13 | 13 | 14 | 14 | 14 | 15 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 26 | 27 |
| 109 | 12 | 12 | 12 | 12 | 13 | 13 | 13 | 14 | 14 | 15 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 25 | 25 |
| 112 | 11 | 11 | 12 | 12 | 12 | 12 | 13 | 13 | 14 | 14 | 15 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 23 | 24 | 24 |
| 115 | 10 | 11 | 11 | 11 | 12 | 12 | 12 | 13 | 13 | 14 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 21 | 22 | 22 | 22 | 22 |

(Available online at: http://labs.russell.wisc.edu/steffan/files/2013/11/Degree-day-look-up-table.pdf.)

# TRAIT ANALYSIS AND CRANBERRY CULTIVAR DEVELOPMENT

ERIC ZELDIN

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The expression of genes in response to development and/or environment results in traits, the characteristics of an individual we can see and/or measure. Plant breeders are primarily interested in selectable traits leading to a desirable horticultural outcome. Cranberry cultivar development involves creating seedling populations based on parents which offer desirable traits; and the subsequent selection for a combination of traits which results in an individual with improved performance in the desired horticultural setting. Cultivar development is only useful when it yields new cultivars which either: 1. Offer significant improvement over existing cultivars within a niche, or 2. Create new niches.

'Stevens' is one step away from the wild and offers many desirable horticultural traits, particularly a relative ease-of-culture and reproducible yields when compared to wild selections. However, 'Stevens' does have some wild-like traits, most notable for Wisconsin is unreliable fruit color development. 'HyRed', which is two steps away from the wild, was developed to provide improved fruit color: earlier, more uniform and more intense. In addition to selection for fruit color traits, 'HyRed' was also selected for rebud (pronounced "ree-bud", a term indicating return bloom) to achieve more uniform yields than the existing early fruit color cultivar, 'Ben Lear'. Another undesirable wild trait in 'Stevens' is excess runner growth, particularly under high nitrogen fertilizer regimes. 'Sundance', also two steps away from the wild, was originally selected for its large berry size, but later it was observed to provide excellent yields and high rebud rates with high nitrogen. Yet 'Sundance' runners very little under a heavy crop load, with nitrogen levels much higher than that which can be safely used with 'Stevens'. 'Sundance' is easy to grow like 'Stevens' and begins to develop fruit color at the same time, but it continues to improve color even in years when 'Stevens' does not. An initial commercial production run of sweetened dried cranberries produced from 'Sundance' fruit yielded excellent results. These traits all together render 'Sundance' a significant improvement over an existing cultivar. 'Ruby Star', three steps away from the wild, offers a new niche. 'Ruby Star' flowers very early and the fruit matures very early as well, usually about three weeks earlier than 'Stevens' and a week earlier than 'HyRed'. Fruit color develops very uniformly on 'Ruby Star', with good color present below the canopy even in late August. 'Ruby Star' has shown exceptionally high rebud and while the berries are relatively small, the number of berries per upright is higher than other cultivars. Unlike 'HyRed' and 'Ben Lear', 'Ruby Star' does not over-ripen readily, even with very dark fruit color. This offers flexibility in harvest timing, throughout the entire month of September.

Development of these cultivars has taken a very long time and involved many difficulties. Variation in the field due to a myriad of reasons, small plot size, excess open area for walkways, weeds, pests and hail all contribute to high maintenance, limited population size and lack of replication. A new cranberry breeding system is being developed in cooperation with the Zalapa USDA Cranberry Genetics Program and Piping Rock Nursery. This has great potential due to the ease of manipulation and low stature of cranberry. The new system employs very high seedling densities with a high degree of control not possible in the greenhouse or field. This system is ideally suited for marker assisted selection, where

DNA markers for the desired traits are used for strong selection pressure; thus fewer individuals will go to field trials and we can do a better job with larger plots and replication. The large populations this new system can accommodate will enhance our ability to do breeding and may rapidly achieve inbred lines, the production of true hybrids, and improved fertility of tetraploids and interspecific hybrids. This system will also be useful for screening for disease and pest resistance, where controlled inoculations and controlled conditions are essential.

The major benefit of this new breeding system is that it is much quicker: high quality DNA for molecular analysis can be recovered from 8-week-old seedlings, vegetative traits can be initially assessed within 8 months and initial fruit evaluations within 20 months. Generation time with early selection can be reduced to three years, depending on the goals and traits to be examined. This system is currently being tested with four different populations examining different traits to verify its potential. Early stage results are very promising so far. Once fully proven, this system may render cranberry the model for woody fruit crop breeding in general.

# CRANBERRY VIRUSES

LINDSAY WELLS and PATRICIA MCMANUS

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Four viruses have been detected in cranberry to date; *Tobacco streak virus* (TSV), *Blueberry shock virus* (BlShV), *Blueberry scorch virus* (BlScV), and *Blueberry red ringspot virus* (BRRV). Two of these viruses, TSV and BlShV, have been confirmed in Wisconsin cranberries, and are associated with berry scarring symptoms (Fig. 1). We have been conducting experiments over the past two growing seasons in an effort to gain a better understanding of the effect(s) these viruses may have on cranberry.

Both TSV and BlShV overwinter in cranberry and are here to stay. As such, research on these viruses will continue in the coming years as we learn to live with and manage viruses in cranberry. The findings of our work to date are summarized below.

**Berry scarring symptoms associated with TSV and BlShV are identical.** When we discovered scarred fruit that tested negative for TSV in 2013, BlShV was detected. Upon this initial detection, there seemed to be slight differences in the berry scarring associated with each of these viruses that would allow us to distinguish the two based on visual assessment of symptoms. However, as more scarred fruit have been observed and tested, it is clear that berry scarring symptoms associated with TSV or BlShV are identical and cannot be used to distinguish the viruses. Likewise, TSV and BlShV are found in the same growing regions, and in some instances on the same marsh. *Blueberry shock virus* has been detected on marshes in both the central and northern growing regions of WI, while TSV has been detected only in marshes in the central part of the state. Virus testing has been limited on northern marshes, and may account for the lack of detection of TSV in this region. Knowing which virus(es) is present will be valuable as we learn more about the biology of each virus and uncover any differences that may affect how they are managed.

**Figure 1.** Berries infected with *Blueberry shock virus* (left), and *Tobacco streak virus* (right).

**TSV and BlShV affect multiple cranberry cultivars.** Table 1 indicates the cultivars in which TSV and BlShV have been detected to date. TSV has been found in all cultivars tested, including both newer hybrid as well as older cultivars. BlShV has been detected in four of the eight cultivars tested, and has primarily been found in older varieties (e.g., 'Stevens', 'Pilgrim', and

'LeMunyon'). Lack of detection of BlShV in 'Crimson Queen', 'HyRed', 'Demoranville', and 'Grygleski Hybrid 1' does not mean that BlShV cannot or does not affect these cultivars, but is either a reflection of limited testing for the virus in these particular cultivars thus far, or that BlShV has not spread to them.

**Table 1.** Cranberry cultivars in which *Tobacco streak virus* and/or *Blueberry shock virus* have been detected.

| Cultivar | TSV detected? | BlShV detected? |
|---|---|---|
| Crimson Queen | √ | |
| HyRed | √ | |
| Demoranville | √ | |
| Grygleski Hybrid 1 | √ | |
| Mullica Queen | √ | √ |
| Stevens | √ | √ |
| Pilgrim | √ | √ |
| LeMunyon | √ | √ |

**What is the best time to sample for TSV, and what plant parts should be tested?** Viruses tend to move toward metabolic "sinks" in plants. As these "sinks" change with cranberry development, the distribution of a virus within a given cranberry upright changes throughout the growing season as well. Table 2 displays the plant parts that should be sampled during various times of the season to ensure reliable detection of TSV if it is present **if you see scarred fruit**. Note that these recommendations are based on research with TSV. We have much less information on BlShV, but until we learn more, we suggest a similar strategy for sampling for BlShV.

**Table 2.** Plant parts to be sampled at different time points in the growing season to ensure reliable TSV detection **if scarred fruit is observed**.

| Plant part to test | Post-bloom until 4th week in July | 1st week of August until ~ 3rd week in August | 3rd week in August until harvest |
|---|---|---|---|
| symptomatic berries | √ | √ | |
| current season leaves on uprights with scarred fruit | | | √ |
| previous season leaves on uprights with scarred fruit | √ | √ | √ |

**If you do not see scarred fruit**, but are curious to know if a virus(es) is present on your marsh, you should collect samples in the following manner:

- Collect ~ 10 uprights from 10 locations representative of a bed.
- 10 uprights = 1 sample.
- Place each sample (10 uprights) into a single plastic bag.
- Refrigerate, but **do not freeze** samples until shipping.

If you do not see scarred fruit, samples can be collected anytime during the season, from before bloom until harvest. It is ideal to collect and ship samples for testing in the same day, but if this is not possible, keeping samples refrigerated will preserve them. Samples should be sent to Agdia, a commercial lab that specializes in virus detections. Agdia has a blueberry and

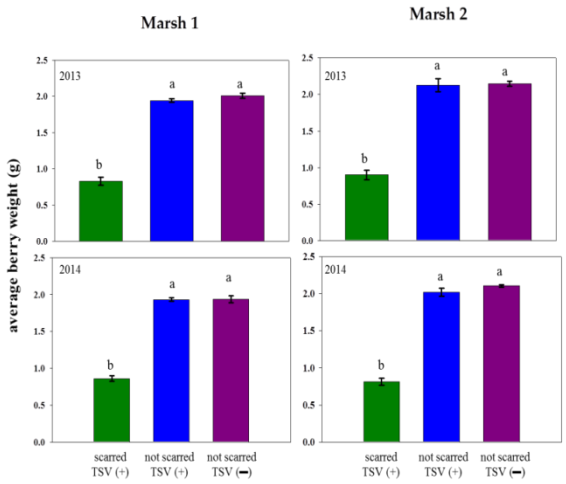


**Figure 2.** Average berry weight (g) per upright for three categories of uprights collected from two cranberry marshes in Warrens, WI in 2013 and 2014.

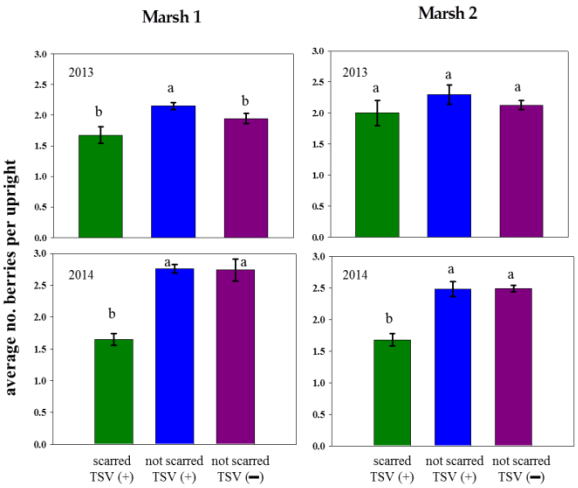


**Figure 4.** Average number of berries per upright for three categories of uprights collected from two cranberry marshes in Warrens, WI in 2013 and 2014.

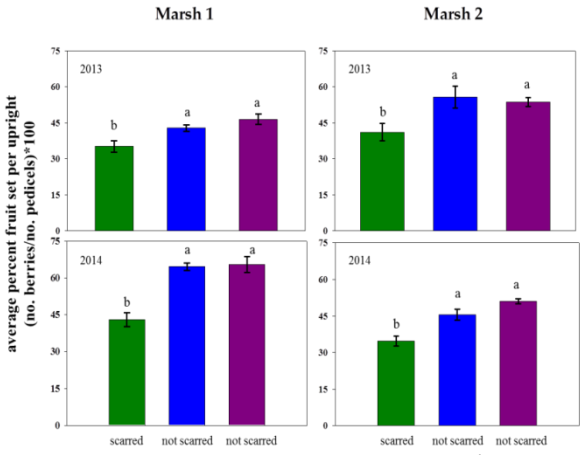


**Figure 3.** Average percent fruit set ((no. berries/no. pedicels)*100) per upright for three categories of uprights collected from two cranberry marshes in Warrens, WI in 2013 and 2014.

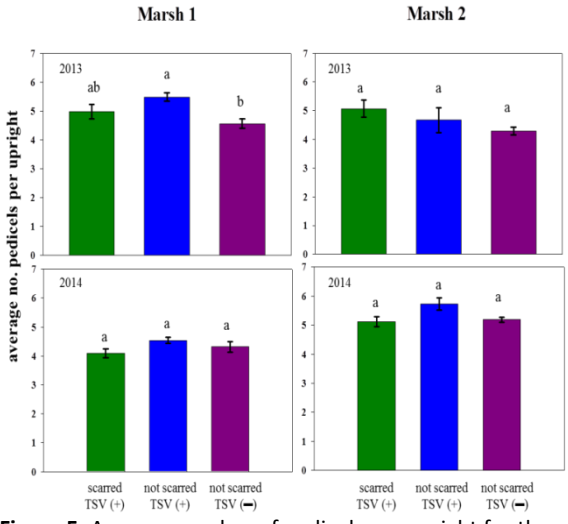


**Figure 5.** Average number of pedicels per upright for three categories of uprights collected from two cranberry marshes in Warrens, WI in 2013 and 2014.

cranberry screen that tests for 11 viruses, including TSV and BlShV. This lab also offers testing for individual viruses if you wish to test only for TSV and/or BlShV. Information on submitting samples can be found on the company's website www.agdia.com or by calling 800-622-4342.

**TSV does not negatively impact yield components once plants have 'recovered' or become tolerant to the virus.** We have demonstrated that cranberry uprights 'recover' from, or become tolerant to, berry scarring symptoms in the year following scarring. Uprights which had produced *scarred, symptomatic*, TSV-positive fruit in 2012 or 2013, produced *non-scarred, asymptomatic*, TSV-positive fruit in 2013 or 2014, respectively. In 2013 and 2014, we evaluated several yield components in cranberry uprights with scarred berries as well as in TSV-positive, 'recovered' uprights. These experiments were conducted at two marshes, and uprights were separated into three categories; scarred, TSV-positive; non-scarred, TSV-positive; and non-scarred, TSV-negative. Results from these experiments are shown in Figs. 2-5. Not surprisingly, berry weight, number of berries per upright, and percent fruit set were significantly reduced for uprights with scarred fruit compared to non-scarred, TSV-positive uprights, or TSV-negative uprights. Alternatively, we found that for all yield components tested, 'recovered', TSV-positive uprights were not negatively affected compared to healthy, TSV-negative uprights. This is good news, as it indicates that at least in the short term, there are no negative impacts of TSV on cultivar 'Mullica Queen' for the yield components tested once plants have 'recovered'.

# WATER TABLE LEVEL EFFECTS ON CRANBERRY IRRIGATION MANAGEMENT

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Increasing temperatures and more intense precipitation cycles predicted by global climate change models (Karl, et al., 2009) can lead to long drought periods (i.e. summer 2012) where irrigation is essential for profitable cranberry production. A method of irrigation that can limit fungus-friendly surface environments and reduce energy inputs into irrigation is maintaining an elevated water table. The elevated water table is able to supply water to the root zoot by capillary rise or upward flow. This study looks at the amount of upward flow supplied by various water table depths, and how a controlled water table affected irrigation.

**Upward flow of water**

We estimated the upward flow from the water table by using the hydraulic gradient between 6 cm (2.4") and 21 cm (8") and the average hydraulic conductivity between the two depths (Figure 1). There are few data points at water table levels shallower than 45 cm because the root zone became too wet and risked reduced aeration. At water table depths deeper than 65 cm, upward flow was not great enough so the root zone dried out, requiring irrigation. Water table depths between 45 and 65 cm, were able to supply up to 2 mm $d^{-1}$ of water or approximately 40% of evapotranspiration losses (Bland, et al., 1996).

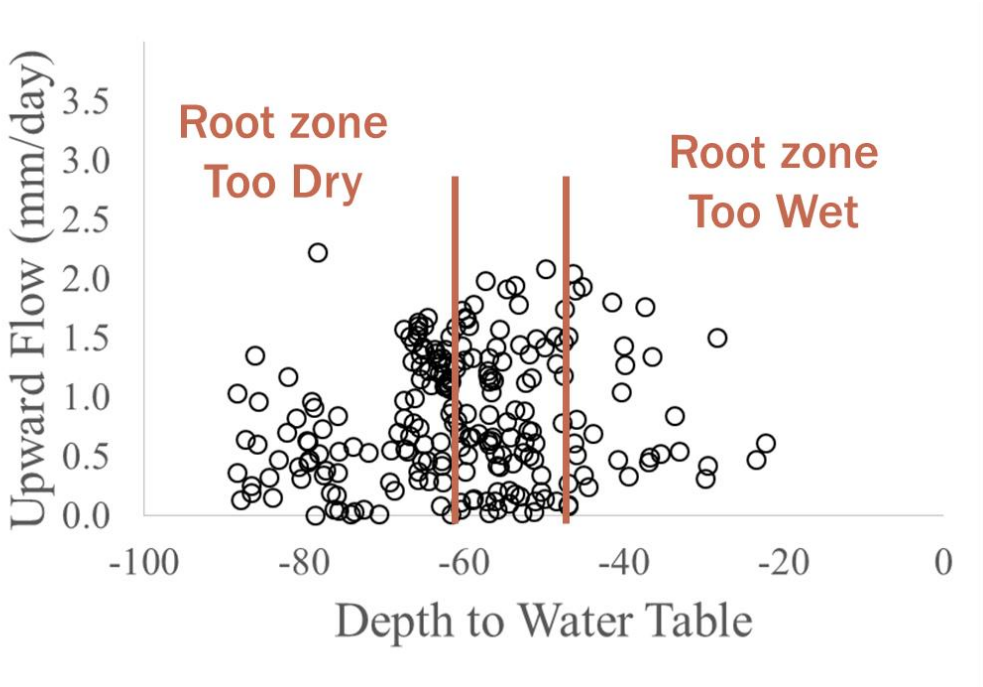


**Figure 1:** Estimated daily upward flow between 6 and 21 cm as a function of water table depth.

**Modelling Confirmation**

Hydrus 1D water flow modelling software was used to simulate root zone tension during a cranberry growing season (Figure 2), as an additional check on our understanding of how water was behaving in the cranberry bed system. In the simulation there was no water input by rainfall or irrigation, to examine how well upward flow from the water table was able to replace water lost through evapotranspiration. With a simulated water table depth of 50 cm, predicted root zone tension ranged from -4 to -5.5 kPa. This is on the wet end of the tension threshold determined by Pelletier, et al. (2013) and with rainfall, oxygen deficiencies in the root zone could limit growth. Using a water table that is 80 cm below the surface, predicted root zone tension was below -8 kPa and would need frequent rainfall or irrigation to assure optimal growth. As in our field results, an ideal water table depth was found around 65 cm (25”). Here root zone tension was maintained right around -6 kPa, allowing the bed to take in rainfall without getting too wet, yet it is able to contribute appreciable water during rain-free periods.

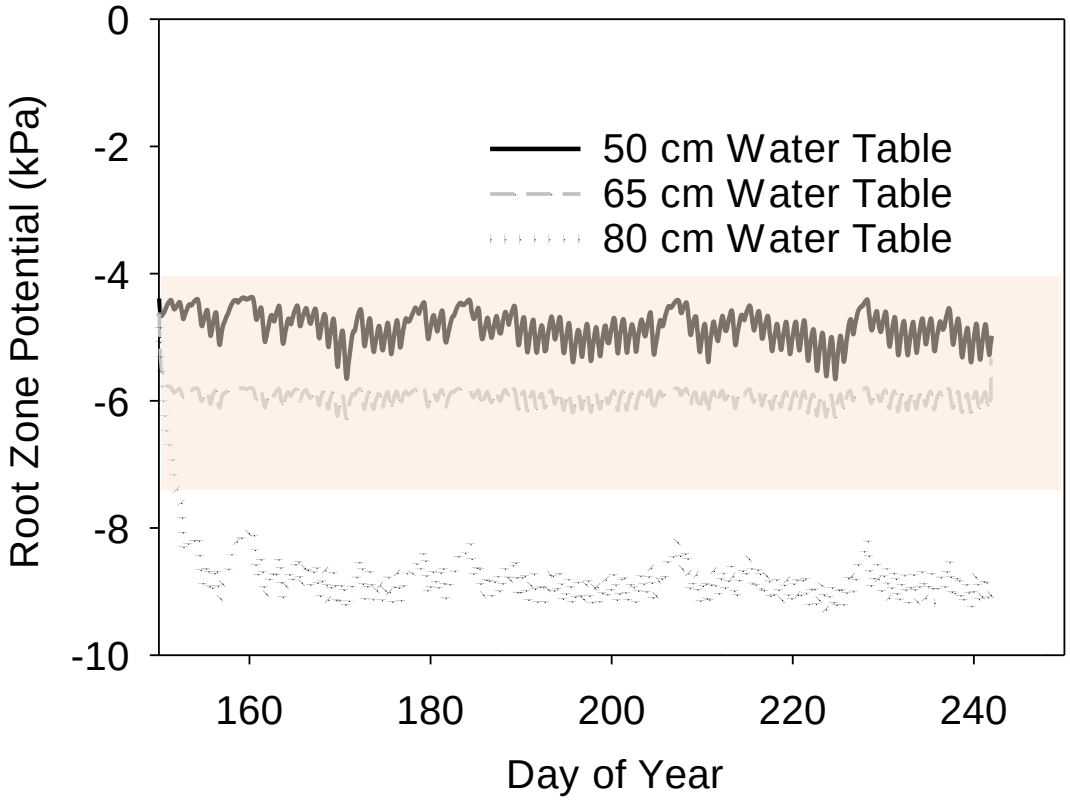


**Figure 2:** Hydrus 1D simulation results of a growing season at 3 fixed water table depths (50, 65, and 80 cm). Simulations were setup to receive no water from irrigation or rainfall to observe the water tables ability to supply evapotranspiration losses.

**Water table management and irrigation**

Two drainage systems were established in the bed examine how water table management affect irrigation needs. Half of the bed was allowed to drain freely while the other half was controlled at a specified depth, between 40 and 60 cm (16" and 24"). Each system was irrigated independently if the root zone tension fell below -7.5 kPa. During the early part of the 2013 growing season, we determined that a 40-45 cm water table resulted in a root zone that was too wet, so the water table was reduced to 60 cm for the end of 2013 and all of 2014 (Figure 3). In 2013, the free drainage area required 7 irrigations compared to only 1 irrigation need for the controlled drainage system. In 2014, more rainfall in August resulted in less overall irrigations. The free drain required 3 irrigations and the controlled drainage didn't require any. There was no difference in yield between drainage systems in either year.

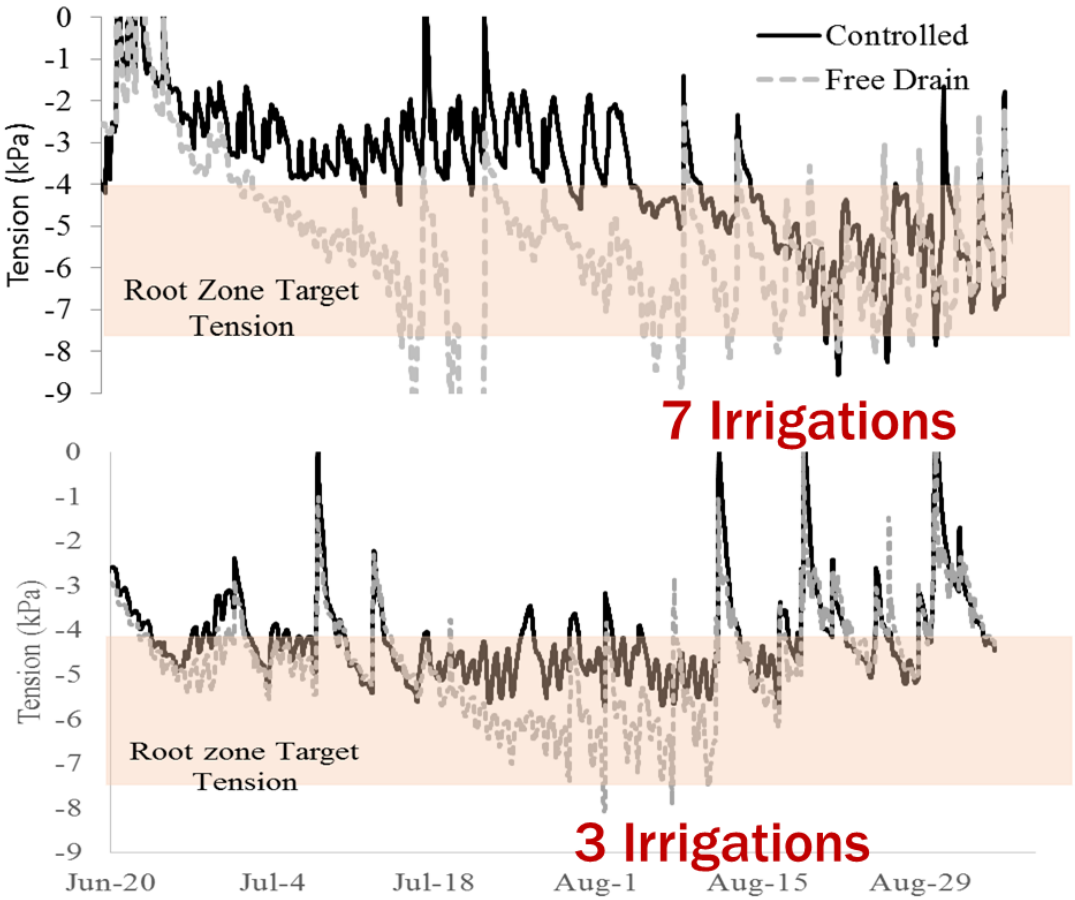


**Figure 3:** Root zone tension (6 cm) used for irrigation management. Average of 4 plots in each of the controlled and free drainage systems.

## Conclusion

Field estimates of upward flow and Hydrus 1D simulations indicate that proper water table management has the potential to supply a significant amount (~40%) of water lost to evapotranspiration. Using a low horsepower pump (2.5 H.P.) to manage water tables resulted in 6 less overhead-irrigation events in 2013 and 3 less overhead-irrigation events in 2014. Low horsepower pumps reduce the energy need for irrigation and sub-surface irrigation reduces wet canopies that can foster disease.

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# PROGRESS TOWARDS ESTABLISHING A MARKER-ASSISTED SELECTION (MAS) PROGRAM AT UW-MADISON

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The projects completed in the Cranberry Genetics and Genomics Lab (CGGL) during 2014 represent a critical leap in the development of a cranberry state-of the-art marker assisted selection (MAS) program in Wisconsin. Cranberry genetic improvement has traditionally been slow and has not utilized genetic or genomic resources. As a result, the cranberry industry relies on only a handful of cultivars which are wild selections or 1st or 2nd generation hybrids of those wild selections (Table 1).

**Table 1**. Origin and release date of commercial cranberry cultivars

| Cultivar | Type | Origin | Release |
|---|---|---|---|
| McFarlin | wild selection | MA, USA | 1874 |
| Searles | wild selection | WI, USA | 1893 |
| BenLear | wild selection | WI, USA | 1901 |
| Stevens | 1st Generation Hybrid | USDA-ARS | 1950 |
| LeMunyon | wild selection | NJ, USA | 1960 |
| HyRed | 2nd Generation Hybrid | UW-Madison | 2003 |
| GH1 | 1st Generation Hybrid | Grygleski | 2004 |
| Crimson Queen | 2nd Generation Hybrid | Rutgers | 2006 |
| Demoranville | 2nd Generation Hybrid | Rutgers | 2006 |
| Mullica Queen | 2nd Generation Hybrid | Rutgers | 2007 |
| Sundance | 2nd Generation Hybrid | UW-Madison | 2011 |
| BG | 2nd Generation Hybrid | Grygleski | 2012 |

Compared to almost all other commercial plant species, cranberry is relatively undomesticated and unselected. Because it is a perennial asexually propagated crop, cranberry genetic improvement has relied on phenotypic selection in very slow cycles that have released cultivars in 25 year intervals. The main cause of these intervals is the need to establish long term test plots of experimental hybrids in grower's marshes which are then phenotypically evaluated for nearly a decade. These test plots require intensive and expensive management techniques in order to ensure their long term genotypic purity (Figure 1).

**Figure 1.** Example of 1ft x 1ft cranberry test plots intensively managed by grower collaborator and individually evaluated by researchers for various traits of importance.

In order to circumvent this problem of long interval selection cycles, a cranberry marker-assisted selection (MAS) program is being established at UW-Madison. Combined with a field-independent high throughput phenotyping system (Zeldin, unpublished), the MAS is a system that will allow UW researchers to increase breeding efficiency by using genetic information to predict a cranberry seedling's yield potential, vigor, disease resistance, fruit quality, or etc. prior to planting that seedling in the field for evaluation.

In general, there are three main components of a MAS program:

1) A set of genetic resources which includes molecular markers placed on a genetic map.
2) Identification of genes associated with important agronomic traits using the molecular markers and genetic map.
3) A system to follow the inheritance of the markers associated with traits of interest using the molecular markers and genetic map.

In the past year, more than 500 novel SSR markers have been developed and validated in the CGGL (Schlautman et al., 2015). These markers will serve as important landmarks in a cranberry SSR based genetic map as the Zalapa lab begins to search for the locations of genes involved in various traits of agronomic importance. Additionally, more than 373,639 single nucleotide polymorphisms (SNPs) have been identified using genotyping-by-sequencing technology and are being integrated into the SSR genetic map to continue the search for important genes to incorporate in a cranberry MAS program (Figure 2).

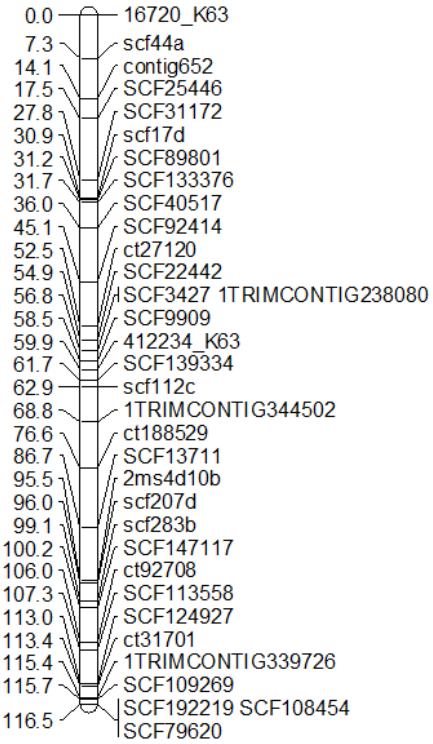


**Figure 2.** Example of a linkage group in the cranberry genetic linkage map. Vertical bar in the center represents a cranberry chromosome. Marker names are located on the right side of the chromosome and the markers genetic position (cM) is on the left side.

One of the biggest limitations to establishing a MAS program is the identification of genes associated with important agronomic traits. In order to effectively perform this step, it is vital that cranberry researchers collaborate among themselves, growers, and industry leaders in deciding which traits are in most need of immediate improvement, and then additionally in designing methods for identifying and analyzing variation in the traits of interest.

Identifying molecular markers and/or genes linked to or associated with the trait of interest is usually accomplished using one of two methods: quantitative trait loci (QTL) mapping

or association mapping. Both methods require large numbers of replicated test plots within controlled environments, and this process can take 3 or more years of phenotypic evaluation.

New additions to the CGGL in 2014 brought new ideas and expertise for designing more efficient phenotypic evaluation techniques. Specifically, by experimenting with imaging technologies for measuring traits such as plant vigor, fruit color, fruit size, and fruit shape, the program has expanded its capacity to analyze more plants each year (Figure 3).

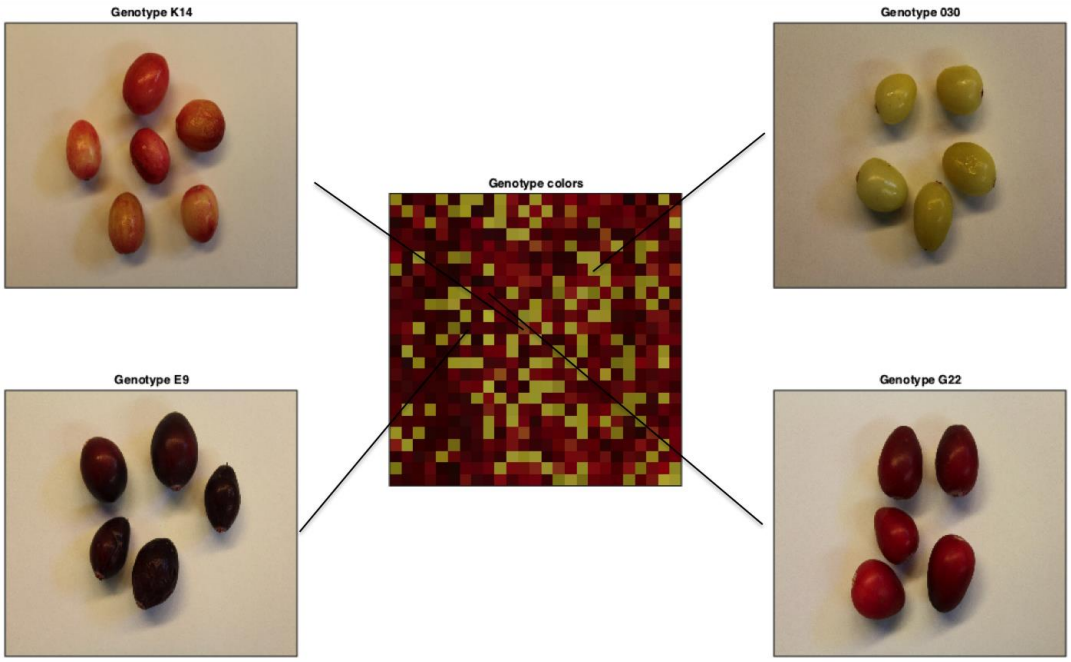


**Figure 3.** Example of using imaging technology to predict fruit size, shape, color, volume, and uniformity

In addition to our measurements of traits such as TAcy, Brix, and titratable acid to identify genotypes with improved fruit quality for juice and sweetened dried cranberries (SDCs), the CGGL has begun to develop methods for using a texture analyzer to measure variation in cranberry fruit firmness for use in improving slicing during SDC processing and in fresh fruit keeping quality (Figure 4).

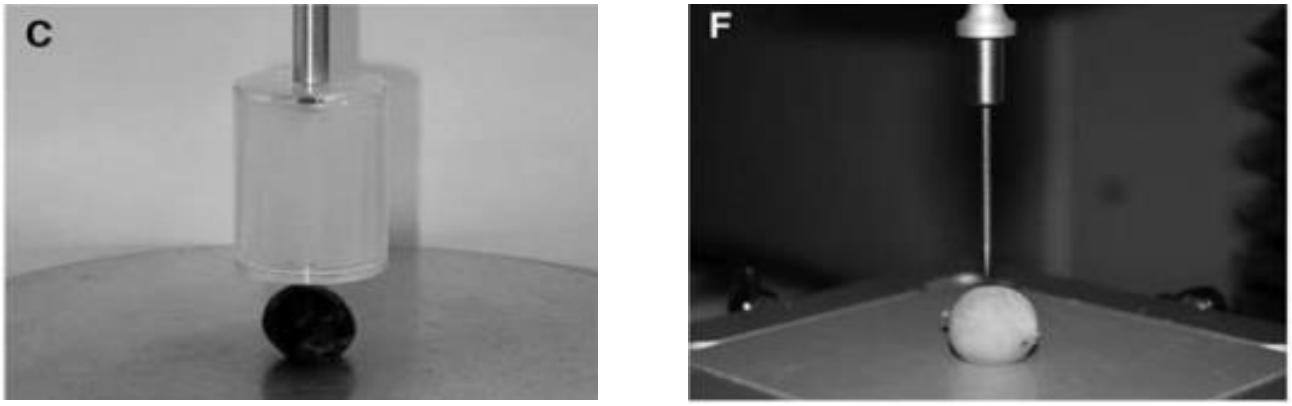


**Figure 4.** Example of texture analysis for measuring fruit firmness using c) a compression test and f) a puncture test (Rolle et al., 2012).

## Conclusion

The molecular markers tested and validated by the CGGL in 2014 (Schlautman et al., 2015) and the improved SSR genetic linkage map (Schlautman, unpublished) represent two important steps in the establishment of a cranberry MAS program at UW-Madison. These resources will be critical components for identifying QTL and marker associations with economically important cranberry traits related to yield, to genes involved in defense pathways of virus, insect, or fungal pathogens, and to genes associated with increased fruit quality for specific cranberry products. The new phenotyping methods and cranberry genetic resources developed in 2014, when combined with a high-throughput field independent breeding system, will be the key for the successful deployment of MAS program in cranberry aimed at generating superior cultivars which meet the current and future challenges of the Wisconsin cranberry growers and the U.S. cranberry industry.

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# CHARACTERIZATION OF NUTRIENT CONTENT OF NEW VARIETIES AND OPTIMIZATION OF TIMING OF TISSUE ANALYSIS IN CRANBERRY

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Tissue nutrient analysis is a key part to fertilizer management decisions. Since plant tissue nutrient content changes over the course of the growing season, it is important to understand these patterns and to take samples during the period of greatest stability in order to best develop nutrient management plans for the coming year, assist in sustainability goals, and maintain a healthy crop. Current recommendations are to sample tissue between August 15 and September 15 (Davenport et al., 1995). Recently introduced cultivars from Wisconsin and New Jersey have not been evaluated for their nutrient stability over the growing season. These new cultivars have been selected for a number of traits, including earliness of flowering, fruiting, and ripening, high yield, enhanced color, and rebud potential, all factors that could have an influence on the timing and degree of nutrient demand within the plant. In addition, other factors may influence the relative stability of tissue nutrient content, such as variable environmental conditions and grower practices. The goal of this project is to 1) compare the changes in tissue nutrient content change of two new varieties compared to a standard variety, and 2) evaluate these patterns of tissue nutrient stability during the season in relation to parameters such as calendar date, plant phenological stage, and growing degree day, to determine the most suitable marker for the timing of tissue sampling.

**Material and methods.** To study patterns of nutrient stability, four sites were selected from the Cranmoor (3) and Tomah (1) areas that each had beds of 'Stevens' (ST), 'HyRed' (HR), and 'Crimson Queen' (CQ). One bed of each variety was sampled at each site with pooled samples taken from each third of the bed. ST beds ranged in age from 17 to 32 years, while HR and CQ bed ages each ranged from four to seven years. Over the growing seasons of 2013 and 2014 new growth (minus flowers or fruit) was sampled and sent to AgSource Cooperative Services for standard cranberry tissue analysis. Sampling was done every two weeks from early June to mid-August, then weekly until early October, for a total of 14 and 12 sample dates in each respective year. Additional data that was collected included canopy height air temperature, plant phenology/stages of growth, grower fertilizer and yield records. Results for the following nutrients are presented: macronutrients nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca), as well as micronutrients zinc (Zn) and copper (Cu).

**Results and Discussion.** Nutrient content values and patterns of change over the course of the growing season were generally similar over the two years (Figures 1-3). The pattern for each nutrient is unique, however, so attention to these patterns can help in the interpretation of test results, particularly if you have needed to sample outside of the traditionally accepted window period.

*Nitrogen*: Values were stable during the window (Figure 1). In 2013 values were generally lower from mid-season on because new stem tissue below the leaves was included (most nitrogen is found in

leaves, as a part of the chlorophyll molecule). A period of fluctuation in values across all cultivars was seen going into the window period in 2014, but then values stabilized. The lowest values early in the season corresponded with late bloom and fruit set for each cultivar were reached approximately one week sooner in HR and CQ than for ST.

*Phosphorus*: Tissue phosphorus levels were the most stable of all the nutrients. Values drop early in season and remain stable from July to October (Figure 1).

*Potassium*: Tissue potassium levels start high early in the season and then drop gradually, as opposed to the faster drop as with nitrogen and phosphorus (Figure 1). Steady drop continued through the window period. In 2013 there was a sharper decline and this occurred slightly earlier in HR and CQ than in ST. Deficiency does not appear to be an issue at any of these sites. Values were most stable in latter part of the window period. High potassium fertilization rates, especially late in the season, have not been shown to increase plant cold hardiness and typically results in lower calcium and magnesium by competing for exchange sites in the soil.

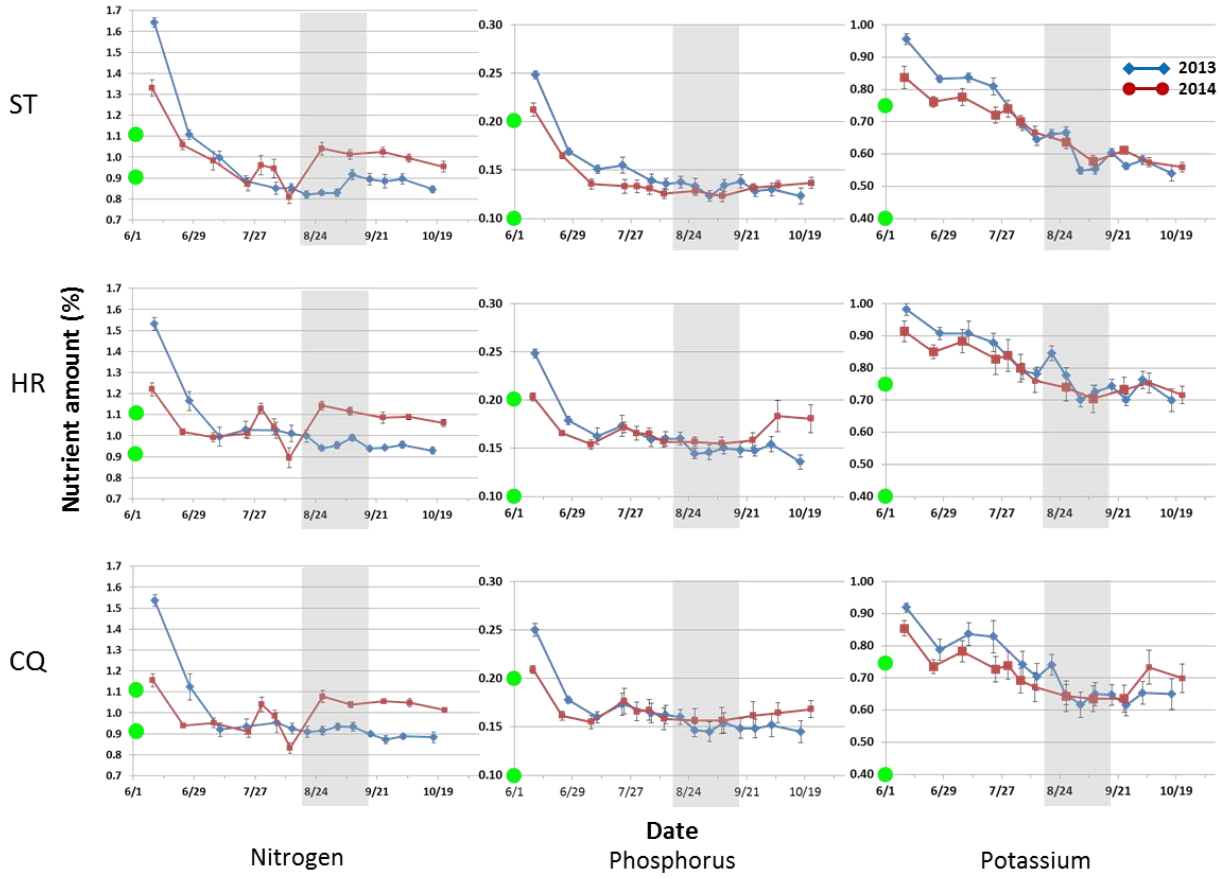


**Figure 5.** Nitrogen, phosphorus, and potassium tissue content for uprights sampled from four central Wisconsin cranberry marshes in 2013 and 2014. Green dots signify normal range for nutrient. Error bars show the standard error of the mean (n=12). The current mid-August to mid-September sampling window is highlighted in gray.

*Magnesium*: Tissues levels of magnesium peak during, or slightly after the current window period, and have the potential to have a wide range (Figure 2). Therefore, it will be important to bear this in mind when comparing values across years.

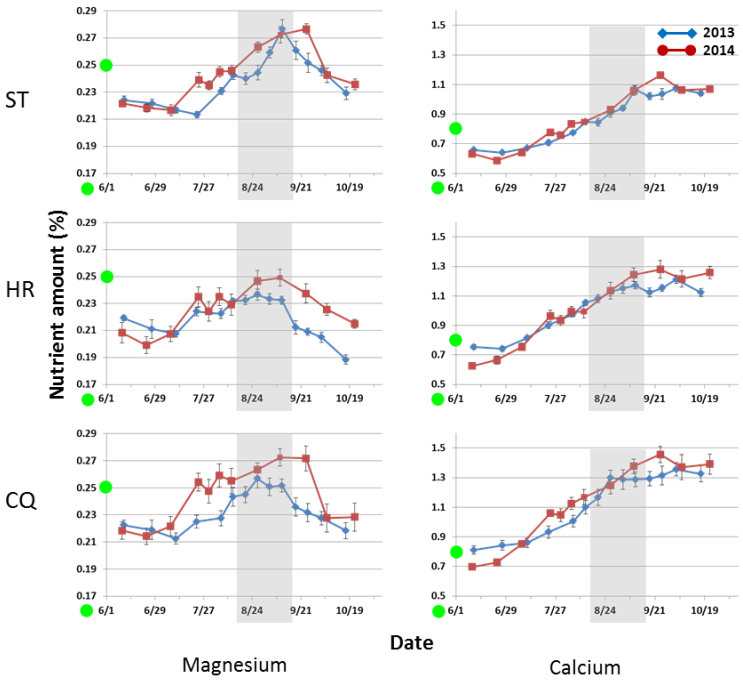


**Figure 2.** Magnesium and calcium tissue content for uprights sampled from four central Wisconsin cranberry marshes in 2013 and 2014. Green dots signify normal range for nutrient (lower points of range for magnesium = 0.15%; for calcium = 0.3%). Error bars show the standard error of the mean (n=12). The current mid-August to mid-September sampling window is highlighted in gray.

*Calcium*: Tissue calcium levels are lowest in the early season and do not peak until late September/early October (Figure 2). Values are notably different at the end of the window period, as opposed to the beginning of it. In both 2013 and 2014, values at these sites were notably above the upper limit of the normal range for most of the growing season.

Zinc: On most sample dates zinc tissue levels were fairly stable with low variability; however, on seemingly random dates zinc levels were both higher and highly variable (Figure 3). This may have been due to contamination on the surface of the leaves or some other cause, but test results higher than the normal range are possible at anytime in the season.

*Copper*: This was the only nutrient in the study that consistently had values at or below the normal range value across all cultivars (Figure 3). Values were lowest in the window period and lower in HR and CQ than in ST. In 2013, values stayed low, whereas in 2014 values rose in late September and early October. Copper deficiency is not commonly discussed in cranberry nutrition, but this may be worthy of attention. In most plant species, the most common symptom of deficiency is yellowing in young leaves. This occurs due to the essential role that copper plays in enzyme function during photosythesis (Havlin et.al., 2014). Copper in the form of $Cu^{2+}$ is strongly bound to organic matter in the soil.

*Comparison of calendar date, growing degree days, and phenology*: Alternatives to considering the timing of changes or unexpected values in tissue nutrient content by calendar date is by either phenology (growth stage) or growing degree days. This would be useful if there are changes that are driven more independently by another factor, like temperature, rather than time. For the two years of this study, growing degree days were not accumulated at rates or totals different enough (Figure 4) to result in different patterns of nutrient content change (data not shown). Although HR and CQ flower,

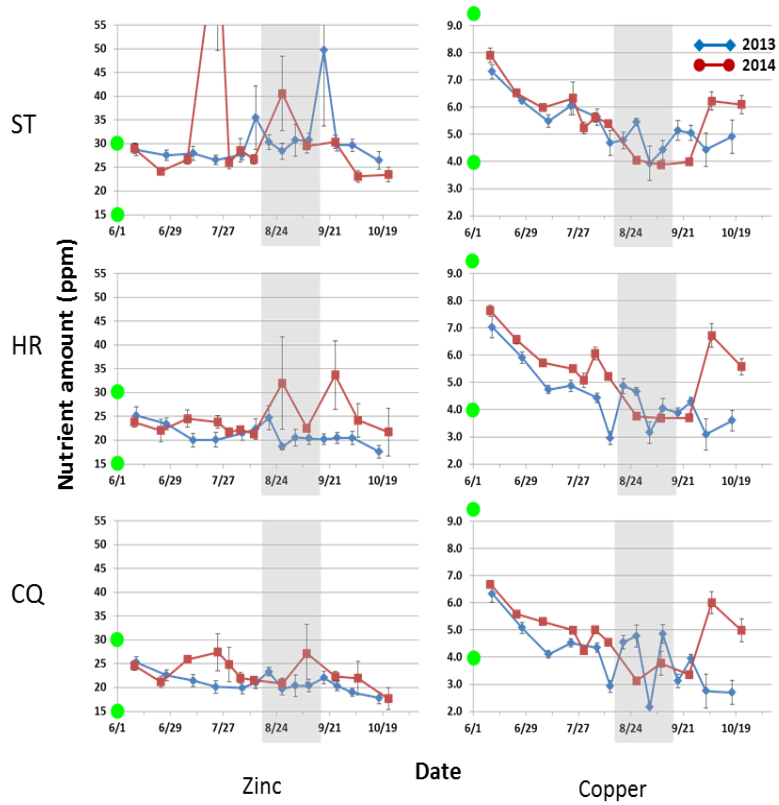


**Figure 3.** Zinc and copper tissue content for uprights sampled from four central Wisconsin cranberry marshes in 2013 and 2014. Green dots signify normal range for nutrient (upper point of range for copper = 10 ppm). Error bars show the standard error of the mean (n=12). The current mid-August to mid-September sampling window is highlighted in gray.

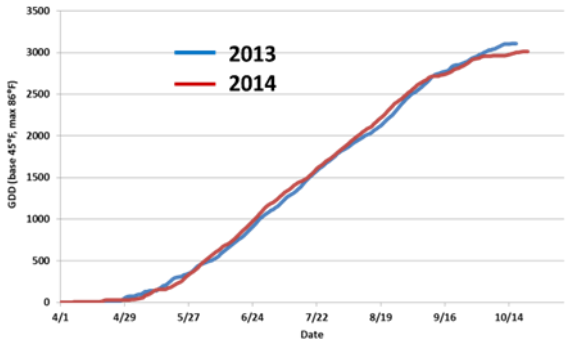


Figure 4. Accumulation of growing degree days (GDD) for Cranmoor/Tomah, Wisconsin area for 2013 and 2014 using canopy-height temperatures from four sites. Daily values calculated from maximum and minimum temperatures, and base and upper limits of 45°F and 86°F.

fruit, and ripen earlier than ST, only small differences in the timing of content change of nutrients such as nitrogen, phosphorus, and magnesium were noticeable in mid to late June (bloom to fruit set), as well as in August and September (fruit ripening).

*Grower management and crop production*: Despite the fact that the HR and CQ beds for this study were much younger than the ST beds, the values and patterns of tissue nutrient content change were similar. Grower records of applied fertilizer (Figure 5) and yield (Figure 6) show that these consistencies occur even though there are differences in grower management and crop production. These growers tend to apply as much or more nitrogen and phosphorus to HR and CQ than to ST. In 2014 there was a wide range of approach to the amount of potassium to apply to all beds (average of 223 lbs/a at Site A to 69 lbs/a at Site D). Yields of ST were more consistent than those of HR or CQ, an indication that the management of these new cultivars is still a work in progress. Despite the differences in predictability, tissue nutrient content levels and their patterns were largely consistent across cultivars and between sites.

## Conclusions

- As with Stevens, the current sampling window of August 15 to September 15 is the best time frame for the newer cultivars of HyRed and Crimson Queen.
- The tissue nutrient content stability of several nutrients, such as nitrogen, phosphorus, and potassium, appear to be more stable in the latter portion of this window (early September).
- Growing degree days and phenology do not appear to be better gauges of tissue nutrient content change than calendar date.

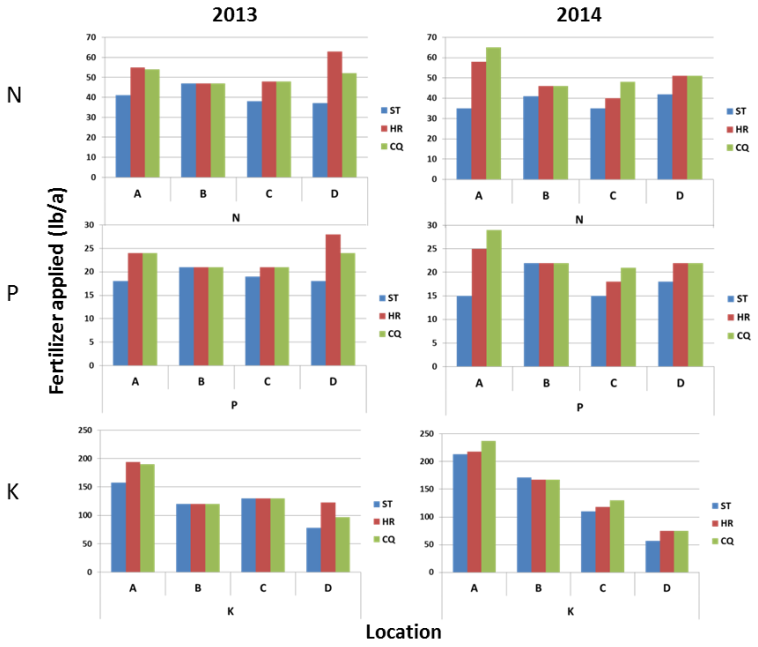


**Figure 5.** Annual fertilizer amounts of nitrogen (N), phosphorus (P), and potassium (K) applied to beds of Stevens (ST), HyRed (HR), and Crimson Queen (CQ) at grower sites A-D in 2013 and 2014.


**Figure 6.** Berry yield in barrels per acre (bbls/a) from beds of Stevens (ST), HyRed (HR), and Crimson Queen (CQ) at grower sites A-D in 2013 and 2014.

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# IMPACT OF HONEYBEE HIVE LOCATION ON VISITATION TO CRANBERRY

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Honeybee pollination is important to Wisconsin cranberry growers. Currently, 89% of Wisconsin cranberry growers who use pollination services rely on honeybees[1] for optimal fruit set. Even though cranberries are able to produce fruit without pollination, fruit set, berry size, and even ripening is maximized by successful pollination[2, 3]. Honeybees ensure that sufficient pollen grains reach the stigma of the flower, otherwise fruits can be small, deformed or altogether absent[3]. Pollination services are an important economic investment for cranberry growers. On average, $140 to $210 per acre is spent on pollination services. Therefore ensuring that cranberry flowers are successfully pollinated is imperative to Wisconsin cranberry growers. Further knowledge of cranberry pollination will allow the cranberry industry to better manage honeybee hives for successful cranberry pollination.

Wisconsin growers have reported observing honeybees fly off the marsh, presumably to forage on other flower resources. Previous studies have shown that fidelity to cranberry varies from day to day. In one study, honeybees were carrying 2-100% cranberry pollen[4]; while in another study, some colonies collected mostly cranberry pollen, 50-99%[5]. The variability in honeybee cranberry pollination could be affected by weather conditions, varying needs of the colony, proximity to additional resources, and hive placement on the marsh.

## OBJECTIVES

In this study, we are investigating whether honeybee hive placement on the marsh impacts the foraging efficiency of honeybees on cranberry. Specifically, we are assessing whether cranberry contribution to the pollen collected by honeybee foragers varies with hive placement. The three hive placements evaluated are (1) near wild habitat, (2) near a water reservoir, and (3) near the center of the marsh (Figure 1).

It is expected that hives placed near wild habitat will display different foraging patterns to hives located in the center of the marsh and near a water reservoir. Water and surrounding cranberry beds may not provide off-farm foraging sources unlike hives near wild habitat. For this reason, honeybees collected from the hives near wild habitat are expected to have a lower cranberry pollen contribution to those honeybee hives placed in the center of the marsh and near a water reservoir.

Objective 1: Pollen composition analysis

In this first objective, we assessed honeybee fidelity to cranberry across different hive locations using pollen morphology analyses and conducted floral assessment surveys to identify the diversity and frequency of flowering plants on the marsh and in wild habitat (wooded and open landscapes). Using pollen morphology analyses, we will also determine the pollen composition of pollen collected by honeybee foragers by identifying and quantifying the abundance of pollen from each plant species as a function of colony proximity to marsh edges.

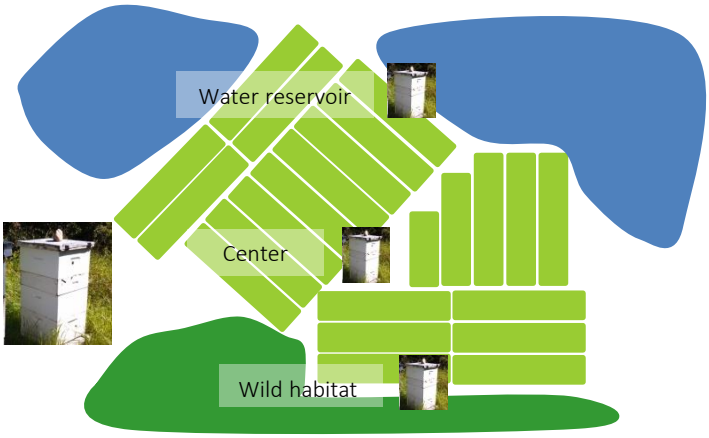



**Figure 1.** Model study site of hive placement: near wild habitat, near a water reservoir, and near the center

This objective is part of a larger project, which includes the following two objectives:

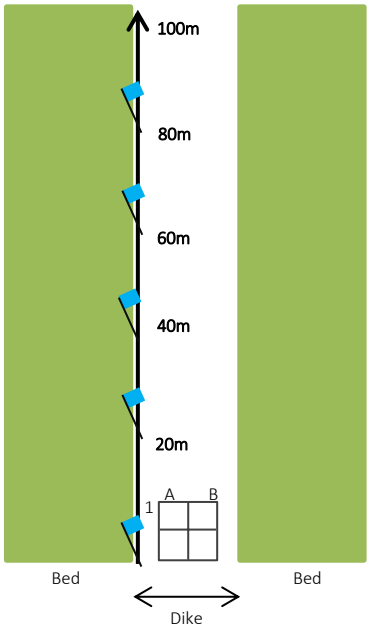
Objective 2: Molecular Analysis by Dr. Juan Zalapa and Dr. Johanne Brunet

Using high-throughput genetic sequencing analysis, we will determine the species diversity in honeybee pollen composition. The application of these genetic tools will be used to assess the diversity, abundance, and taxonomy of plant species that honeybee forage on.

Objective 3: Isotopic analysis by Dr. Shawn Steffan

Using isotopic tools, we will measure the extent to which honeybees forage off-site. We use nitrogen signatures on the marsh and off the marsh as a function of colony proximity to marsh edges.

**OBJECTIVE 1: POLLEN COMPOSITION ANALYSIS**




During the 2014 field season, we collected honeybees returning to hives with pollen at the 3 different locations and conducted the floral assessment survey. In total, we collected 569 bees from 3 locations (near water reservoir, wild habitat, and center) at 5 sites (A-E). In the lab, we developed methods for determining pollen composition and abundance. Using a hemocytometer slide, we quantified cranberry versus non-cranberry pollen grains using pollen grain morphology.

**Figure 2.** Transect set-up for on-marsh floral assessment. There were 5 sampling points along the 100m transect line consisting 1x1 m squares

We ran 100m transects for the floral assessment survey (Figure 2). At each site, there was a total of 8 transects: six on the marsh along the dikes, and two in the wild habitat next to the marsh, one in wooded and one in open landscapes. Percent cover and percent bloom was recorded for each flowering plant species at each transect point.

The current results show that on a particular day, contribution of cranberry pollen to honeybee hives vary from 0-96% cranberry pollination (Figure 3a). We also found that there was no difference based on location, with on average, two-thirds of all bees foraging on cranberry, regardless of hive location (Figure 3b).

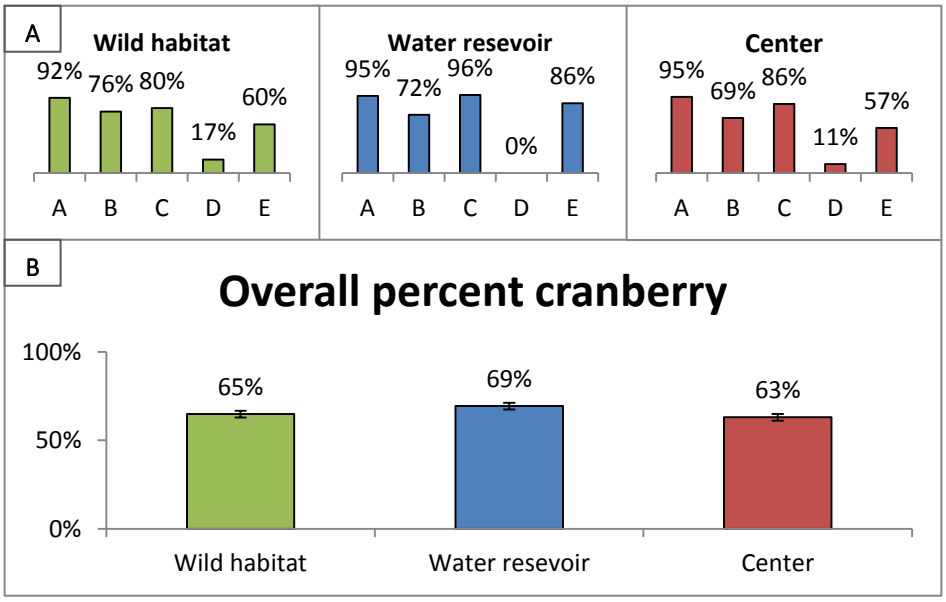



**Figure 3. (A)** Percent cranberry pollen per site (A-E) for each hive location. **(B)** Overall percent cranberry pollen per

From the floral assessment, we have compiled a list of the most common flowering plants on the marsh and off the marsh (Table 1).

**DISCUSSION**

Our results follow previous studies that found that cranberry pollination varies greatly from day-to-day and across colonies[4, 5]. In our study, cranberry pollen contribution was variable from site to site. Contrary to our expectations, there was no difference in honeybee fidelity to cranberry across hive placement locations (near water reservoir, wild habitat, and center). Further studies are necessary to understand the causes and impact of the observed variability in cranberry pollination. Some of the variability could be due to management practices, landscape and availability of alternate flower resources on the marsh and in the surrounding landscape, as well as abiotic factors such as weather. We suspect that the low amount of cranberry pollen carried by bees at site D could be due to a fish emulsion fertilizer that was

applied that day and may have deterred the bees from foraging on cranberry flowers, consequently not pollinating cranberry. We sampled each marsh on a single day so these results represent but a snapshot on where bees are foraging during cranberry bloom.

Table 1. Floral assessment showing most common plants on the marsh (dikes) and off the marsh (open and wooded).

| OFF THE MARSH | ON THE MARSH |
|---|---|
| **Open** | **Dikes** |
| Swamp Dewberry | White Clover |
| Canada Thistle | Sheep Sorrel |
| Cranberry | Orange Hawkweed |
| Wild Strawberry | Canada Thistle |
| Broadleaf Plantain | Broadleaf Plantain |
| Steeplebush | Common Cinquefoil |
| Goldenrod | Wild Strawberry |
| Birdsfoot Trefoil | Yellow Woodsorrel |
| Common Cinquefoil | Yarrow |
| **Wooded** | |
| Wild Strawberry | |
| Bittersweet Nightshade | |
| Blueberry | |
| Chokeberry | |
| Orange Jewelweed | |
| Cranberry | |
| Bog Birch | |
| Narrowleaf Hawkweed | |
| Yellow Woodsorrel | |

## FUTURE RESEARCH: NEXT OBJECTIVES

During spring 2014, we will shift our focus to the other two objectives: molecular analysis and isotopic analysis of the pollen collected by bees. We will determine the extent to which honeybees forage off the marsh by looking at the nitrogen signature of the pollen collected through isotopic analysis. With the use of genetic tools, we will identify the plant species that honeybees collected pollen from. The combination of technologies and techniques (botanical, isotopic, and genetic) provides a detailed description of foraging patterns on cranberry marshes at a fine scale.

In the next field season, we plan to refine this study to determine the impact of hive placement on the marsh. Data collection will likely occur on multiple days at each marsh, allowing us to gain further insight in the day-to-day variability observed in cranberry pollination.

## ACKNOWLEDGEMENTS

We would like to acknowledge our funding sources, Wisconsin Cranberry Board Inc. and Wisconsin Cranberry Grower Association. Also many thanks to our collaborators, Dr. Johanne Brunet, Dr. Shawn Steffan, and Dr. Juan Zalapa. Lastly, field data collection would not have been possible without our volunteers: Kathryn Hietala-Henschell, Olivia Bernauer, Tierany Bougie, Elissa Chasen, Miguel Hernandez, Hannah Gaines Day, Scott Lee, Erin McMahan, Keith Phelps, Emma Pelton, Walter Salazar, Janet Van Zoeren, Kelly Wallin, and Eric Weisman.

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# IMPACT OF CRANBERRY POLLINATION ON HONEY BEE COLONIES AND OF SUPPLEMENTARY FEEDING DURING POLLINATION

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**PROBLEMATIC**

Over the past years, many beekeepers reported colonies weakened after doing cranberry pollination. The idea of weakening their colonies refrain some beekeepers to rent them for cranberry pollination. Weakened colonies would result in a reduce income for the beekeeper and a reduced pollination offer would be detrimental to the cranberry industry growth.

**OBJECTIVE:**

1. Evaluate the impact of doing the cranberry pollination on honey bee colonies
2. Determine if a supplemental feeding of pollen supplement and/or sugar syrup would prevent the weakening of the colonies
3. Verify if feeding the bees have a negative impact on cranberry pollination

**HYPOTHESES**:

1. Honey bee colonies doing cranberry pollination will be weaker than those that did not
2. Supplemental feeding during pollination will prevent weakening of the colonies
3. Supplemental feeding will not affect negatively bee foraging activity on cranberry

**METHOD**

45 colonies were split in 5 experimental groups (Table 1).

**Table 1**. Experimental set up

| **Group 1**<br>**Negative control** | **Group 2**<br>**Positive control**<br>**Cranberry** | **Group 3**<br>**Feeding 1**<br>**Cranberry** | **Group 4**<br>**Feeding 2**<br>**Cranberry** | **Group 5**<br>**Feeding 3**<br>**Cranberry** |
|---|---|---|---|---|
| | | 15L of 1:1 sugar syrup | 5 lb of pollen supplement | 15L of 1:1 sugar syrup<br>5 lb of pollen supplement |
| **N=9 colonies** | **N=9 colonies** | **N=9 colonies** | **N=9 colonies** | **N=9 colonies** |

Before pollination, colonies were split in 2 apiaries near the research center. They were an equal number of colonies from the 5 experimental groups in an apiary. So, in one apiary there were 25 colonies (5/group) and 20 in the other one (4/group). Colonies of groups 2 through 5 were used for cranberry pollination (June 17$^{th}$ to July 9$^{th}$ 2010). After the pollination, colonies were returned to their respective initial apiary. The colonies from experimental group 1 always remained in the apiaries. Colonies strength had been balanced the week prior to the pollination. Hives consisted of 2 standard Langstroth bodies of 10 frames.

During cranberry pollination, sugar syrup was fed using Miller type feeders (colonies received a 5L feeding per week for 3 weeks). Pollen supplement was a commercial product distributed in 1 lb patties so colonies fed pollen supplement received 5 patties each. To determine the feeding impact on bee foraging activity, the pollen collected from bottom pollen traps during a period of 24 hours after the feeding was analysed.

The brood and honey production of the colonies were monitored until the following spring as well as colony survival.

**RESULTS AND DISCUSSION**

By comparing data from group 1 and 2, we did not measure nor observe any detrimental effect on the honey bee colonies from doing cranberry pollination. The only significant difference in all the parameters we followed was the honey production during the 3 weeks of the cranberry pollination. Colonies from group 1 stored 57 lb of honey during these 3 weeks while those from group 2 gathered only 19 lb. However, based on our previous experiences where we had colonies hardly producing 2 lb of honey in a cranberry marsh, we found the honey production of group 2 rather high. The pollen collected in the traps showed that colonies had an easy access to other floral sources, especially white clover (probably from nearby cultivated fields). In the colonies of group 2, less than 20% of the pollen collected came from cranberry. Thus, we can't rule out that cranberry pollination is not detrimental to honey bees as it might happen in area with less floral diversity (wider cranberry marsh).

After the pollination groups 2, 4 and 5 had the same brood area but group 3 had about half a frame less brood. This had been caused by the swarming fever more important in colonies from group 3 as a queen would slow egg laying rate to reduce its ovaries in preparation of the swarming flight. So sugar syrup did not enhance brood production but even seems to induce swarming which is not a good thing for the beekeeper! Groups 3 and 5 store about 12 lb more honey during the cranberry pollination than groups 2 and 4. This was actually the sugar syrup we fed those two groups. One month after the pollination, all colonies performed similarly in all aspects and they did so until the following spring. Results did not showed a positive impact of supplemental feeding on the colony development. This was to be expected since no negative effect of being in the cranberry marsh was observed.

Concerning the foraging activities of the colonies, pollen quantities were highly variable from one colony to another therefore we could not perform statistical analysis on pollen yield. Instead we looked at the ration of the pollen collected from each floral source. 17% of the pollen collected by the bees from

groups 2 and 4 came from cranberry. So feeding pollen supplement patties did not affect negatively the cranberry foraging activities of the honey bees. But for the groups 3 and 5, the ratio of cranberry pollen was 50%. Group 3 alone reached 57%. Feeding sugar syrup enhanced cranberry foraging activity by a factor of nearly 3. This was unexpected. We think that the cranberry flower gives little nectar but good amount of pollen. By feeding sugar syrup, we filled the nectar need of the bees and they would become less interested to travel long distances to gather nectar from more prolific sources. They would instead focus more on the closer cranberry blossom.

**Table 2.** Ratio of cranberry pollen collected

| **Group 2 Positive control Cranberry** | **Group 3 Feeding 1 Cranberry** | **Group 4 Feeding 2 Cranberry** | **Group 5 Feeding 3 Cranberry** |
|---|---|---|---|
| 19% | 57% | 16% | 43% |

**CONCLUSION**

We did not measure a negative impact of doing the cranberry pollination for honey bee colonies but a test in a wider cranberry bog is needed to confirm that it is without doubt not detrimental to honey bees. Supplemental feeding of pollen supplement and/or sugar syrup during the pollination would not enhance colonies development and not refrain bees from foraging on cranberry blossoms. Feeding sugar syrup will even enhance cranberry foraging but could also induce swarming in bee colonies. Therefore a more specific study on a feeding method that would enhance cranberry blossom foraging without inducing swarming is needed.

# ASSESSMENT OF RESISTANCE OF CRANBERRY VARIETIES TO INSECT PESTS

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Wisconsin's cranberry industry is currently looking for ways to improve sustainability and to incorporate more Integrated Pest Management (IPM) strategies into growing practices. Host plant resistance (HPR) is an important component of IPM that has not been extensively studied in cranberries. HPR refers to heritable properties in plants that improve their natural resistance against insects and other pests. This resistance can be due to physical properties of the plant such as leaf toughness or chemicals in the plant that deter insect feeding and oviposition or impair insect development.

HPR has been researched in many other crops, and the research has been used to breed more resistant varieties of those crops. However, only a handful of resistance studies have been done in cranberry and those studies focused on pests and varieties that are uncommon in Wisconsin, which is the world's largest producer of cranberries. Promisingly, some of these studies have indicated that some varieties may be more resistant than others ([1,2]), however, more research needs to be done with other pests and varieties.

Our research focuses on HPR in cranberries. The overall objective is to assess the susceptibility of several cranberry varieties commonly grown in Wisconsin (Stevens, Ben Lear, GH-1, Mullica Queen, and HyRed) to the three most economically important cranberry pests in the state: blackheaded fireworm (BHFW), sparganothis fruitworm (SFW), and cranberry fruitworm (CFW).

The complete project will address three objectives in order to assess resistance:

1) Evaluate field population densities of the target pests in the five cranberry varieties.
2) Determine development rates of SFW on these varieties in the lab.
3) Determine oviposition preference of SFW females on these varieties in the lab.

At this point, we have completed the first objective. We plan to complete the second and third objectives in the spring and summer of 2015.

Methods and Materials for Objective One: Field Population Density Study

*Adult Population Densities*

This study was carried out in the summers of 2013 and 2014. We used five different sites at commercial marshes in central Wisconsin and used beds of five different varieties: Stevens, Ben Lear, GH-1, Mullica Queen, and HyRed. In each bed, we placed four pheromone traps baited with commercially available, species-specific pheromone lures, one trap with a pheromone bait for BHFW, one with a bait for SFW, a third with a bait for CFW and a fourth control trap with no pheromone bait. Each bed was next to at least one bed of the same variety, so the traps could be placed between the two beds to minimize the likelihood of moths flying in from beds with other varieties (Fig. 1).


**Figure 1.** Example of the layout of beds at study sites. Diamonds indicate trap placement.

The traps used a female sex pheromone lure, so they attracted only male moths. Every week, we collected the traps and counted the number of male moths found in each trap. Counts were averaged for all weeks of the first flight for both years. Pheromone lures were changed every month, although problems were encountered with the SFW and CFW lures for the first few weeks in 2013, prompting us to change lure suppliers partway through the season.

*Larval Population Densities*

Using the same study beds, plus their adjacent bed of the same variety, we walked 100 m transects along the bed edges collecting all red, damaged berries within a meter width. The red berries were returned to the lab and damaged berries were counted, then dissected and the

larvae inside were counted and identified to species. The study was repeated three weeks in a row, the three weeks were averaged for each bed, and the averages were compared.

Results:

*Adult Population Densities*

Our trap catches indicated a great deal of variability among sites, years, and species (Fig. 2). Some sites had much higher numbers of one or all of the pests than others did. We found significant differences in SFW populations among the different varieties. Populations were significantly lower in beds of Ben Lear and Mullica Queen than in Stevens and GH-1.

HyRed had significantly lower population densities than Stevens (Fig. 3). There were no significant differences between populations of BHFW, although there appears to be a non-significant trend of lower populations in GH-1 (Fig. 4).There were no significant differences among varieties for CFW (Fig. 5).

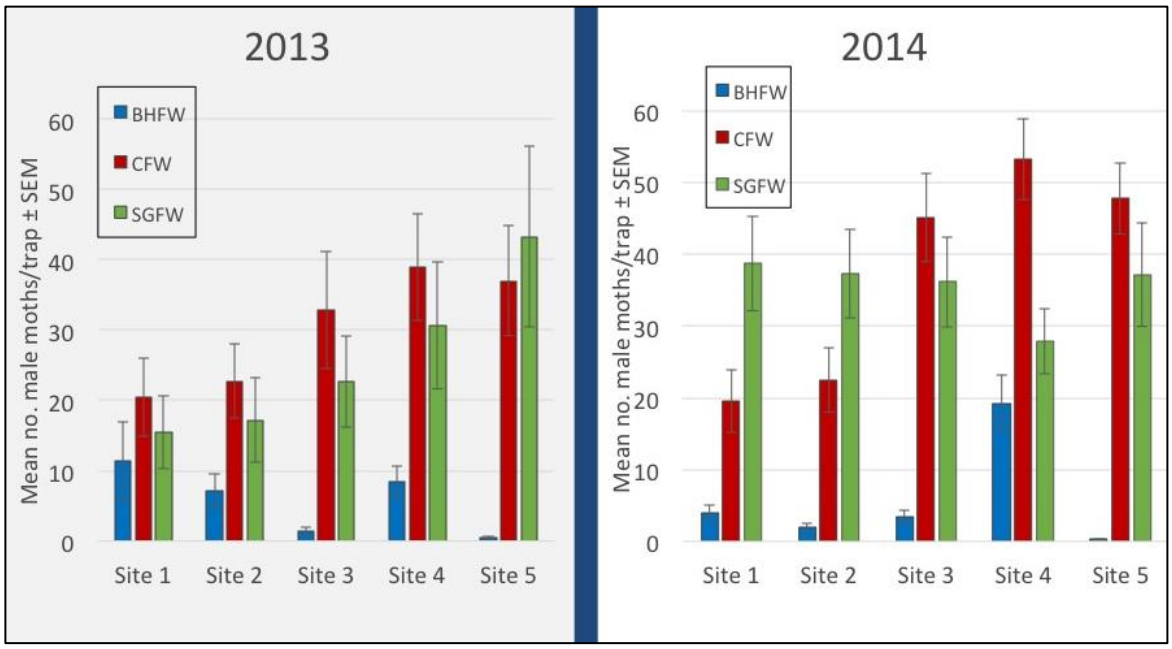


**Figure 2.** Variation among years, sites, and species. Different colored bars indicate different species and black bars indicate standard error.

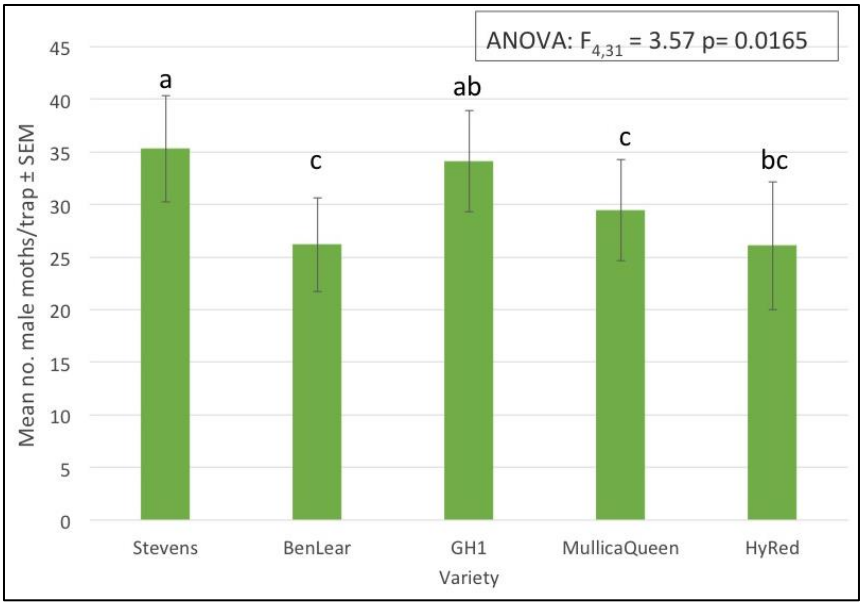


**Figure 3.** Average number of male SFW moths per trap for all weeks of first flight for both seasons. Black bars indicate standard error and letters indicate significant difference.

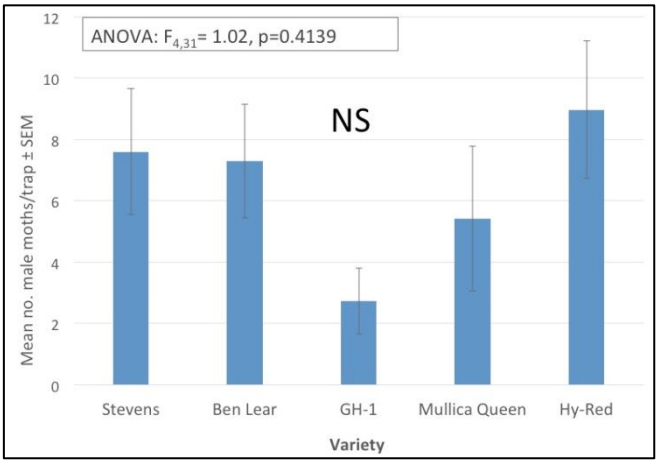


**Figure 4.** Average number of male BHFW moths per trap, averaged over all weeks of the first flight for both seasons. The black bars indicate standard error and NS indicates no significant differences among the means.

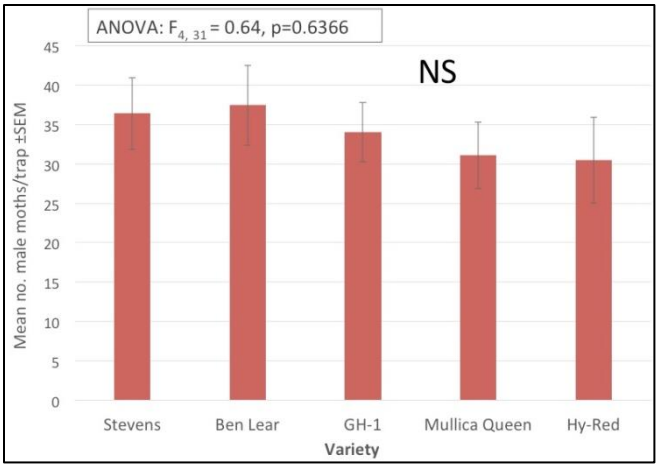


**Figure 5.** Average number of male CFW moths per trap, averaged over all weeks of the first flight for both seasons. The black bars indicate standard error and NS indicates no significant difference among the varieties.

*Larval Population Densities*

Larval infestation rates were quite variable across all sites, and perhaps because of this variability, there was no significant difference across varieties (Fig. 6). Nearly all of the larvae found were cranberry fruitworm.

Discussion:

We found a significant difference in sparganothis fruitworm field population densities among the varieties. Ben Lear and Mullica Queen showed lower population densities than both GH-1 and Stevens and HyRed was significantly lower than Stevens. SFW was, however, the only species that showed a significant difference in population densities. There was no significant difference in larval counts among varieties, however, because nearly all of the larvae collected were cranberry fruitworm, this corresponds with the adult trap count data which indicated that CFW does not have significantly different populations among varieties. The data showed variability in overall moth populations among the different sites which could be due to different management strategies, differences in conditions at the different sites, or hotspots of pest outbreaks in some sites.

These finding contradict a similar study that found that gypsy moth exhibited a preference for Ben Lear in lab feeding assays ([2]).However, this study used gypsy moth, which has different biology from SFW.

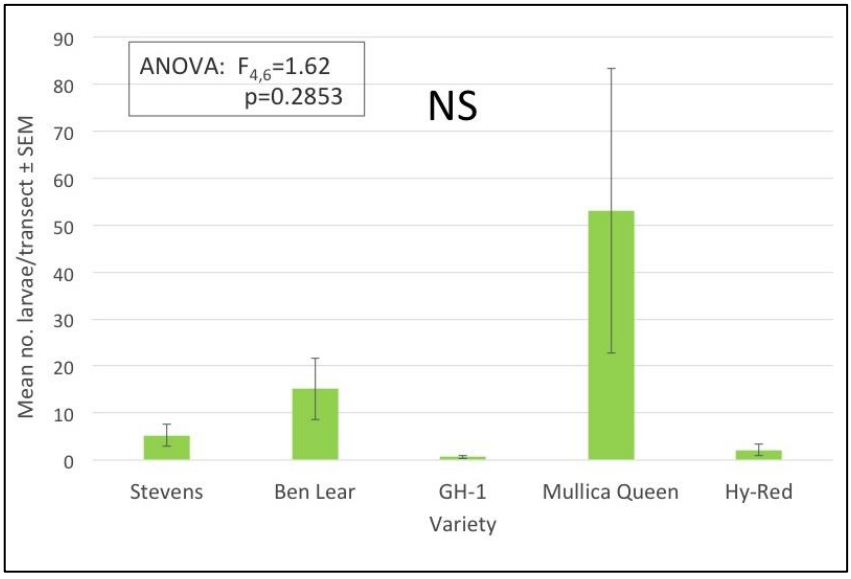


**Figure 6.** Average number of larvae in berries per transect. The black bars indicate standard error and NS indicates no significant difference.

To explore why these particular varieties hosted smaller pest populations, we looked for genetic relationships among the varieties. Ben Lear is a parent of HyRed, so some aspect of this possible resistance may be inherited. However, Mullica Queen has a completely different genetic background than the other two.

According to anecdotal evidence, Ben Lear is one of the earliest varieties to bloom and set fruit every year. The hybrids Mullica Queen and HyRed also bloom and set fruit earlier than varieties such as Stevens and GH-1. One explanation could be that the phenology of these earlier varieties does not line up with critical SFW degree-day benchmarks ([3]), e.g., SFW oviposition or development periods, leading to lower SFW populations in these varieties.

Despite the fact that we have found different populations of SFW in different varieties, we still do not have a clear picture of a resistant variety. Ongoing and future laboratory assays measuring development rates and oviposition preference in SFW will hopefully help to fill in the gaps in this picture and complete the assessment. Since other research has found a difference in cranberry varieties in the lab, ([1,2]) we expect to see significant results as well.

If we do find a more resistant variety, that variety could be used in new plantings or incorporated into future breeding programs to create new varieties with more naturally occurring resistance. This, in turn, could reduce the need for chemical control and lead to more sustainable management.

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# CARNIVOROUS ARTHROPODS AFTER A SPRING FLOOD: EVIDENCE OF BIOLOGICAL CONTROL?

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**Background:** Approximately half of Wisconsin's cranberry growers replace a spring pesticide application with a 1-2 day spring flood. Previous work has shown that the spring flood is an effective pest control strategy for *Sparganothis* fruitworm, cranberry fruitworm, and black-headed fireworm, and that there is no reduction in yield due to flooding (Steffan et al. 2012). However, it remains unclear through what mechanisms pest suppression takes place, and therefore how to optimize these beneficial effects. It is interesting to note that the flood and resulting removal of trash (detritus) affect not only the insects present at the time of flooding, but also alter the physical structure of the understory, with profound consequences to its inhabitants.

A complex community of arthropods is present on every cranberry marsh, including the herbivores (i.e. pest caterpillars) which are most noticeable to many growers because they directly harm the plant. Additionally there are detritivores (i.e. springtails, which feed on the detritus and trash in the understory and have no direct effect on the plant), generalist predators (i.e. spiders, which may eat whatever prey they come across), and specialist parasitoids (often wasps, which tend to specialize on a single pest species). The predators and parasitoids indirectly help the crop through biological control, which at its best can be a highly efficient pest control strategy. This occurs when insect predators consume significant numbers of pests (Marucci and Moulter 1992). However, the effectiveness of the predators and parasitoids depends on a variety of factors, including the structure of their habitat and the availability of alternative prey species.

Factors such as habitat structure and prevalence of alternative prey species differ between beds that received a spring flood and those that received a concurrent pesticide application. These differences may increase the effectiveness of biological control agents in beds that were flooded over beds that received an insecticide application.

We hypothesized that the pest suppression provided by flooding is actually due to an increase in biological control, as predators may be encouraged (by the lack of springtails and other detritivores) to eat more caterpillars and other pest species. To investigate these interactions we looked at the population dynamics of detritivores, herbivores, and generalist predators in cranberry beds following the removal of detritus in a spring flood.

**Methods:** During the summer of 2014, field investigations took place on 12 beds in a single commercial cranberry marsh in central Wisconsin. All beds were of Stevens variety and approximately of the same age. Half of the beds received a spring flood ("Flood") and half

received a spring insecticide spray ("Spray") instead. All "Flood" beds were flooded for approximately 30 hours in late-May. All "Spray" beds received an insecticide application during that same week.

Arthropod communities were sampled in the beds seven times: one pre-treatment sampling event in mid-May, five sampling events in the weeks following treatment, and one the week following an insecticide application that was applied to all beds in early July. Samples were taken each week with pitfall traps, sweep-netting, and pheromone-baited traps. Pitfall traps targeted active insects in the understory, while sweep-netting targeted insects in the canopy. The pheromone-baited traps sampled for *Sparganothis* fruitworm, cranberry fruitworm, and black-headed fireworm.

**Results:** There was no difference in the abundance of detritivores (springtails) between flooded and sprayed beds (not shown). Populations started high and decreased rapidly, then stayed near zero for the rest of the summer.

There were more generalist predators (Fig. 1) and a trend of more parasitoids in the "Flood" beds than in the "Spray" beds. This suggests that predators and parasitoids thrive following the flood, although it's unclear if the flood directly helps them or if the difference is due to the absence of spray in the "Flood" beds. It is likely that these predators consume a significant number of detritivores; this may be why the springtail population remains low throughout the spring.

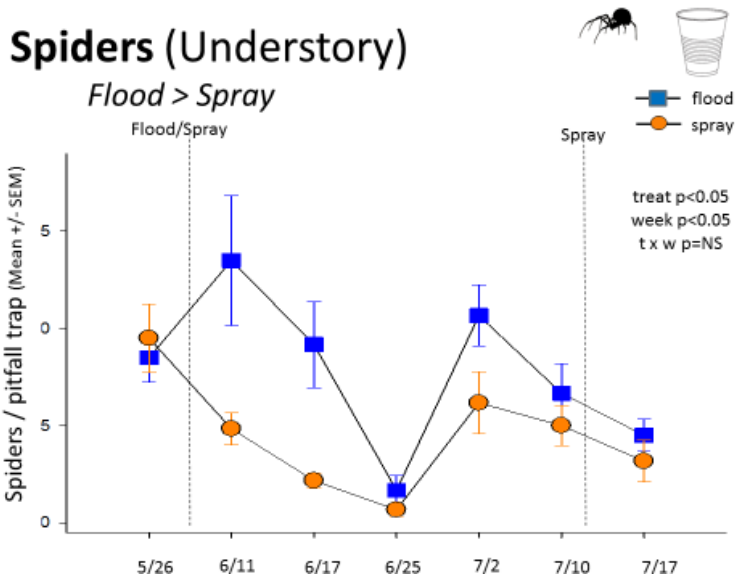


Figure 1. Number of spiders caught in pitfall traps by week, with more spiders in flooded than in sprayed beds. Note: excessive rainfall caused trap malfunction on the week of June 25th.

Spiders and parasitoids also are likely to consume caterpillar pests. Future research will look more specifically at the ability of spiders to control caterpillar populations.

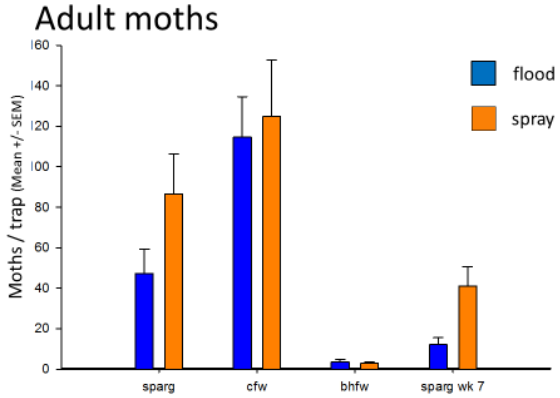


Figure 2: Adult male moths caught in pheromone-baited traps. From left to right: Sparganothis fruitworm, cranberry fruitworm, black headed fireworm, and Sparganothis fruitworm from just the peak flight week.

Flooding resulted in reduced pest populations for the three main moth pests (Fig. 2). The number of cranberry fruitworm and black-headed fireworm moths caught in pheromone-baited traps were the same in flooded as in sprayed beds. In fact, during the peak flight week, there were fewer *Sparganothis* fruitworm moths caught in flooded than in sprayed beds. This upholds previous research showing that flooding is a highly effective pest control strategy in cranberries.

**Discussion and Future Research:** There is ample evidence, both from this study and previous work published in the Cranberry Proceedings, that populations of moths are controlled in flooded beds equally as well as they are following an insecticide application. This sets up the question I am investigating – what specific aspect of the flood provides pest suppression in cranberry cultivation? Last summer I showed that populations of both spiders and parasitoid wasps are greater in beds that were flooded rather than sprayed, which may indicate that the mechanism through which the flood enacts pest suppression is by maintaining healthy populations of naturally-occurring predators and parasitoids. These in turn may prey upon, and thus reduce, caterpillar populations.

Detritivore populations followed the same pattern in flooded and sprayed beds. However, this does not necessarily mean that the dynamics between predators, herbivores, and detritivores is the same in flooded and sprayed beds. Prior to this study, detritivores were expected to be more populous in "Spray" beds than in "Flood" beds, because detritus offers them food (allowing them to reproduce more rapidly) and habitat (places to hide from spider attacks). The lack of observed difference between the "Flood" and "Spray" beds may be due to extensive predation from spiders driving all populations to zero throughout the summer. Further, differences in detritus between "Flood" and "Spray" beds may alter the number of spiders present or their effectiveness at controlling caterpillars, so spiders may still play a role in the driving factor of the flood's effectiveness.

In order to more specifically determine the potential of spiders and parasitoids to enact pest suppression, in both flooded and in sprayed beds, we will be conducting a combination of field and laboratory work aimed at the relationships between predators/parasitoids, herbivores, and detritivores. If predators and parasitoids are found to be effective biological control agents, able to provide significant pest suppression, managing the marsh to support their populations would be a highly cost-efficient tool in the IPM toolbox. Further, flooding appears to be an effective method to control pests while concurrently maintaining healthy populations of beneficial predators and parasitoids.

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# DO FUNGICIDE APPLICATIONS AFFECT BEE FIDELITY TO CRANBERRY?

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**Maximizing the effectiveness of honey bees for cranberry pollination**

Each year, the majority of Wisconsin cranberry growers spend thousands of dollars to rent honey bees for pollination. Grower observations suggest that honey bees are flying off marsh and foraging elsewhere. Why are honey bees leaving the marsh and how can growers encourage bees to stay on the marsh to pollinate the cranberries?

A number of factors influence the behavior of bees and whether they stay on marsh or not. Some of these factors, such as weather and habitat in the surrounding landscape are out of the control of the growers, and some, such as hive placement and timing of spray applications, are within control of the grower. Here, we discuss how two factors, the surrounding landscape and fungicide application, may influence bees and their pollination of cranberry.

**How does wooded habitat in the landscape influence the contribution of honey bees to yield?**

From previous research (Gaines-Day 2013), we know that native bees are strongly influenced by the surrounding landscape; as the amount of woodland within 1 km (~0.6 miles) of the marsh increases, abundance and diversity of native bees also increase. This is likely due to the fact that this wooded habitat provides nesting and foraging resources which the bees need to survive. Since honey bees are able to fly further than most native bees and communicate among themselves as to the location of good resources, it is likely that honey bees are also using off-marsh floral resources. This may explain why growers observe honey bees flying off marsh.

If bees are leaving the marsh, is the contribution of honey bees to cranberry pollination diminished in certain landscapes? To answer this question, we collected historical yield and honey bee data from 38 cranberry growers in central Wisconsin. We created a plot of hive density (hives/ac) versus yield (bbl/ac) and separated the points by the amount of woodland in the surrounding 1 km (Fig. 1). From this figure, we found that yield increased with increasing hive density for marshes set in low-woodland landscapes (<42% woodland) but there was no relationship between yield and hive

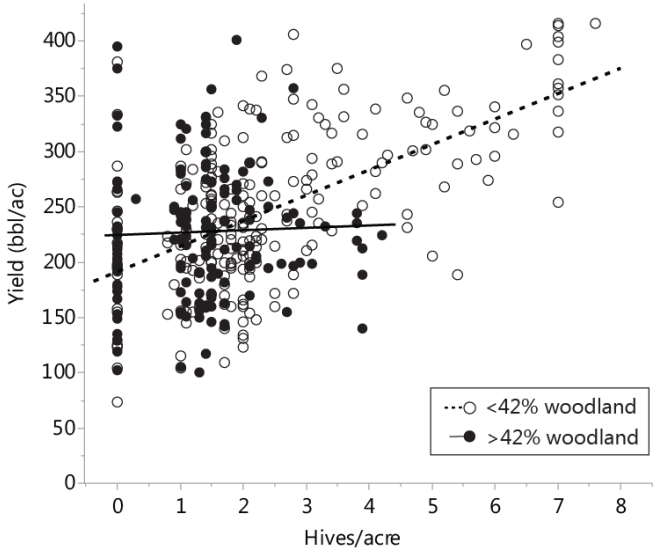
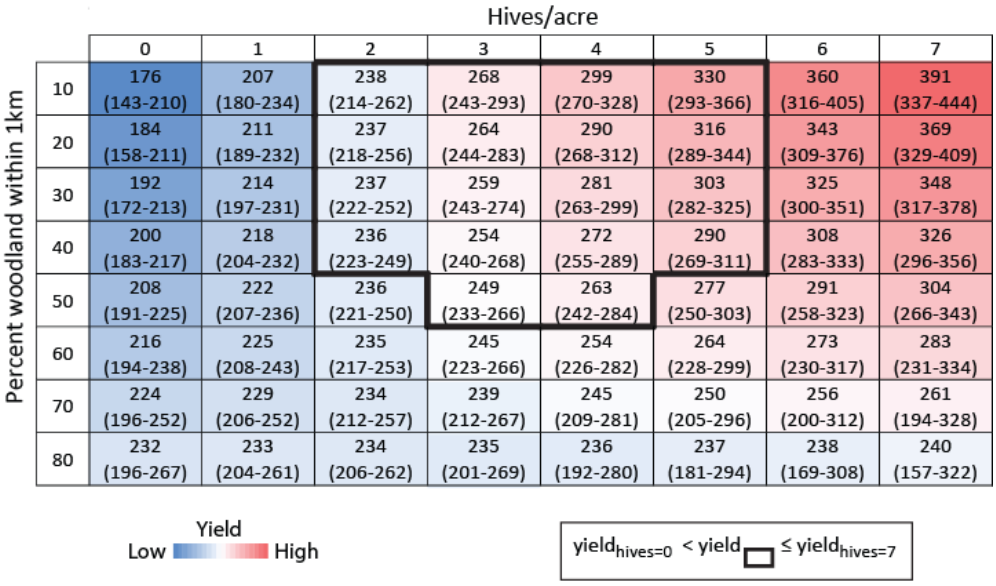



**Figure 1.** The relationship between cranberry yield and honey bee hives is different in high- and low-woodland landscapes.

density for marshes set in high-woodland landscapes (>42% woodland). This indicates that growers in low-woodland landscapes are receiving a big benefit from honey bees while growers in high-woodland landscapes are not getting any benefit. It is possible that bees at marshes in high-woodland landscapes are finding more attractive floral resources off-marsh whereas bees on marshes in low-woodland landscapes find the cranberries more attractive than the alternative.

Using this same data, we created a model to determine how cranberry yield would vary as hives/acre increases in different landscapes. The model predicts that yield is more likely to increase for marshes with 10-50% woodland when the number of hives/ac ranges from 2-5 hives/ac (fig. 2). The model also predicts that yield will not increase at marshes with more than 60% woodland no matter




| Percent woodland within 1km | Hives/acre 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 10 | 176 (143-210) | 207 (180-234) | 238 (214-262) | 268 (243-293) | 299 (270-328) | 330 (293-366) | 360 (316-405) | 391 (337-444) |
| 20 | 184 (158-211) | 211 (189-232) | 237 (218-256) | 264 (244-283) | 290 (268-312) | 316 (289-344) | 343 (309-376) | 369 (329-409) |
| 30 | 192 (172-213) | 214 (197-231) | 237 (222-252) | 259 (243-274) | 281 (263-299) | 303 (282-325) | 325 (300-351) | 348 (317-378) |
| 40 | 200 (183-217) | 218 (204-232) | 236 (223-249) | 254 (240-268) | 272 (255-289) | 290 (269-311) | 308 (283-333) | 326 (296-356) |
| 50 | 208 (191-225) | 222 (207-236) | 236 (221-250) | 249 (233-266) | 263 (242-284) | 277 (250-303) | 291 (258-323) | 304 (266-343) |
| 60 | 216 (194-238) | 225 (208-243) | 235 (217-253) | 245 (223-266) | 254 (226-282) | 264 (228-299) | 273 (230-317) | 283 (231-334) |
| 70 | 224 (196-252) | 229 (206-252) | 234 (212-257) | 239 (212-267) | 245 (209-281) | 250 (205-296) | 256 (200-312) | 261 (194-328) |
| 80 | 232 (196-267) | 233 (204-261) | 234 (206-262) | 235 (201-269) | 236 (192-280) | 237 (181-294) | 238 (169-308) | 240 (157-322) |

**Figure 2.** Yield (± 95 % CI) as predicted by number of hives/ha and the amount of woodland in the surrounding landscape. The optimal number of hives is determined as the number of hives where predicted yield is greater than yield when hives are absent (hives=0) and equal to yield when hives equals 18 which is indicated by the black outlined box.

how many hives/acre are used. To more clearly visualize the results presented in tabular format above (Fig. 2), we also created figures demonstrating the relationship between predicted yield and hives/ac at both 10% woodland (fig. 3A) and 80% woodland (fig. 3B). Yield (± 95% CI) is represented by the red bars and lack of overlap between bars indicates statistically significant differences. From these graphical representations, it is clear that yield increases rapidly as hives/ac increase at 10% woodland, but yield does not increase with increasing number of hives at 80% woodland. Although it appears that honey bees may not be as useful to growers in high-woodland landscapes, this non-crop habitat does provide valuable resources for the native bees. Native bees, in turn, provide valuable pollination services to the growers and act as an insurance policy against continued honey bee decline. In the absence of honey

bees, native bees will continue to provide pollination services and the availability of wooded habitat provides these bees with the resources they need to survive.

**Conclusion**

- Cranberry yield increases as hives/acre increase when little woodland is present in the surrounding 1 km.
- Marshes in high-woodland landscapes may not be experiencing much benefit from the use of honey bees.
- As the amount of woodland in the surrounding landscape increases, the abundance and diversity of native bees increases, providing "free" pollination services to the growers and acting as an insurance policy against honey bee declines.

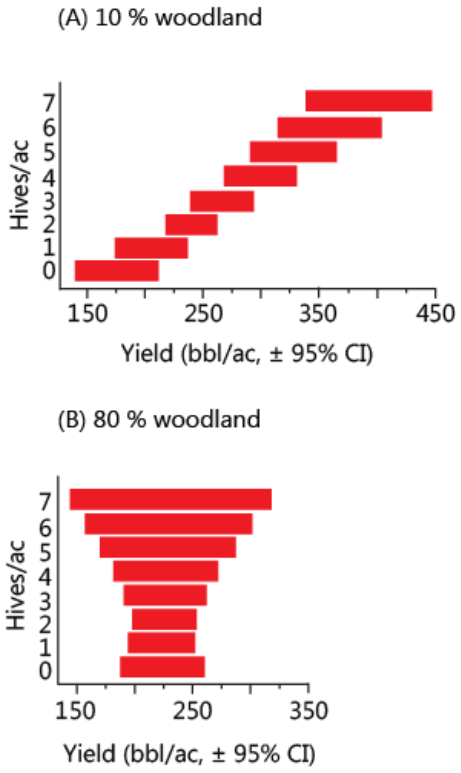



**Figure 3.** Relationship between cranberry yield and the number of hives/ac in landscapes with (A) 10% woodland within 1km and (B) 80% woodland within 1km. Lack of overlap between bars indicates statistically significant differences.

**Does fungicide application during bloom influence bee fidelity to cranberry?**

Some factors that influence honey bee fidelity to cranberry are outside the control of the growers. Others, however, are within the control of the growers. The placement and arrangement of honey bee hives, for example (see Guzman and Guedot in this year's proceedings) or the timing and selection of chemical pesticides and fertilizers are decisions that are made by the grower. Fungicides, in particular, are a pesticide that is often applied to blooming crops and may alter the behavior of the bees (e.g., Sprayberry et al. 2013).

In 2014, we conducted a field study to determine how honey bee and bumble bee fidelity to cranberry is altered by the application of fungicides. To do this, we collected pollen from the legs of bees on six sample dates at varying time intervals post-fungicide spray. Pollen was taken back to the lab to determine the percent of cranberry pollen and other pollen found in each ball of pollen.

We found that honey bees collected while foraging within the cranberry bed had nearly 100% cranberry pollen (fig. 4A). This pattern did not change in relation to fungicide application indicating that honey bees did not alter their foraging behavior in response to the spray. Bumble bees did not collect as much cranberry pollen as honey bees, but the amount of cranberry pollen they collected also did not vary in response to fungicide applications (fig. 4B).

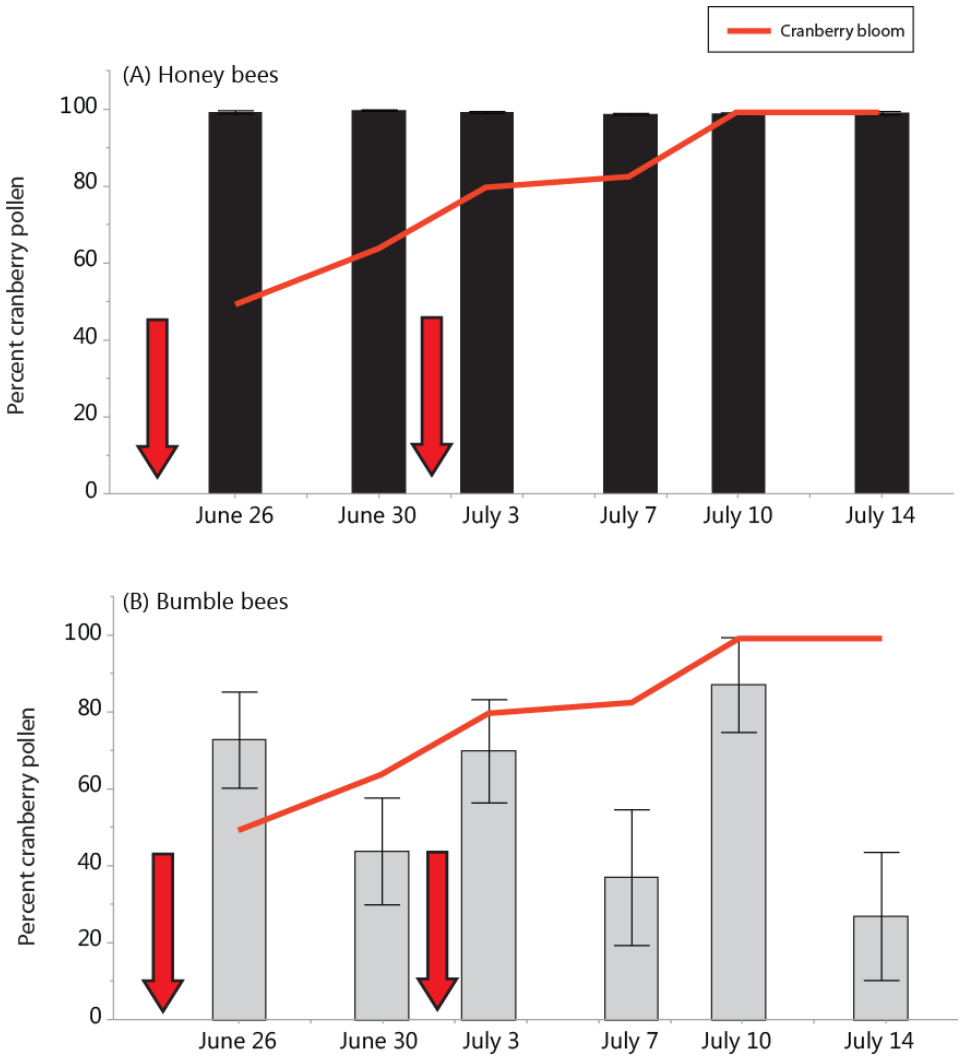



**Figure 4.** The foraging behavior of (A) honey bees and (B) bumble bees did not vary in response to fungicide applications during bloom. Red arrows indicate fungicide application.

**Conclusion**

- Honey bees collected foraging directly on cranberry collect nearly 100% cranberry pollen regardless of fungicide application.
- Bumble bees collect less cranberry pollen than honey bees but the percentage does not appear to change depending on fungicide application.
- Future research should look at colony-scale foraging behavior since fungicide applications may cause honey bees to leave the marsh more frequently even though those bees remaining on the marsh still visit cranberry.

**Acknowledgements**

We would like to thank our cranberry grower collaborators for providing data and access to their property. We also thank Claudio Gratton and the Gratton Lab, the Steffan Lab, and the Guédot Lab for support and feedback on this project. Field and lab assistance was provided by Chris Watson and Aidee Guzman. This research was partially funded by a UW Hatch Grant to Claudio Gratton.

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## MULTI-SPECIES MATING DISRUPTION IN CRANBERRIES

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Mating disruption (MD) has proven to be an important approach to pest population suppression. It is predicated on the concept of preemptive pest control, in which plumes of synthetic sex pheromones prevent males from tracking the authentic plumes of females. This process intercedes in the basic function of egg fertilization, rendering all eggs of a generation largely nonviable. The approach is powerful and does not necessitate companion applications of insecticide. In US apple and pear orchards, for example, the emergence of MD in the early 90s (Fig. 1 at right, from Jones *et al.* 2010) allowed many growers to shelve most of their insecticides. Mating disruption has worked so well for the apple/pear industry of Washington that MD is now a mainstay of almost every orchard in the Pacific Northwest (Jones *et al.* 2010).

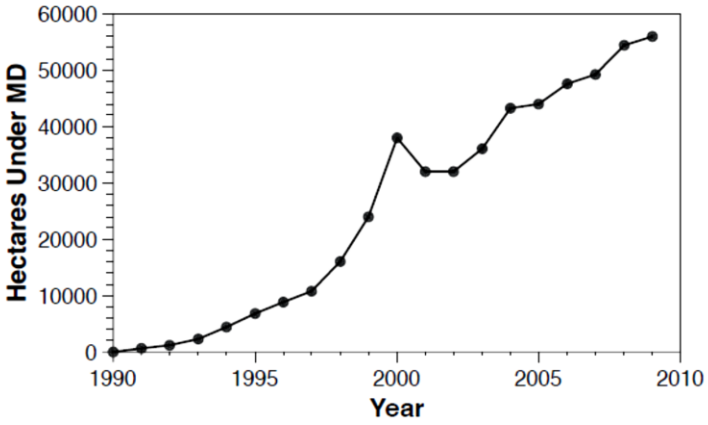



**Figure 1.** Estimated hectares of apples treated with mating disruption in Washington 1990–2009

Mating disruption has been explored in cranberries, as well. Three separate approaches were tested in the mid- to late 90s, all directed at black-headed fireworm. In the earliest study, the fireworm pheromone was loaded into polyvinyl chloride carriers (PVC "ties") and deployed in cranberry beds in British Columbia (Fitzpatrick *et al.* 1995). This approach was successful at reducing mating frequencies and had adequate longevity, but the labor-intensive nature of coiling ties around cranberry uprights made this approach difficult. Another pheromone dispensing system was subsequently investigated in Wisconsin cranberries (Baker *et al.* 1997). This system relied upon Metered Semiochemical Timed Release Systems (MSTRS™), which were battery-powered devices that "puffed" pheromone plumes at periodic intervals. Unfortunately, this system suffered from low point-source densities in the field, ostensibly because each MSTRS™ device was expensive, so relatively few per-acre could be installed. The third dispensing system tested was a sprayable pheromone formulation by 3M Products (St. Paul, MN). This material was

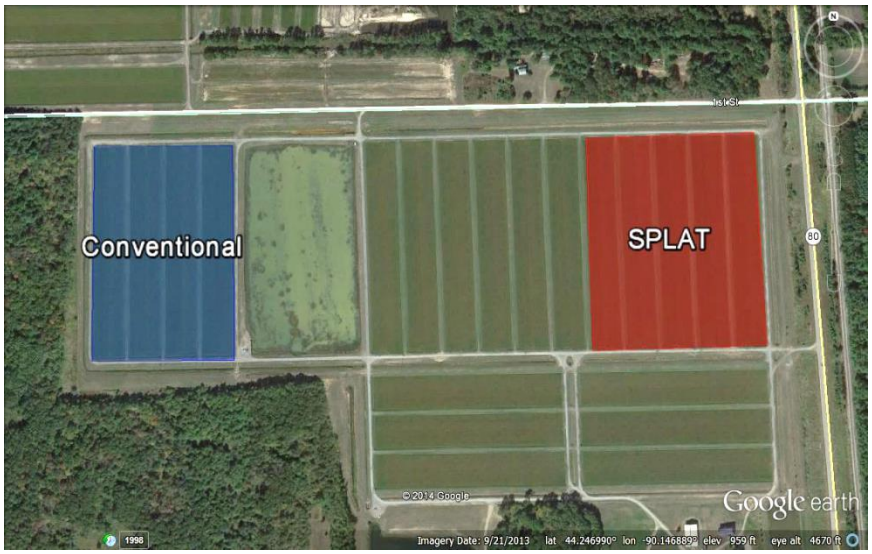
*Black-headed fireworm*

sprayed over plant surfaces, obviously achieving countless point-sources in the field; however, the trade-off in this case was that the material was spread so thin that the pheromone volatilized too quickly. Of course, the most noteworthy aspect of past MD research is that in each instance, fireworm mating was effectively disrupted to some degree. This suggests MD has a place in cranberries, but the pheromone dispensing system needs to meet high standards for efficacy and commercial feasibility.

*SPLAT® point-source, adhered to cranberry runners*

The struggle to find an appropriate dispenser for pheromones in cranberries appears to explemplify the "Goldilocks effect" (an exceedingly narrow range of acceptable trade-offs). SPLAT® should allow us to resolve the issue, striking a cost-effective balance between longevity and point-source density. In a variety of systems (e.g., vineyards, pome and stone fruit orchards, blueberries, forest systems), SPLAT® has effectively "shut down" pheromone-baited traps, meaning that male moths could not find the traps in SPLAT®-treated zones (see Fig. 5 above; gypsy moth program, Onufrieva *et al.* 2010).

Our primary goals in the current MD research program have been to demonstrate that a pheromone-based mating disruption program can reliably shut down mating and thereby reduce populations of the major insect pests of Wisconsin cranberries. In 2012, 2013, and 2014, we engineered a pheromone delivery system that allowed us to test the efficacy of SPLAT® in Wisconsin cranberries. To create the 2-species blend, SPLAT® formulations were



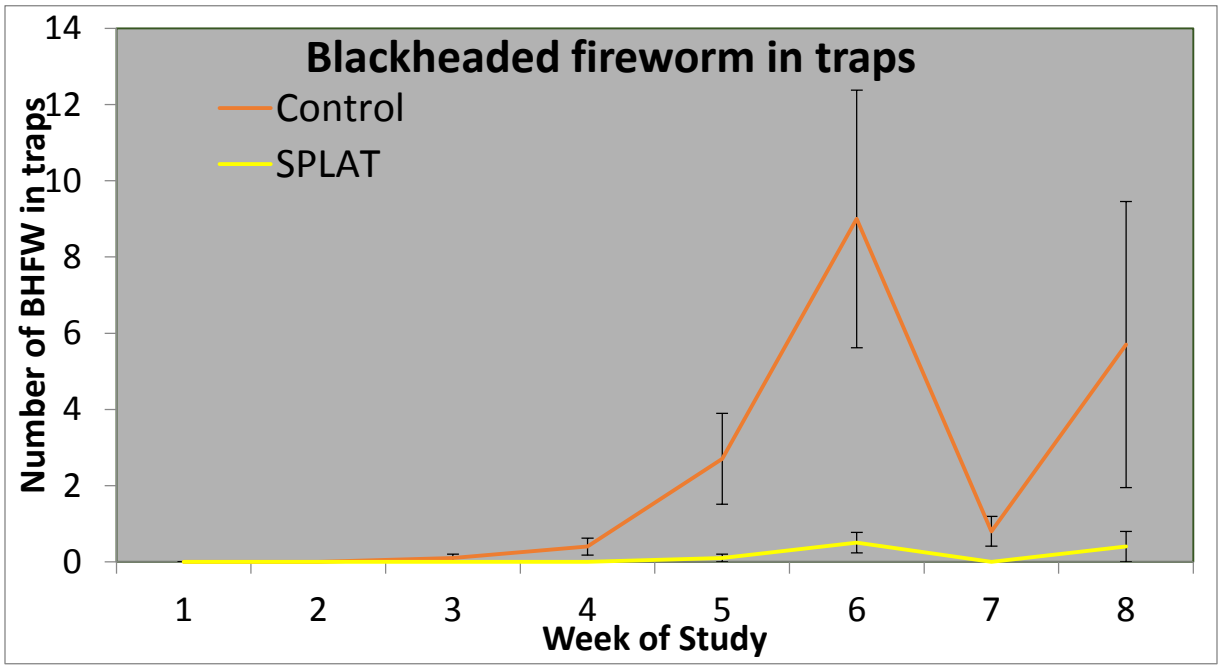

*Field layout (~9 acre block of MD) at a marsh.*

loaded with the pheromones of each pest species, then blended in the field prior to application. The pheromones of cranberry fruitworm, *Acrobasis vaccinii*, are *E*8,*Z*10-15:Ac and *(E)*-9-pentadecen-1-ol acetate, mixed at a 100:4 ratio (McDonough *et al.* 1994). This pheromone was applied at a rate corresponding to 15g/ha. The pheromone of the black-headed fireworm, *Rhopobota naevena*, is (*Z*)-11-tetradecen-1-ol acetate was applied at 116g/ha, based on past efficacy work (Fitzpatrick *et al.* 1997).

Over these last three years, we have accomplished the following: 1) created a multi-species blend using SPLAT® as the carrier, 2) determine the longevity of SPLAT® point-sources as a function of size and shape, 3) established ideal point-source spatial distributions and densities in the field, 4) deployed SPLAT® at field rates over large acreage, and 5) achieved control of cranberry fruitworm and black-headed fireworm populations.

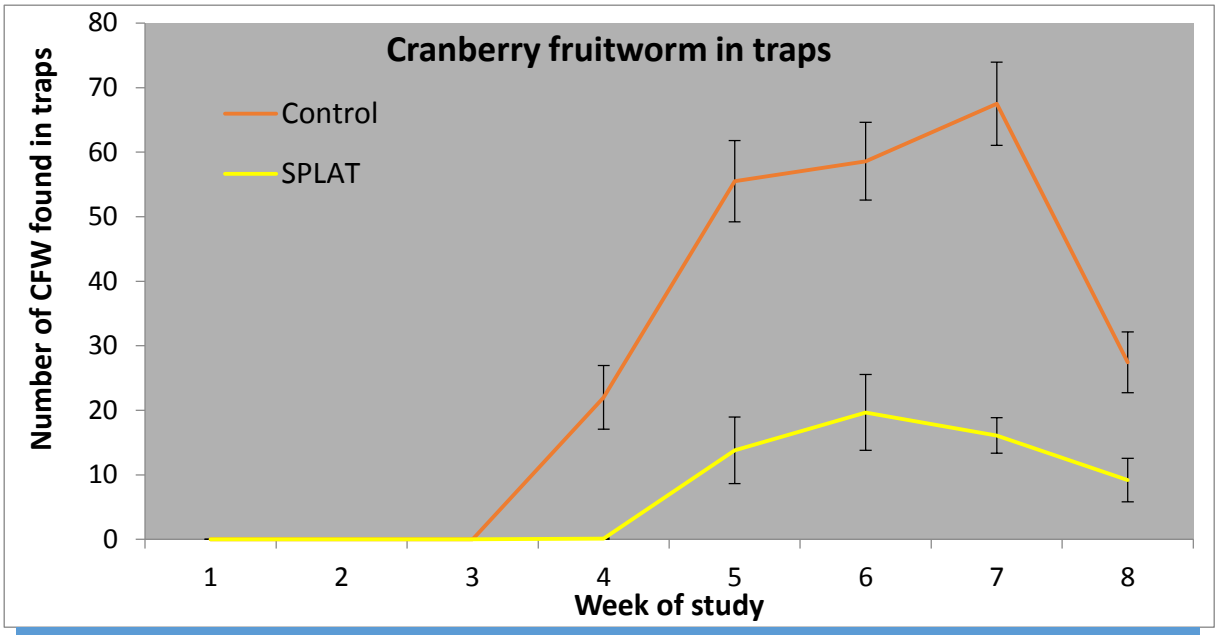
In 2014, SPLAT® was applied at a rate of 1,000 point-sources per acre. A total of 50 acres was treated across 5 marshes (8-10 acre blocks at each marsh). A control block (conventional spraying regimen) was also monitored on-site. Our data showed that there was significantly less trap-catch for black-headed fireworm ($F = 12.19$, $P < 0.001$) and cranberry fruitworm ($F = 81.59$, $P < 0.001$). In fact, there was a 95% reduction of trap-catch for fireworm. This suggests that moth mating was substantially reduced in the MD blocks. For cranberry fruitworm, there was a 75% reduction, which is good evidence of mating disruption, but clearly there is room for improvement.

Importantly, the number of infested berries in SPLAT-treated blocks was 52% reduced, a significant reduction ($F = 5.83$, $P = 0.029$) and again evidence that fruitworm mating and reproduction was substantially reduced.



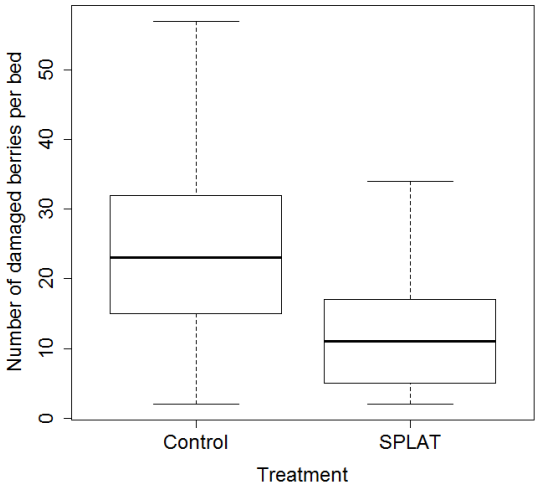

*BHFW trap-catch in treated and untreated blocks, 2014.*

Altogether, this is evidence that MD can provide effective pest control for two of the major insect pests attacking Wisconsin cranberries. When used as a complement or replacement for insecticides, MD represents a sustainable, durable IPM tactic. Mating disruption programs will contribute toward the goal of reducing insecticide residues in US cranberries, which should help to facilitate access to international markets.




*CFW trap-catch in treated and untreated blocks, 2014.*

Future work will involve increasing pheromone loads in SPLAT, and increasing the acreage treated. MD works best when applied over large areas, so it is important to scale up the deployment of SPLAT. The 2015 growing season will be focusing on mechanized SPLAT deployment and larger acreages.




*52% reduction of infested berries in SPLAT-treated blocks.*

# 2014 CRANBERRY PEST MANAGEMENT FIELD RESEARCH REPORT

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The spring 2014 weather was somewhat atypical. April weather was rather normal - warming temperatures and ample, periodic rains. However May was cooler than normal and with more rain than average. The remainder of the growing season was as expected although the summer overall was cool – there were only two days in which the daily high temperature exceeded 90 F. As a result of these growing conditions and diligent pest control efforts by growers, testable infestations of insects and diseases were sometimes difficult to source.

## Fungicide Trials:

The 2014 fungicide trial objectives were to:

1) Evaluate registered fungicides for early rot, fruit rot and cottonball management; and,
2) Evaluate eight candidate products for early rot, fruit rot and cottonball control.

Evaluated products included Bravo, Evito, Dithane, Indar, Abound, Proline, Tavano, Regalia, Orbit/Tilt and eight experimental fungicides.

Seven fungicide trials were conducted – three for cottonball disease, two for fruit rot and two for early rot. Twelve products, thirteen treatments and two applications/treatment was the standard testing format. Application schedules were: (two applications/schedule) - early rot - 50% bloom + 10 days; fruit rot - late bloom /early fruit set + 10 days; cottonball - 10% and 50% bloom.

Two of the cottonball trials had testable disease pressure, one of the trials had good fruit rot pressure and one of the early rot trials had testable disease pressure. Early rot is a disease primarily in one to four year old new plantings. Since there have been relatively few new plantings of early rot susceptible varieties in Wisconsin in recent years this disease complex has become less prevalent. Most growers typically apply one or two fungicide maintenance applications - this diligence on their part combined with less-than-conducive weather conditions have resulted in fewer disease testing opportunities.

Two recently registered bio-fungicides, Tavano (Certis) and Regalia (Marrone), and the conventional fungicide Proline (Bayer) were the targeted products. Standard commercial fungicides were included for comparison.

For cottonball control Tilt/Orbit, Indar, Indar + Abound, Evito, Proline and two of the candidate fungicides were highly efficacious. Tavano, Regalia and one of the candidate fungicides did not provide acceptable cottonball control.
For fruit rot control, Indar + Abound and Proline provided stellar disease control.
Bravo, Dithane, Abound and Evito provided acceptable control. Tavano and Regalia were ineffective.

**Table 1** Fungicide effectiveness (in 2014 and in a historical perspective)

| | Rate/acre | Early Rot | Fruit Rot | Cottonball |
|---|---|---|---|---|
| **Bravo WeatherStik 6SC** | 6.6 pt | ++ | ++ | -- |
| **Dithane 75DF** | 6 lb | + | ++ | -- |
| **Abound 2.08SC** | 15.5 oz | ++ | ++ | ++ |
| **Indar 2F** | 12 oz | +++ | + | +++ |
| **Abound + Indar** | 15.5 + 12 | +++ | +++ | +++ |
| **Abound + Indar** | 8 + 6 | +++ | +++ | +++ |
| **Proline 4SC** | 5.7 oz | +++ | +++ | +++ |
| **Evito 4SC** | 5.7 oz | ++ | ++ | ++ |
| **Tavano 5%SC** | 6.5 oz | ??? | ++ | + |
| **Regalia 5%EC** | 32 oz | + | + | + |
| **Tilt/Orbit 3.6EC** | 6 oz | -- | -- | +++ |

Performance rating scale - "--" inadequate control, "+" - 70 – 79% control, "++" - 80 – 89% control, "+++" – 90%+ control

For 2015, the objectives are threefold – 1) continue to monitor disease control performances of registered products, 2) continue to investigate candidate products and 3) investigate the potential for using less fungicides – reduced rates and reduced schedules. With these results we should be able to develop disease control programs that are not reliant on Bravo (potential to be banned by European Union) and that decrease the risk of fungicide resistance.

**Insecticide Trials:**

The objectives of the 2014 insecticide trials were to:

1) Evaluate registered insecticides on our main insect pests
2) Evaluate three candidate insecticides on our main insect pests
3) Evaluate foliar vs. soil applications of insecticides against flea beetle

Fifteen insecticide trials were conducted targeting seven insect pests: tipworm, cranberry fruitworm, sparganothis fruitworm, span worm, blackheaded fireworm, flea beetle, and leaf

hopper. Sixteen products, twenty treatments and one to two (pest dependent) applications/treatment was the standard testing format. All of the trials had testable insect pressures.

Two recently registered bio-insecticides, Grandevo and Venerate (Marrone), and two recently registered conventional products, Closer and Venom, were the targeted products. Standard commercial insecticides were included for comparison.

Altacor was highly effective for the control of all tested insect pests. Belay, Assail, Imidan and diazinon were also effective across-the-board. Most of the worm-specific products, Intrepid, Delegate and Confirm, were efficacious for the control of fruitworms, blackheaded fireworms and loopers. Neither Venerate, Grandevo, Closer nor Venom provided commercially acceptable insect control. Two of the three candidate insecticides demonstrated good control efficacy on all pest insects.

**Table 2.** Effectiveness of foliar-applied insecticides (in 2014 and in a historical perspective)

| | Rate /acre | Tip worm | Fruit worm | Sparg fw | Span worm | Fire worm | Flea beetle | Leaf hopper |
|---|---|---|---|---|---|---|---|---|
| **Grandevo 30G** | 3 lb | -- | ++ | ++ | ++ | + | -- | -- |
| **Venerate 94L** | 8 qt | -- | ++ | ++ | ++ | + | -- | -- |
| **Venom 70SG** | 4 oz | -- | + | + | + | + | +++ | ++ |
| **Closer 2.2SC** | 5.7 oz | -- | -- | -- | -- | -- | + | -- |
| **Altacor 35WG** | 4.5 oz | ++ | +++ | +++ | ++ | +++ | +++ | +++ |
| **Assail 30SG** | 6.9 oz | + | +++ | ++ | +++ | ++ | +++ | + |
| **Belay 2.1SC** | 4 oz | ++ | +++ | ++ | +++ | ++ | +++ | + |
| **Delegate 25WG** | 6 oz | -- | +++ | +++ | +++ | ++ | + | -- |
| **Diazinon 4EC** | 3 qt | + | ++ | + | ++ | ++ | +++ | ++ |
| **Imidan 70WP** | 4 lb | + | ++ | + | ++ | ++ | +++ | ++ |
| **Intrepid 2F** | 16 oz | -- | +++ | ++ | +++ | + | -- | -- |
| **Confirm 2F** | 16 oz | -- | +++ | ++ | +++ | + | -- | -- |
| **Knack 0.86EC** | 16 oz | -- | ++ | + | + | -- | -- | -- |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Lorsban 4E** | 3 pt | **++** | **++** | **++** | **++** | **++** | **++** | **++** |
| **Rimon 0.83EC** | 12 oz | **--** | **++** | **++** | **++** | **++** | **+** | **--** |

Performance rating scale - "--" inadequate control, "+" - 70 – 79% control, "++" - 80 – 89% control, "+++" – 90%+ control

Flea beetles are a recent pest control challenge that has received considerable concern from growers and crop consultants. Although flea beetles rarely cause economic losses they are easily controlled with a number of registered foliar-applied insecticides (Table 3). A project was conducted to investigate the potential for watered-in soil incorporation of insecticides for the control of the soil phase (larvae) flea beetles. Neither pre-bloom soil applications of labeled rates of Altacor, Belay and Assail nor post-bloom soil applications of Altacor or Assail were adequately effective for the later-season flea beetle adult control (table 4). Although a post-bloom soil application of an accelerated, high rate (12 oz/a) of Belay did provide excellent control, this treatment is likely cost prohibitive. As previously observed, foliar applications of all three products effectively controlled flea beet adults in this trial (Table 4).

**Table 3.** Foliar-applied insecticides for flea beetle adult control (in 2014 and a historical perspective)

| **Product** | **Rate/acre** | **Flea Beetle** |
|---|---|---|
| **Actara 25WDG** | 4 oz | **+++** |
| **Assail 30SG** | 4 oz | **+++** |
| **Belay 2.1SC** | 4 oz | **+++** |
| **Lorsban 4E** | 1.5 pt | **++** |
| **Diazinon 4EC** | 1 qt | **+++** |
| **Imidan 70WP** | 1 lb | **+++** |
| **Altacor 35WG** | 3 oz | **+++** |
| **Orthene 97 or Sevin 4E** | 0.7 lb/ 2 pt | **++** |
| **Confirm 2F** | 16 oz | **--** |
| **Delegate 25WG** | 6 oz | **++** |
| **Intrepid 2F** | 16 oz | **--** |
| **Rimon 0.83EC** | 12 oz | **+** |

Performance rating scale - "--" inadequate control, "+" - 70 – 79% control, "++" - 80 – 89% control, "+++" – 90%+ control

**Table 4.** Flea beetle control - soil vs foliar applications - 2014

| Treatment | % Control |
|---|---|
| **Altacor 4.5 oz Pre Bloom Soil** | 9 |
| **Altacor 4.5 oz Post Bloom Soil** | 10 |
| **Altacor 4.5 oz Foliar** | 94 |
| **Belay 12 oz Pre Bloom Soil** | 7 |
| **Belay 12 oz Post Bloom Soil** | 88 |
| **Belay 4 oz Foliar** | 92 |
| **Assail 5.3 oz Pre Bloom Soil** | 18 |
| **Assail 5.3 oz Post Bloom Soil** | 68 |
| **Assail 5.3 oz Foliar** | 89 |

For 2015 the objectives are threefold – 1) continue to monitor the insect control performances of registered products, 2) continue to investigate candidate products and 3) investigate the potential for flea beetle control.

**Herbicide Trials:**

Wisconsin cranberry marshes are becoming more and more weed free. There are still some areas with weed problems but the opportunities to find sites with weed infestations in large enough patches for trials are getting difficult to find due to the effectiveness of registered tools. The objectives of the 2014 herbicide testing program were fourfold: 1) Target weeds that are escaping our current herbicide arsenal. Of primary interest are maples, leatherleaf, northern St Johnswort and dewberry. 2) Evaluate two new replacement Devrinol products. 3) Continue to evaluate and display the benefits of using alternative herbicide types to prevent the development of weed resistance. 4) Evaluate candidate herbicides for potential uses in cranberries. Twelve herbicide trials were conducted in 2014.

After years of failed attempts we may have found a solution to controlling maples and leatherleaf. Glyphosate products applied via wick wipers control maples but the kill-time is slow. Glyphosate has not been effective in the control of leatherleaf. Combinations of glyphosate with other products, labeled and not labeled for uses in cranberries, have not been particularly encouraging. In 2014 two trials were conducted using glyphosate plus companion

products and/or experimental surfactant systems (see specific glyphosate product labels and notes below for surfactant instructions). The results of combining glyphosate with these experimental tools showed great promise for the control of maples and leatherleaf.
Effective control of northern St Johnswort and dewberry continue to be elusive. Both weeds were controlled with the glyphosate plus the experimental surfactant. However because of the low growing stature of these weeds it is difficult to apply to the weeds and avoid contact with the cranberries.
UPI has introduced two new Devrinol formulations, 50-XT and 2-XT, into the cranberry herbicide market. The benefit of these products is that they extend the time required for incorporation by lessening the risk of ultraviolet degradation. Four trials were conducted in 2014 to determine if these new formulations provided weed control comparable to those of the existing formulations. The weed control efficacy from the new formulations was similar to that of the old formulations and no other differences in performance were noted.
There are few new candidate herbicides that have not already been field-tested. Five candidates were evaluated in 2014. All of these were either not effective for the control of weeds common in Wisconsin cranberries or were phytotoxic to cranberries.

**Wiping weeds in cranberries: what's allowable in Wisconsin?**

The persistence of those pesky maples and other tall weeds in Wisconsin cranberries has spurred a number of questions about wiping weeds. Unfortunately, the herbicide labels can be quite confusing and differ among trade names when it comes to specialized application techniques like wiping.

Here are a couple of general aspects that need to be considered prior to loading the wiper:

1) **Not all glyphosate product labels include cranberries or wiper applications, so read carefully!**

2) **Glyphosate labels for the many products available differ greatly in whether a surfactant is allowed or not in wiper applications**. Many (but not all) say: "Do not add surfactant to the herbicide solution when using a wiper applicator". This varies by product, often based on the surfactant system that is already with the herbicide in the container. Again, please read the label carefully!

The research that we've described at field days and at Cranberry School is designed to collect data that supports expanding herbicide and surfactant wiper weed control options in the future. The early results of this work are encouraging and we will further expand our efforts in the 2015 growing season. In the meantime, please be sure to follow the current labels.

**Future for Cranberry Pesticides:**

In registration processes are 3 new insecticides, 2 new herbicides and 5 new fungicides.

**Threats to Our Pesticide Arsenal:**

Several products in our cranberry pesticide arsenal are being threatened with registration and environmental issues (Table 5).

**Table 5 Pesticides at risk**

| Product | Threats |
|---|---|
| **Bravo** | Export residues |
| **Evito** | Export residues |
| **Proline** | Export residues |
| **QuinStar** | Export residues |
| **Belay** | Threat to bees |
| **Assail** | Threat to bees |
| **OP Insecticides** | Threat to the environment |

**New Cranberry Products (Non-Pesticides):**

**LPE Fruit Quality Enhancer:**

Six growth regulator trials were conducted in 2014 and six in 2013 to evaluate two LPE (lysophosphatidylethanolamine) products for their potential to influence cranberry fruit ripening and the enhancement of fruit quality - anthocyanin and sugar content. The benefits derived from multiple tested use patterns (rates, schedules) of LPE were minimal. At a projected price of $150-$200 per acre the potential for these products is dubious.

**APSA-80**

A multi- purpose product from Amway that can be used as a pesticide surfactant and as a soil amendment that improves soil/water properties – soil applied for improved water infiltration and soil compaction relief.

# 2015 CRANBERRY SCHOOL GROWER SURVEY RESULTS

CHRISTELLE GUÉDOT, MATT LIPPERT, and PATRICIA McMANUS

Once again, here are the results of the live survey of growers present in the room at the 2014 Cranberry School. The survey was conducted using Turning Point 5 (Turning Technologies, LLC) software and clicker hardware. Growers were provided with clickers to allow for live anonymous responses to be collected. Questions were displayed on screens and respondents were allowed to select answers. After all responses were collected, the polling was closed, and the results of the survey were displayed on the screens. The "count" column indicates the number of growers that responded and the "percent" column indicates the % of respondents. Thank you for participating!

**1) Was your crop up in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes, my crop was up from 2013 | 25% | 17 |
| No, my crop was down from 2013 | 75% | 50 |
| **Totals** | 100% | 67 |

**2) If your crop was less than expected in 2014, what was the main reason?**

| | Responses | |
|---|---|---|
| | percent | count |
| In season weather | 28% | 15 |
| Winter damage | 9% | 5 |
| Vine stress/ big crop | 19% | 10 |
| Vine stress/ harvest tracks | 0% | 0 |
| Reduced inputs | 7% | 4 |
| Pest pressure | 0% | 0 |
| More than one of the above | 37% | 20 |
| **Totals** | 100% | 54 |

**3) What weather factor was the most negative for the 2014 crop?**

| | Responses | |
|---|---|---|
| | percent | count |
| Long harsh winter | 13% | 8 |
| Cool late spring | 6% | 4 |
| Cool summer | 22% | 14 |
| More than one of the above | 38% | 24 |
| None of the above | 21% | 13 |
| **Totals** | 100% | 63 |

**4) What kind of winter damage did you experience on your marsh?**

| | Responses | |
|---|---|---|
| | percent | count |
| Leaf drop on edges due to snow drifts | 65% | 17 |
| Leaf drop on entire bed due to extreme snow | 4% | 1 |
| Didn't flood soon enough | 0% | 0 |
| Wind burn | 12% | 3 |
| More than one of the above | 19% | 5 |
| **Totals** | 100% | 26 |

**5) In 2014 we reduced these inputs:**

| | Responses | |
|---|---|---|
| | percent | count |
| We didn't | 57% | 35 |
| Bee hives | 3% | 2 |
| Labor | 11% | 7 |
| Fertilizer | 5% | 3 |
| Herbicide | 2% | 1 |
| Insecticide | 2% | 1 |
| Fungicide | 3% | 2 |
| More than one of the above | 16% | 10 |
| **Totals** | 100% | 61 |

**6) What was the main yield reducing pest for the 2014 vs. the 2013 crop?**

| | Responses | |
|---|---|---|
| | percent | count |
| Insects | 31% | 16 |
| Disease/ Rot | 29% | 15 |
| Weeds | 27% | 14 |
| More than one of the above | 12% | 6 |
| **Totals** | 100% | 51 |

**7) What was the main positive influence of the 2014 year vs. 2013?**

| | Responses | |
|---|---|---|
| | percent | count |
| Vines rebounded from low yield in 2013 | 8% | 4 |
| Favorable in-season weather | 20% | 10 |
| Newer marsh is maturing | 25% | 13 |
| Better harvest equipment | 16% | 8 |
| It's me- I did it! | 31% | 16 |
| **Totals** | 100% | 51 |

**8) To what percentage of your cranberry acres do you apply fungicides?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0% | 23% | 15 |
| 1-25% | 20% | 13 |
| 26-50% | 3% | 2 |
| 51-75% | 5% | 3 |

| | | | |
|---|---|---|---|
| More than 75% | | 48% | 31 |
| | **Totals** | 100% | 64 |

**9) Do you use fungicides to control fruit rot?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes, every year | 43% | 28 |
| In some years | 28% | 18 |
| No | 29% | 19 |
| **Totals** | 100% | 65 |

**10) Do you use fungicides to control cottonball?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes, every year | 14% | 9 |
| In some years | 6% | 4 |
| No | 80% | 52 |
| **Totals** | 100% | 65 |

**11) Do you feel that your weed pressure impacts cranberry yield?**

| | Responses | |
|---|---|---|
| | percent | count |
| No impact | 14% | 9 |
| Yes, but by less than 10% | 80% | 51 |
| 11-25% | 3% | 2 |
| > 25% | 3% | 2 |
| **Totals** | 100% | 64 |

**12) In 2014, did you:**

| | Responses | |
|---|---|---|
| | percent | count |
| Use pre-emergent herbicides only | 1% | 1 |
| Use post-emergent herbicides only | 1% | 1 |
| Use both pre- and post-emergent herbicides | 96% | 64 |
| No herbicides used | 1% | 1 |
| **Totals** | 100% | 67 |

**13) Which is your worst weed enemy?**

| | Responses | |
|---|---|---|
| | percent | count |
| Northern St. Johnswort | 18% | 12 |
| Dewberry | 24% | 16 |
| Trees- (maples, willows, etc.) | 34% | 23 |
| Perennial grasses | 18% | 12 |
| How dare you ask – I don't have weeds! | 6% | 4 |
| **Totals** | 100% | 67 |

**14) How many days should cranberry school be?**

| | Responses | |
|---|---|---|
| | percent | count |
| 2 days | 51% | 35 |
| 1 day | 42% | 29 |
| Something else | 7% | 5 |
| **Totals** | 100% | 69 |

**15) How many bumblebee colonies per acre did you bring in during 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0 | 59% | 39 |
| 1-2 | 18% | 12 |
| 3-5 | 18% | 12 |
| 6-8 | 2% | 1 |
| >8 | 3% | 2 |
| **Totals** | 100% | 66 |

**16) How many honeybee hives per acre did you bring in during 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0 | 3% | 2 |
| 1-2 | 44% | 28 |
| 3 | 23% | 15 |
| 4-7 | 20% | 13 |
| 8 or more | 9% | 6 |
| **Totals** | 100% | 64 |

**17) In 2014, did you bring in: ***

| | Responses | |
|---|---|---|
| | percent | count |
| More beeboxes/acre (honeybees or bumblebees) than in 2013? | 51% | 19 |
| Fewer bee boxes/ acre (honeybees or bumblebees) than in 2013? | 49% | 18 |
| **Totals** | 100% | 37 |

*Unfortunately, "same as 2013" was omitted from the answer list...

**18) Thinking ahead 10-20 years, would you consider diversifying into other crops to be more resilient when cranberry prices are low?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 38% | 24 |
| No | 63% | 40 |
| **Totals** | 100% | 64 |

**19) If you were to diversify, which crops?**

| | Responses | |
|---|---|---|
| | percent | count |
| Blueberries or other adapted small fruit | 10% | 6 |
| Vegetables | 0% | 0 |
| Cash grains, corn-soy | 11% | 7 |
| Specialty crops such as hops, hazelnuts, mint, ginseng Christmas trees | 14% | 9 |
| None of the above | 29% | 18 |
| Not sure | 37% | 23 |
| **Totals** | 100% | 63 |

**20) Do you own a drone?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 7% | 5 |
| No | 90% | 62 |
| What the heck is a drone? | 3% | 2 |
| **Totals** | 100% | 69 |

**21) What outcomes have you noticed from soil moisture monitoring?**

| | Responses | |
|---|---|---|
| | percent | count |
| Higher yields | 39% | 21 |
| Lower yields | 0% | 0 |
| Drought/damage | 9% | 5 |
| Excessive growth | 0% | 0 |
| Nothing really | 52% | 28 |
| **Totals** | 100% | 54 |

**22) What is your top insect pest?**

| | Responses | |
|---|---|---|
| | percent | count |
| Black headed fireworm | 1% | 1 |
| Cranberry fruitworm | 44% | 30 |
| Sparganothis fruitworm | 31% | 21 |
| Tipworm | 4% | 3 |
| Flea beetle | 16% | 11 |
| Other | 3% | 2 |
| **Totals** | 100% | 68 |

**23) How many insecticide sprays did you apply during the 2014 growing season?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0-1 | 6% | 4 |
| 2-3 | 62% | 40 |
| 4-5 | 29% | 19 |
| 5-6 | 3% | 2 |
| >6 | 0% | 0 |
| **Totals** | 100% | 65 |

**24) Was your number of insecticide sprays in 2014…?**

| | Responses | |
|---|---|---|
| | percent | count |
| Up from 2013 | 12% | 8 |
| Down from 2013 | 19% | 13 |
| The same as 2013 | 69% | 47 |
| **Totals** | 100% | 68 |

**25) Per acre, how much do you spend each year on insecticides?**

| | Responses | |
|---|---|---|
| | percent | count |
| $0-40 | 4% | 2 |
| $41-80 | 24% | 13 |
| $81-120 | 28% | 15 |
| $121-160 | 33% | 18 |
| $160-200 | 11% | 6 |
| **Totals** | 100% | 54 |

**26) How many pesticide (insecticide, fungicide, herbicide) did you apply during bloom in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0 | 14% | 9 |
| 1-2 | 72% | 46 |
| 3-4 | 11% | 7 |
| > 4 | 3% | 2 |
| **Totals** | 100% | 64 |

**27) Which type of pesticides did you spray during bloom in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| Fungicides | 14% | 9 |
| Herbicides | 0% | 0 |
| Insecticides | 38% | 24 |
| More than one of the above | 37% | 23 |
| None of the above applied during bloom | 11% | 7 |
| **Totals** | 100% | 63 |

**28) How many fungicide applications were made during bloom in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0 | 48% | 32 |
| 1 | 34% | 23 |
| 2 | 13% | 9 |
| > 2 | 4% | 3 |
| **Totals** | 100% | 67 |

**29) Which fungicides did you apply during bloom in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| Abound | 19% | 13 |
| Bravo (Echo, Equus, Daconil) | 4% | 3 |
| Indar | 6% | 4 |
| Dithane (Penncozeb, Manzate) | 1% | 1 |
| Copper (Kocide…,) | 0% | 0 |
| Orbit/Tilt/ Propimax | 1% | 1 |
| > than one of these | 19% | 13 |
| No fungicide during bloom | 49% | 33 |
| **Totals** | 100% | 68 |

**30) How many insecticide applications were made during bloom in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0 | 29% | 19 |
| 1 | 54% | 35 |
| 2 | 17% | 11 |
| > 2 | 0% | 0 |
| **Totals** | 100% | 65 |

**31) Which insecticides did you apply during bloom in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| Altacor | 33% | 21 |
| Neonicotinoid (Assail, Belay, Admire, Actara,...) | 2% | 1 |
| Organophosphate (Lorsban, Diazinon, Imidan, Orthene,...) | 5% | 3 |
| Carbamate (Sevin,...) | 0% | 0 |
| Spinosyn (Delegate, Entrust,...) | 3% | 2 |
| Insect growth regulator (Intrepid, Confirm, Rimon,...) | 27% | 17 |
| Organic Insecticide (Grandevo, Dipel, Venerate,...) | 0% | 0 |
| > 1 of above | 13% | 8 |
| None of above | 19% | 12 |
| **Totals** | 100% | 64 |

**32) Do you grow "newer" hybrid cranberry cultivars (e.g. UW-Madison, Rutgers, Valley Corp./Grygleski)?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 68% | 51 |
| No | 32% | 24 |
| **Totals** | 100% | 75 |

**33) How many acres of newer hybrid cultivars do you grow?**

| | Responses | |
|---|---|---|
| | percent | count |
| 0 | 21% | 14 |
| < 5 acres | 15% | 10 |
| 5-15 acres | 15% | 10 |
| > 15 acres | 50% | 34 |
| **Totals** | 100% | 68 |

**34) Do you grow cultivars from the UW-Madison program?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 44% | 31 |
| No | 56% | 40 |
| **Totals** | 100% | 71 |

**35) Do you grow cultivars from the Valley Corporation/Grygleski program?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 53% | 37 |
| No | 47% | 33 |
| **Totals** | 100% | 70 |

**36) Do you grow cultivars from the Rutgers program?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 51% | 37 |
| No | 49% | 35 |
| **Totals** | 100% | 72 |

**37) What is the main advantage of newer cultivars over older cultivars?**

| | Responses | |
|---|---|---|
| | percent | count |
| Establish and come into bearing sooner | 5% | 3 |
| Higher yields | 70% | 46 |
| More consistent and predictable performance from one year to the next | 15% | 10 |
| Other | 11% | 7 |
| **Totals** | 100% | 66 |

**38) What is the main disadvantage of growing newer cultivars?**

| | Responses | |
|---|---|---|
| | percent | count |
| Higher cost of plugs/vines | 47% | 32 |
| Seem to be more susceptible to diseases | 34% | 23 |
| Restrictions/rules regarding propagating and sale | 15% | 10 |
| Other | 4% | 3 |
| **Totals** | 100% | 68 |

**39) Cultivar genetic (DNA) purity in cranberries is:**

| | Responses | |
|---|---|---|
| | percent | count |
| Important | 70% | 56 |
| Not important | 8% | 6 |
| Not sure | 23% | 18 |
| **Totals** | 100% | 80 |

**40) Have you tested vines for genetic purity?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 37% | 29 |
| No | 63% | 49 |
| **Totals** | 100% | 78 |

**41) If you have tested vines for purity has it influenced your management decisions (e.g. bed renovation plans)?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 46% | 17 |
| No | 54% | 20 |
| **Totals** | 100% | 37 |

**42) The trait most important in new cultivars is:**

| | Responses | |
|---|---|---|
| | percent | count |
| High/consistent yield | 61% | 45 |
| Insect & disease resistance | 11% | 8 |
| Herbicide resistance | 0% | 0 |
| Post-harvest storage quality | 14% | 10 |
| Nutritional content | 1% | 1 |
| Taste/sensory factors | 7% | 5 |
| Cold Tolerance | 3% | 2 |
| Other | 4% | 3 |
| **Totals** | 100% | 74 |

**43) Did you use the new fungicide Proline (prothioconazole) in 2014?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 10% | 8 |
| No | 90% | 75 |
| **Totals** | 100% | 83 |

**44) Losing chlorothalonil (Bravo, Daconil, Echo, Equus) registration would:**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Not matter to us because we don't use it | | 51% | 40 |
| Be difficult but manageable | | 39% | 31 |
| Be devastating/we rely heavily on chlorothalonil | | 10% | 8 |
| | **Totals** | 100% | 79 |

**45) Do you have adequate resources to answer all of your questions about growing cranberries and maintaining your marsh?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Yes | | 51% | 42 |
| No | | 49% | 40 |
| | **Totals** | 100% | 82 |

**46) Do you track growing degree days?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Yes | | 45% | 39 |
| No | | 55% | 47 |
| | **Totals** | 100% | 86 |

**47) If you track or would start tracking growing degree days, for what purpose would you do this?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Insect control | | 23% | 18 |
| Disease control | | 0% | 0 |
| Fertilizing | | 1% | 1 |
| More than one of the above | | 70% | 55 |
| Other | | 6% | 5 |
| | **Totals** | 100% | 79 |

**48) How many sprays were applied specifically for flea beetle?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0 | | 66% | 56 |
| 1 | | 15% | 13 |
| 2 | | 7% | 6 |
| 3 | | 8% | 7 |
| 4 or more | | 4% | 3 |
| | **Totals** | 100% | 85 |

**49) For flea beetle, were the sprays foliar or soil drench applications?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Foliar | | 97% | 33 |
| Soil drench | | 3% | 1 |
| | **Totals** | 100% | 34 |

**50) Where do flea beetles typically spend the winter?**

| | Responses | |
|---|---|---|
| | percent | count |
| Mostly in the dikes | 17% | 13 |
| Mostly in the beds *CORRECT ANSWER!* | 80% | 60 |
| Off-marsh sites | 3% | 2 |
| **Totals** | 100% | 75 |

**51) Have you observed scarred, distorted berries on your marsh that resemble virus injury?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 39% | 33 |
| No, not seen this and we have been looking | 47% | 40 |
| No, but we have not looked for it either | 14% | 12 |
| **Totals** | 100% | 85 |

**52) Have you had scarred berries/ uprights tested for viruses?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 34% | 28 |
| No | 42% | 35 |
| Have not seen scarred berries on our marsh | 24% | 20 |
| **Totals** | 100% | 83 |

**53) If you have had tissue tested for viruses, which were detected?**

| | Responses | |
|---|---|---|
| | percent | count |
| Tobacco Streak Virus | 34% | 11 |
| Blueberry Shock Virus | 13% | 4 |
| Blueberry Scorch Virus | 0% | 0 |
| More than one of these | 13% | 4 |
| Other | 16% | 5 |
| Don't remember | 25% | 8 |
| **Totals** | 100% | 32 |

**54) If you have had a virus confirmed, how concerned are you about its impact?**

| | Responses | |
|---|---|---|
| | percent | count |
| Not concerned at all | 15% | 6 |
| Somewhat concerned | 49% | 19 |
| Very concerned | 36% | 14 |
| **Totals** | 100% | 39 |

**55) Should the industry devote resources to understand virus impact on yield or vine health?**

| | Responses | |
|---|---|---|
| | percent | count |
| Yes | 92% | 77 |
| No | 8% | 7 |
| **Totals** | 100% | 84 |

**56) Are you in favor of a durable, effective pheromone-based mating disruption system for cranberries?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Yes | | 69% | 59 |
| No | | 12% | 10 |
| I don't know | | 20% | 17 |
| | **Totals** | 100% | 86 |

**57) What proportion of your insect control budget would you be willing to spend on a mating disruption system that reliably controlled cranberry fruitworm and black-headed firworm?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 20% | | 31% | 23 |
| 40% | | 38% | 28 |
| 80% | | 18% | 13 |
| None of the above | | 14% | 10 |
| | **Totals** | 100% | 74 |

**58) What % of your insect control budget would you be willing to spend on a mating disruption system that reliably controlled only cranberry fruitworm?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0% | | 8% | 6 |
| 20% | | 54% | 42 |
| 40% | | 23% | 18 |
| 80% | | 6% | 5 |
| None of the above | | 9% | 7 |
| | **Totals** | 100% | 78 |

**59) What % of your insect control budget would you be willing to spend on a mating disruption system that reliably controlled Sparganothis fruitworm?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0% | | 18% | 13 |
| 20% | | 51% | 37 |
| 40% | | 25% | 18 |
| 80% | | 3% | 2 |
| None of the above | | 4% | 3 |
| | **Totals** | 100% | 73 |

**60) Have the relatively new herbicides, such as Callisto and QuinStar, affected the amount of herbicide you use?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| I use less herbicide now than in the past | | 46% | 37 |
| I use more herbicide now than in the past | | 9% | 7 |
| I'm not sure or it depends on the year | | 45% | 36 |
| | **Totals** | 100% | 80 |

**61) What factors do you consider for the timing of your winter flood for making ice?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Weather forecast | | 34% | 30 |
| Presence of frost on the soil | | 0% | 0 |
| What other growers are doing | | 2% | 2 |
| 1 & 2 | | 34% | 30 |
| 1 & 3 | | 9% | 8 |
| 2 & 3 | | 3% | 3 |
| All of the above | | 18% | 16 |
| | **Totals** | 100% | 89 |

**62) Are you concerned with the harvest flood potentially affecting the hardiness of buds and leaves during fall?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Yes | | 45% | 39 |
| No | | 55% | 47 |
| | **Totals** | 100% | 86 |

**63) Do you feel well informed on the factors affecting cold hardiness of cranberry vines during fall/early winter?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Yes | | 52% | 43 |
| No | | 48% | 39 |
| | **Totals** | 100% | 82 |

**64) Do you feel well informed about changes in cranberry vine cold hardiness from ice-off to bud swell?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Yes | | 44% | 36 |
| No | | 56% | 45 |
| | **Totals** | 100% | 81 |

**65) If you flood in early spring after the ice is off, what is the main purpose of this flood?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Frost protection | | 23% | 19 |
| Pull frost out | | 22% | 18 |
| Trash removal | | 36% | 30 |
| Insect control | | 11% | 9 |
| Disease control | | 1% | 1 |
| I don't spring flood | | 7% | 6 |
| | **Totals** | 100% | 83 |

**66) With which of the following herbicides should a surfactant be used?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Callisto | | 36% | 29 |
| Casoron | | 1% | 1 |
| Quinstar | | 7% | 6 |
| 1 & 3 | | 52% | 42 |
| All of the above | | 4% | 3 |
| | **Totals** | 100% | 81 |

**67) In 2014, how many sprays did you apply specifically for cranberry fruitworm? (multiple choice)**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0 | | 9% | 8 |
| 1 | | 33% | 28 |
| 2 | | 47% | 40 |
| 3 | | 9% | 8 |
| 4 or more | | 1% | 1 |
| | **Totals** | 100% | 85 |

**68) In 2014, how many sprays were specifically for sparganothis fruitworm?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0 | | 29% | 24 |
| 1 | | 41% | 34 |
| 2 | | 22% | 18 |
| 3 | | 6% | 5 |
| 4 or more | | 1% | 1 |
| | **Totals** | 100% | 82 |

**69) In 2014 how many sprays were specifically for blackheaded fireworm?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0 | | 53% | 42 |
| 1 | | 44% | 35 |
| 2 | | 1% | 1 |
| 3 | | 1% | 1 |
| 4 or more | | 1% | 1 |
| | **Totals** | 100% | 80 |

**70) In 2014, how many sprays were specifically for tipworm?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| 0 | | 76% | 61 |
| 1 | | 20% | 16 |
| 2 | | 3% | 2 |
| 3 | | 0% | 0 |
| 4 or more | | 1% | 1 |
| | **Totals** | 100% | 80 |

**71) Which of the following are neonicotinoids?***

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Altacor, Knack, Intrepid | | 37% | 26 |
| Intrepid, Rimon, Confirm | | 26% | 18 |
| Imidan, Lorsban, Diazinon | | 26% | 18 |
| Assail, Belay, Closer, Venom **MISSING CORRECT ANSWER!** | | | |
| All of the above | | 11% | 8 |
| | **Totals** | 100% | 70 |

*Unfortunately, the correct answer had been removed from the list...Our apologies!

**72) Which of the following are insect growth regulators?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Altacor, Delegate, Sevin | | 14% | 9 |
| Intrepid, Rimon, Confirm *CORRECT ANSWER!* | | 79% | 50 |
| Imadan, Lorsban, Diazinon | | 3% | 2 |
| All of the above | | 3% | 2 |
| | **Totals** | 100% | 63 |

**73) Which of the following are organophosphates?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Altacor, Delegate, Sevin | | 12% | 9 |
| Intrepid, Rimon, Confirm | | 0% | 0 |
| Imidan, Lorsban, Diazinon *CORRECT ANSWER!* | | 88% | 65 |
| All of the above | | 0% | 0 |
| | **Totals** | 100% | 74 |

**74) When considering surfactants with your pesticides:**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| I use the same one every year if possible | | 40% | 29 |
| I use whatever the dealer delivers with the pesticide | | 34% | 25 |
| I'm not that concerned about which surfactant brand I use | | 26% | 19 |
| | **Totals** | 100% | 73 |

**75) The evaluations from the 2014 cranberry school asked if the audience could be polled for research topics, so here's your chance! In what <u>one area</u> do you most want to see more research?**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Fertilizer/nutrition/ timing | | 39% | 35 |
| Insect management | | 12% | 11 |
| Disease management | | 12% | 11 |
| Weed management | | 12% | 11 |
| Soil health | | 7% | 6 |
| Cold hardiness | | 13% | 12 |
| Water management | | 3% | 3 |
| | **Totals** | 100% | 89 |

**76) Same question as 75)**

| | | Responses | |
|---|---|---|---|
| | | percent | count |
| Pollination | | 27% | 24 |
| Business management Finances/Budgets | | 10% | 9 |
| Personnel Management | | 2% | 2 |
| Harvest techniques/Equipment | | 17% | 15 |
| Canopy temperature management | | 14% | 12 |
| GPS applications | | 5% | 4 |
| Applying research to practice at the marsh | | 25% | 22 |
| | **Totals** | 100% | 88 |