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PROPOSED NATIONAL SUSTAINABILITY STANDARDS: IMPLICATIONS FOR THE CRANBERRY INDUSTRY

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From environmentally-concerned groups to buyers, retailers and consumers, "sustainability" is certainly the current buzzword in many industries, including agriculture. Several retailers and agricultural industries are independently developing sustainability standards, indices, and certification programs for their businesses and others throughout the supply chain. Additionally, national sustainability standards, which would ultimately encompass all agricultural crops, have been proposed or are in development by multiple groups. The intent of this presentation is to give an overview and update on national sustainability standards, and to outline potential implications for cranberry production.

While the concept of sustainable agriculture has been a point of discussion for several years, the desire to use it as a marketing tool or to add value to products in the marketplace is a relatively recent development. Individual retailers and suppliers, such as Walmart, are developing sustainability scorecards and standards. For example, McDonald's recently agreed to comply with a shareholder request to look at ways to reduce pesticide use in potatoes and document such progress. As a result, growers may be required to fill out several surveys to sell to multiple buyers, in addition to current requirements for good agricultural practice (GAP) surveys.

In response, multiple entities are developing national standards that would be applicable to agriculture in general and could be used to certify agricultural production with a single survey, thus reducing the duplicative efforts required to satisfy multiple buyers. Three national sustainability standard efforts are now taking place: the Field to Market efforts led by the Keystone Center, the Stewardship Index for Specialty Crops, and the American National Standards Institute efforts organized by Scientific Certification Systems.

Scientific Certification Systems developed the "Draft American National Standard for Trial Use for Sustainable Agriculture." This standard was proposed to the American National Standards Institute (ANSI) in 2007, an organization that develops and implements voluntary standards for a variety of industries. The Leonardo Academy, a Madison-based organization accredited by ANSI, is leading the standard development process. After an initial meeting of the Standards Committee in September 2008, the initial draft standard will be re-tooled. Those critical of the initial draft standard have cited two primary issues: 1) the standard set organic production as the highest level of sustainability, and may in fact be duplicative of current organic standards in some areas;

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and, 2) the initial standard prohibited the use of genetically modified crops. The groups involved in this standard development are in the process of developing a new draft standard.

The Keystone Center Field to Market group consists of entities with varying interests, including several food and fiber national commodity groups, environmental organizations, end-users and retailers, and academia. The goal of this group is not to develop a certification system, but to develop a grower tool that can be used to gauge production and sustainability metrics relative to neighbors, regional and national producers of a given crop. The proposed tool would allow growers to identify potential areas of improvement as well as to follow sustainability trends through time in terms of production efficiency per unit of production area. The Field to Market participants are currently investigating methodology and feasibility of quantifying sustainability parameters, such as water quality and energy use, at the grower level. The focus of this group is on major agronomic crops, such as cotton, corn, soybeans and wheat.

The Stewardship Index for Specialty Crops has taken an approach analogous to Field to Market, but with a focus on specialty food crops. The approach is outcome-based and not practice-based, and has focused on self-evaluation instead of certification. This group has organized several well-attended webinars and educational venues on parameters that would be included in the people, planet and profit parameters of sustainability.

While these efforts and others are currently very active, quantifying agricultural sustainability poses many challenges.

1. Agriculture is a complex biological system overlaid with an equally complex management system. Therefore, an inclusive standard across regions and crops is logistically challenging.
2. Quantifying sustainability could be costly, particularly with parameters such as water quality, where there is no substitute for expensive laboratory analyses.
3. At some point, participants or leaders may need to weight parameters in order to make difficult choices. This will raise questions of differing values systems. For example, which is more important: preserving rural farmland or preserving water?

Many involved have indicated that, ultimately, consumers will determine the success of such programs. So, will consumers pay for sustainability? The Healthy Grown potato program in Wisconsin provides an interesting case study. The Healthy Grown potato program is a unique collaboration among growers, academics and environmentally-oriented NGOs. The research-based program was built with over 20 grants totaling $2.7 million, about $200,000 per year in research support directly from growers, and about 15 to 20 researchers involved through time. In terms of documenting and improving “sustainability” parameters, Healthy Grown has been a great success. Between 2001 and 2005, IPM adoption increased 30 to 40% while pesticide toxicity scores decreased. The program is third-party certified by Protected Harvest and is rigorous. In market surveys, 70% of consumers said that they were likely to purchase Healthy Grown potatoes, and of those, 88% indicated that they would pay $0.25 more than standard potatoes. However, in 2004 and 2005, only 1% of the certified crop was sold as Healthy Grown. It appears that there is a strong disconnect between what consumers say they will buy and what is actually riding around in their grocery carts.

The measurement of "sustainability" parameters, such as the carbon footprint, has been successfully adopted in industrial processes; however, there are a couple of key differences between these efforts in industry versus agricultural production. First, the parameters often surveyed in industrial processes can be and are currently quantified with something as simple as a meter, such as electricity, natural gas and water usage, whereas those proposed for measurement in agriculture are much more nebulous, such as fair labor, rural community value and biodiversity. Second, the outcome of measuring these parameters in industry is often an implementation of efficiencies that slow the meter down - i.e. quantifying sustainability saves money. We have not yet been able to demonstrate a similar relationship in agriculture.

NATIVE BEES IN WISCONSIN CRANBERRY

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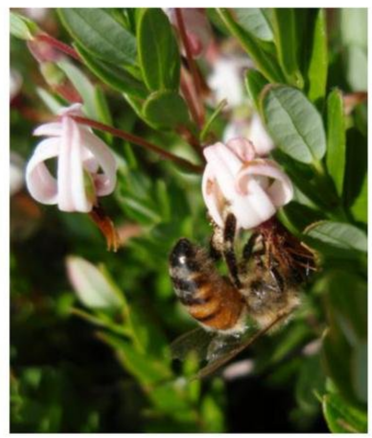
Background

Pollination is a valuable ecosystem service (NRC 2007) worth an estimated $14.6 billion annually in the United States (Morse & Calderone 2000). One in every three bites of food we eat is dependent, directly or indirectly, on insect pollination (Klein et al. 2007). Historically, farmers have relied upon one species, the non-native honey bee (*Apis mellifera*) for their pollination requirements. In recent years, however, honey bees have declined drastically as a result of mites, disease, and the recent emergence of Colony Collapse Disorder (CCD)(Stokstad 2007). As CCD continues to spread and devastate honey bee colonies, farmers will need to seek alternative ways of pollinating their crops.

A honey bee pollinating cranberry.



Native bees also provide valuable pollination services (Losey and Vaughan 2006, Winfree et al. 2008) but have largely been overlooked and are at risk of decline due to habitat fragmentation, intensified agriculture, and agri-chemical exposure (Kearns et al. 1998, Kremen and Rickets 2000). Native bees, unlike honey bees, are mainly solitary and do not produce honey. They nest in patches of bare ground or in hollow stems. In the springtime the adult bees emerge after over-wintering as pupae and begin foraging for nectar and pollen. In order for native bees to survive, flower resources must be readily available throughout their entire flight period. Previous studies have shown that the abundance and diversity of native bees in agro-ecosystems increase with proximity to natural habitat (e.g. Kremen et al. 2004, Morandin and Winston 2006) and areas with diverse floral resources (Potts et al. 2003). In order to inform management strategies to protect and enhance native bee communities in agricultural landscapes, it is essential to understand how habitat configuration and farm management affect native pollinators.

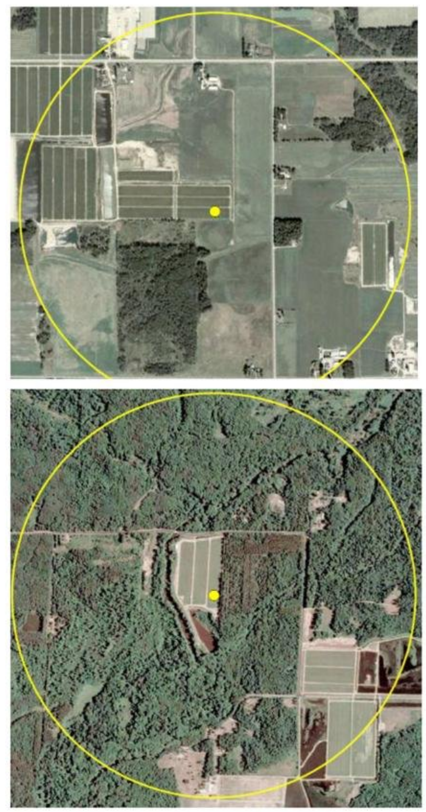
Megachile addenda may be an important cranberry pollinator.

Cranberry production is especially vulnerable to pollinator declines due to its dependence on insect pollination. While most cranberry growers rent honey bees each year for pollination, previous research has shown that native bees are more efficient pollinators of cranberry than honey bees (Cane and Schiffhauer 2003). To date, 44 species of native bees have been documented pollinating cranberry (Cane et al. 1996, Delaplane & Mayer 2000, Free 1993, Mackenzie & Averill 1995, Stubbs & Drummond 1997) and I have personally recorded over 100 species present in the Wisconsin cranberry system (Gaines, unpublished data). Native bees alone are able to provide sufficient pollination for some cranberry bogs in Ontario, Canada (Mohr and Kevan 1987), and this may also be possible in Wisconsin (Evans and Spivak 2006). In light of recent pollinator declines and the importance of pollinators to cranberry, the objective of my research is to determine **to what extent the variation in native bee communities depend on surrounding landscape as well as local farm management and to determine how much native bees contribute to the pollination of cranberries.**

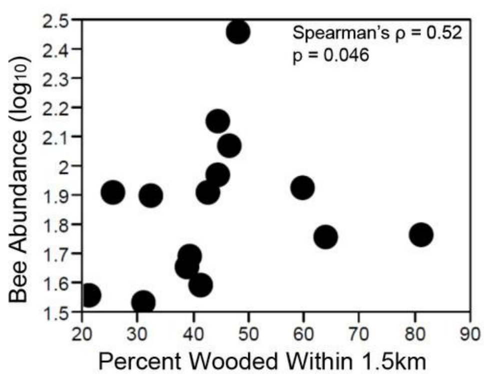
Preliminary Research

In 2008 I did an initial survey of native bees at 15 commercial marshes in central Wisconsin. I selected my sample sites so that the landscape within one km of the marsh varied from 20-83% woodland and 0-39% agriculture (see aerial photos at right). Using blue, yellow, and white pan traps filled with soapy water (which to a bee looks like a flower), I sampled once before, twice during, and once after cranberry bloom. The bees were identified to species and I then analyzed my data based on surrounding landscape.

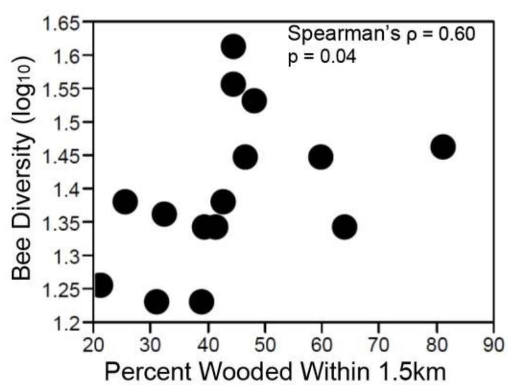
Overall, I collected 1282 specimens representing 108 species of native bees. The native bee species composition changed as a function of surrounding woodland and agriculture. The total number of bee species and specimens collected increased as wooded habitat increased (see graphs below) and decreased with increasing agriculture in the surrounding kilometer.



Two marshes surrounded by agriculture (top) and woodland (bottom).



Native bee abundance (l) and diversity (r) increased with increasing wooded habitat in the surrounding landscape.



From this initial study, I found that native bees are abundant and diverse in Wisconsin cranberries, suggesting their contribution to cranberry pollination could be significant. As the causes of honey bee die-offs remain uncertain, growers will need to seek alternative pollination methods. Habitat management and landscape planning may be one way for growers and communities to enhance native bee populations and thus pollination services on their farms.

Future research plans

In 2010 I will continue to study native bees in Wisconsin cranberry. I will continue to look at how surrounding landscape influences native bees as well as studying how local farm practices affect native bees. I plan to look at which bees are actually visiting cranberry flowers and determine how much they are contributing to pollination. The overall goal of my research is to understand what factors influence native bees and inform growers about ways to enhance native bee pollinators on their farms.

Acknowledgements

Thank you especially to the growers who allowed me to collect bees at their properties. Thanks to Adam Higgins, Emily Fricke, and Carl Kaiser for field assistance. Thanks to Jayne Sojka and Dan Mahr who helped me find field sites. Funding for this research has been provided by a UW Hatch grant to Claudio Gratton.

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NEW BUGS, OLD REMEDIES

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Background

A few new insects are generating some interest in some Wisconsin cranberry beds. I am not certain that they are really abundant enough to cause economic problems at this point, but if that becomes the case we already have effective tools for managing them.

Note that in the following I have listed some insecticide products that are not labeled for these specific pests on cranberry. However, these are products which are registered for the target pests on other crops, and are registered for other pests on cranberry. Use of such products on cranberry is legal as long as the usage pattern conforms to cranberry label restrictions, such as the maximum rate, maximum seasonal usage, and preharvest interval (PHI).

Rose chafer, *Macrodactylus subspinosus*, is a native insect in the scarab beetle family. The larva is a type of white grub that feeds on the roots of grasses and is largely confined to areas of sandy soils. The adult beetles are day-active insects, often found on flowers; they are about ½" long and of a yellowish-tan color. The adult beetles are notoriously common scourges of gardens and crops, feeding on a multitude of different types of plants, from grasses to fruit trees and rose bushes. For some reason, in recent years rose chafer has taken a modest liking to cranberry. If it appears that the numbers in cranberry beds are sufficiently high that damage may result, carbaryl (Sevin) is registered (7 day PHI). Other products registered on cranberry that can be used include Assail (1 day PHI) and Imidan (14 day PHI). In addition to insecticides, traps are commercially available which, in other situations (such as home gardens) have been adequately effective in reducing rose chafer populations.

Japanese beetle, *Popillia japonica*, is also a type of scarab beetle and the larva is yet another type of white grub, feeding on the roots of grasses and other plants. Japanese beetle is not native to North America but was accidentally introduced into New Jersey in 1916 and has been gradually increasing its range in the United States. It entered Wisconsin some 10-15 years ago and is still increasing its range in our state. The adult beetle is about ½" long, with greenish head and pronotum and reddish wing covers (elytra). They are active during the day and are strong flyers. Like rose chafer, the adults feed on flowers, fruits, and leaves of many types of plants. They can occur for a prolonged period in the summer, especially in July and August, but some individuals will continue to occur until the first hard frost. In Massachusetts and New Jersey it is occasionally a pest of cranberry, so several insecticides are registered including Actara (30 day PHI), Assail (1 day PHI), Pyganic (0 day PHI), and Sevin (7 day PHI). Other acceptable products include Imidan (14 day PHI) and Orthene (75 day PHI). There are also insect traps commercially available for Japanese beetle, but because the lures are so effective, and because the beetle is such a strong flyer, the traps are known to often attract more insects than they catch. Therefore, if the traps are anywhere near plants that need to be protected, the traps can actually result in higher levels of plant injury.

Gypsy moth, *Lymantria dispar*, is another non-native species; it was accidentally introduced into Massachusetts in about 1869. Like Japanese beetle, it is still expanding its range in the eastern United States. In fact, at the present time, Wisconsin (and spreading into Minnesota and Iowa) is on the leading edge of its range expansion. Most of the eastern half of the state is considered generally infested and no longer managed by state and federal agencies. However, the populations in the central and western part of the state are still becoming established, and state and federal agencies form a team involved in a "slow the spread" effort to knock back the biggest populations westward of the main line of infestation. Gypsy moth is primarily a pest of deciduous trees, but when populations are large it can also attack conifers and various types of shrubs. On the east coast it can be a pest of cranberry, especially during outbreak periods when the larvae strip forests of all their vegetation and then seek other sources of food. The larvae look something like tent caterpillars (but they do not spin silken webs or tents). The larvae get up to about 2" long when fully grown, are noticeably bristly, and the larger larvae have 5 pairs of blue spots followed by 6 pairs of reddish spots in two rows down the back. The male moths are brown and capable of flying; the female moths are whitish and fully winged but incapable of flight. Each female lays all her eggs in one buff-colored egg mass containing 400-800 or more eggs. The following insecticides are registered against gypsy moth on cranberry: Assail (1 day PHI), *Bacillus thuringiensis* (various brands; 0 day PHI), Confirm (30 day PHI), Imidan (14 day PHI), Intrepid (14 day PHI – note endangered species restrictions), Orthene (75 day PHI), Pyganic (0 day PHI), and Sevin (7 day PHI). Other effective products with cranberry registration include Delegate (21 day PHI) and Entrust (21 day PHI – acceptable for certified organic production).

FUTURE CRANBERRY SELECTIONS:
WHICH TRAITS MAY BE CRITICAL FOR 2050?

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Although we have been conducting a cranberry genetic improvement and evaluation program for multiple decades now, the 2009 growing season was one of our most enlightening experimental periods for both short and long term decision-making. Not only did the evaluation plots of a number of our selections mature and produce exciting results, but new information became available which highlighted highly visionary but not fully understood factors that may have profound impacts on the future cranberry industry in Wisconsin. We will be exploring three seemingly separate but really highly interrelated themes: (1) performance observations for our new hybrid selections, (2) climate change in Wisconsin's cranberry production region, and (3) presence and potential impacts of bacteria living in cranberry plants. All three of these themes are complex and to undergo a discussion of all of them in one presentation may seem ludicrous, but this is the challenge that we were given and will now attempt.

2010 Performance Update - University of Wisconsin Cranberry Breeding Project

The Cranberry Breeding Program has moved forward on a number of projects in the last year and in particular we are preparing a new cultivar for release. Below is a summary of the philosophies and major activities of the breeding project during the last year.

The general philosophies of the cranberry breeding program at the University of Wisconsin–Madison have been developed for both practical reasons and to reflect grower inputs. They include the following.

1. Utilize "Participatory Plant Breeding," where stakeholders help direct the research and are involved in the selection process.
2. Meet the needs of the growers of Wisconsin.
3. Not duplicate existing cultivars.
4. Build-in resiliency both to individual cultivar releases and to the program as a whole.
5. Selections released in part for yield will be "proofed." In other words, before release, high yield results will be obtained from a minimum 0.5 acre bed with conventional harvest; in addition specific, reproducible yield parameter traits (such as return bloom, berry size, berries per upright, etc.) must be present.
6. Test selections at multiple locations in the state; this insures the general applicability of a selection for Wisconsin, striving to serve all the growers of the state.

7. At this time we have determined that both the immediate and long-term needs of the growers of Wisconsin are reproducibly high yields covering the range of the harvest season, increasing both yield and efficiency of grower and handler operations.

We have identified several selections that meet the goal of covering the range of harvest timings. 'Stevens' is quite late in Wisconsin and the release of 'HyRed' in 2002 has provided the growers with a significantly earlier cultivar. While 'HyRed' was released specifically for early, improved fruit color, it was also selected for some improved yield parameter traits, in particular general bud set and return bloom (or "rebud", a high propensity for bud set on fruiting uprights). This has resulted in some impressive yields, including a farm-record 532 barrels per acre on a four-year-old, 3.5 acre bed in Juneau County (originally planted from only 1500 lbs. of vines for the whole bed). This bed was harvested September 15th, 2009, and had excellent fruit color with very few "blonds" or "pinks" (very low colored fruit). A short video clip can be viewed on the web at http://www.youtube.com/watch?v=V41XY8U9eUs, showing the extent of fruit cover on this bed before corralling, and zooming in to show the excellent fruit quality.

A very promising new selection that matures even earlier than 'HyRed' is currently under evaluation at two locations, and has demonstrated very favorable yield parameter traits: specifically high rebud, high number of berries per upright and the potential for high upright density. This selection has not been "proofed" yet; however a four acre bed at a third location will be planted in 2010 to accomplish this goal.

Another selection, "WI92-A-X15" (or just 'A-X15') has been under evaluation for many years at several sites. Initially, 'A-X15' did not meet the breeding goals at the time (good fruit color by September 15th), but its excellent vigor and large berry size warranted further examination. Upon scale-up, 'A-X15' has reproducibly demonstrated many desirable yield parameter traits (excellent bud set, large berry size, early and late berry bulking), uniformly good establishment, excellent fertilizer response and fruit maturation before 'Stevens' (developing fruit color by late September and early October even in years 'Stevens' barely makes color). In 2009, 'A-X15' was "proofed" with a conventionally planted, conventionally harvested four-year-old bed which yielded nearly double the farm average for established 'Stevens' (Table 1).

It appears likely that fertilizer tolerance and response play a major role in the yield success of 'A-X15'. 'Stevens' is well known for its tendency to make runners if over-fertilized with nitrogen, often at the expense of fruit and/or bud set. 'A-X15' does runner well in young plantings, but still sets a lot of uprights and buds. This results in good canopy establishment and good yields in young plantings (Table 1, note nitrogen levels applied). Nitrogen levels that support good results with 'A-X15' would cause excessive overgrowth and likely yield losses in 'Stevens'.

Table 1. 2009 yield results for three- and four-year-old 'A-X15' from conventionally planted and harvested beds compared to the farm average for established 'Stevens' on a farm in Wood County, WI. Note difference in nitrogen levels applied.

	A-X15 4-yr-old	A-X15 3-yr-old	Established 'Stevens'
Yield (B/a)	476	242	243
Area planted (acres)	0.7	2.2	66
N applied (lbs/acre)	74	74	42

The fertilizer tolerance and response of 'A-X15' was especially evident in a well-established planting in Monroe County. Most of a 4000+ square foot plot was "over-fertilized" in an attempt to produce propagation material. This attempt failed as virtually no runners were produced (Fig. 1). Further examination of the effects of extra fertilizer confirmed a higher nitrogen content in the tissue and an estimated 10% increase in yield; but the major difference was a greatly increased level of bud set, particularly rebud (Fig. 2). There was a heavy crop load and the concept of being able to fertilize for the current year's crop as well as the following year's (through increased bud set) is very desirable.

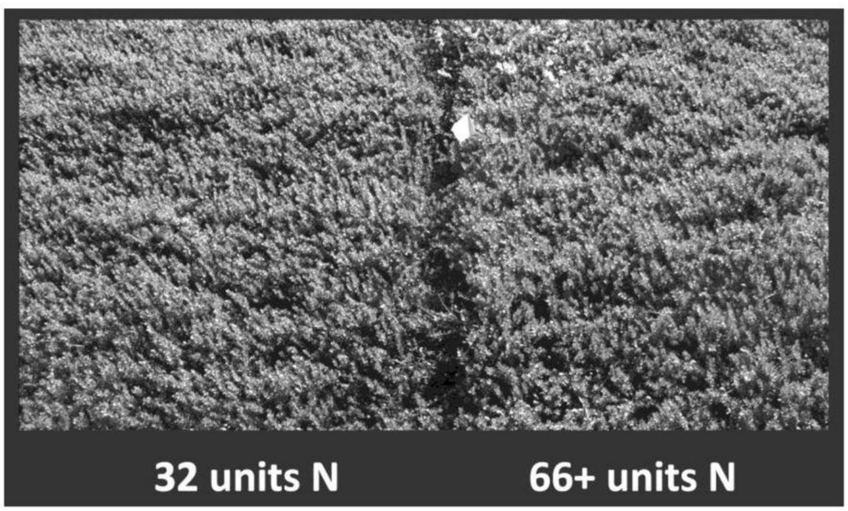

Fig. 1. Fertilizer tolerance of 'A-X15' demonstrated in an established plot in Monroe County, WI. The area to the left received 32 units of nitrogen as did the rest of the bed; the area to the right received an extra 34 units of inorganic nitrogen and another 45 units of slow-release organic fertilizer. Virtually no runners were observed at either nitrogen level.

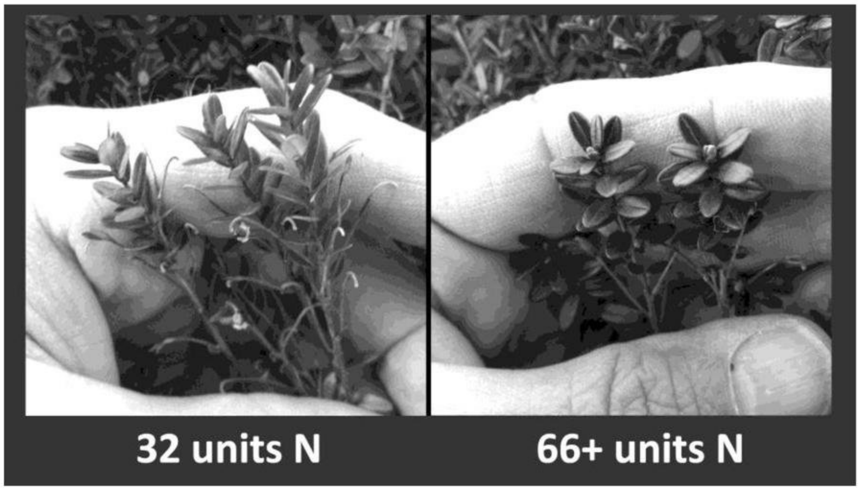

Fig. 2. Fertilizer response on fruiting uprights of 'A-X15' from the plot in Fig 1. The higher nitrogen level greatly increased the rebud (bud set on uprights that fruited in the current year). Bud set overall was much greater at the higher nitrogen level, but average upright size was not different.

With these results we feel confident in releasing 'A-X15' as a new cranberry cultivar. 'A-X15' has been accepted by the Wisconsin Alumni Research Foundation for patenting and ten acres are ready for planting in 2010. 'A-X15' should be commercially available in small quantities in 2011 and in greater supply after that year.

The breeding program is still advancing other promising new selections, particularly to utilize a variety of germplasm sources and avoid a concentrated gene pool that might lead to problems in the future. Despite having a number of selections to work with, a new set of crosses has been performed to specifically address possible effects of climate change currently occurring in Wisconsin and discussed below. Selections from these crosses will seek to maximize resiliency and take advantage of these changes for the benefit of the growers of Wisconsin in the future (Fig. 3).

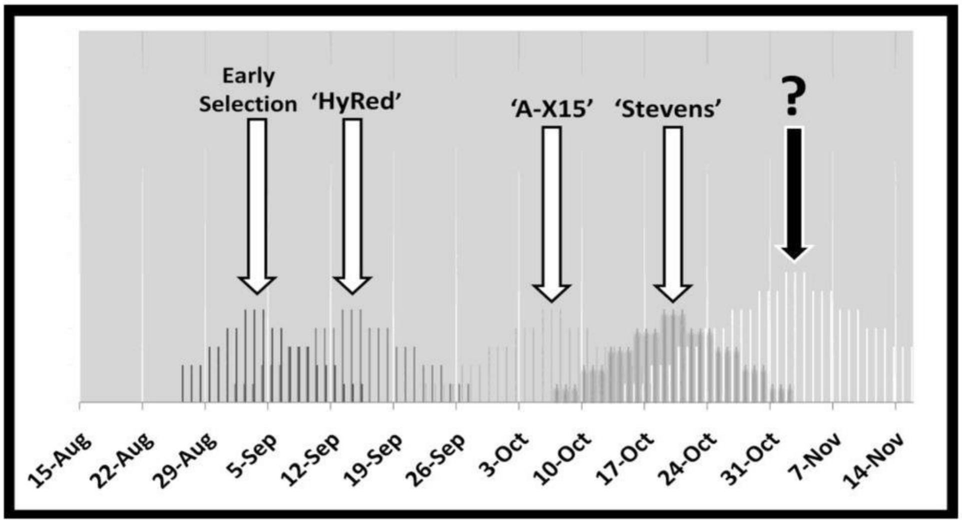

Fig. 3. A theoretical distribution of cultivars covering the range of the harvest season. One potential goal is to take advantage of climate changes that are occurring as indicated by current climatological models. The theoretical late cultivar indicated by a question mark in black may become a reality if early-flowering and late-maturing selections can maximize yields due to better exploitation of the changing growing season in Wisconsin.

Climate Change in Wisconsin's Cranberry Production Region

We have all heard various scenarios about global warming and climate change and many times it is difficult to bring this discussion 'down home' to where we are doing everyday farming. What we want to do today is to make you aware of an extensive array of new information that allows a much more place-specific discussion. This information is not from the work in our research program, but is the result of a large, multi-investigator and multi-agency working taskforce referred to as the Wisconsin Initiative on Climate Change (WICCI, see http://wicci.wisc.edu/index.htm). Much of the effort is lead by the Center for Climatic Research at the Nelson Institute for Environmental Studies at UW-Madison, but be assured that agricultural researchers are also involved.

One approach by this group was to collect decades of already existing data from the extensive Weather Station Network in Wisconsin to detail the historical trends in climate in the state. Among the vast amounts of summarized information that is available, several trends, such as the following two, are of particular importance to the state's cranberry industry.

1. Temperature changes have occurred. The state has generally become warmer, but this has not been uniform around the various regions. Figure 4 shows the change in annual average temperature from 1950-2006 around the state; we have added a map of counties encompassing the principal cranberry production areas in the state. What is apparent is that the most significant increases in climate warming closely match the cranberry production regions.

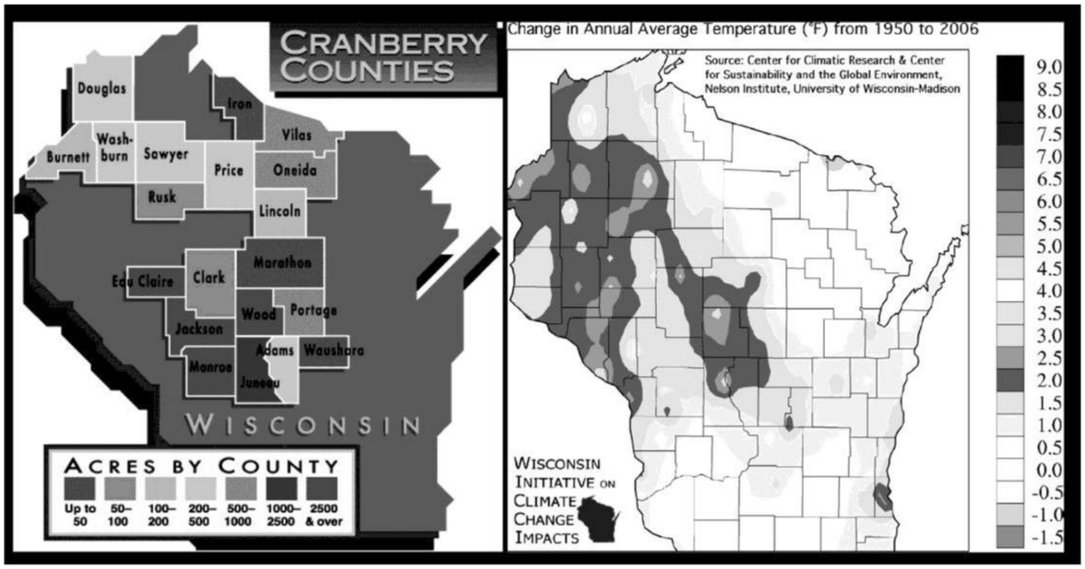

Fig. 4. Cranberry production in Wisconsin by county (left) compared to change in average annual temperature in Wisconsin (right). The areas of the state with the greatest average increase in temperatures coincide with some of the areas with the largest cranberry production.

2. The greatest warming also has varied by season with the most warming occurring in the winter and spring. Why this is particularly important for the cranberry industry is that there has been a significant increase in the length of the growing season. Since the length of the growing season has always been a challenge for Wisconsin growers, this impact of climate change may indeed be beneficial to cranberry production and may have actually contributed to the increasing yields recorded in Wisconsin during the past decade.

Another set of information that is emerging are predictions of what might occur in the next decades - will these changes in our climate continue? Such predictions rely on complex computer-based models and the reliability of such tools is increasing, although the perspective that this is still a prediction is important to maintain. Some of the relevant ideas emerging from the WICCI group include the following.

1. Wisconsin will continue to warm with an increase of another 4 to 9 °F by mid-century predicted.
2. Winter and early spring will be wetter and warmer. Although the longer growing season may improve our yields and fruit quality, if the early parts of the season become warmer and more humid, concerns about increased fruit rot problems will arise.
3. A general trend associated with the warming of the atmosphere is an increase in variability of the weather; that is, the weather patterns during the growing season may take on more occurrences of extreme events and less predictability. As I talk to farmers throughout Wisconsin, this factor is the scariest.

If one sits back and considers how to prepare for such climate changes, a theme that is emerging in such discussions is to maximize 'resiliency' of the industry. That is, whether predicted changes actually occur or not, it is probably a good bet to assume they will and thus be as flexible in production and processing practices as possible. How might plant breeding contribute to such resiliency? As was referred to in the breeding program update section, we feel that some approaches are a no-brainier.

1. Maximize diversity of cultivars in plantings. That is, it may be even more important to avoid what is called 'genetic vulnerability' by planting as diverse a variety of cranberry cultivars as possible so that the vulnerability of any one of them to climate changes will not be critical. Fortunately, the spectrum of choices of high performing cranberry cultivars has dramatically increased and will undoubtedly continue to expand in the near future.
2. Take a proactive advantage of the longer growing season. One way to do this is to plan to maximize the diversity of fruit maturity timing through the production regions. We anticipate the opportunity to have very early, midseason, and late season harvest periods.
3. Our genetic improvement efforts should place disease and pest resistances at a higher priority. This goal is much easier to discuss than to successfully undertake, however one approach is the idea to more thoroughly understand and exploit the symbiotic associations between microorganisms and the cranberry plant, as is discussed next.

Presence and Potential Impacts of Bacteria Living in Cranberry Plants

As many of you know, over the last three to four decades, we have undertaken and perfected the approaches for growing and genetically manipulating woody crops such as cranberry in sterile, 'test-tube' environments, now widely termed 'microculture'. Interestingly, throughout this time, we have observed occasional emergence of bacteria from what we previously thought were 'sterile', microorganism-free plants. Unfortunately, the tools to fully explore this phenomenon was not available until recently and due to a fortunate convergence of separate projects, we have again engaged in studying the association of bacteria living in woody plants. The term commonly used to describe such a critter is an "endophyte." An endophyte is a microorganism that colonizes living, internal tissues of plants (any part) without causing any immediate overt negative effects on the host plant.

Endophytes have been lightly studied for some time and are now rapidly attracting considerable interest. Here are some things we know.

- All plants surveyed have them.
- Fungi and bacteria are most common.
- Most complex associations may be with long-lived perennials (such as cranberry).
- Implicated in having many effects in an array of crops.
    - Reducing effects of pests (diseases, insects)
    - Modifying plant growth (such as through hormone production)
    - Complex interactions with other associations
        - Mycorrhizae

- Nutrition (e.g. nitrogen fixation)

During the last year, with some exploratory funds provided by Ocean Spray Cranberries, Inc. and a competitive grant through the College of Agricultural and Life Sciences using funds from the Gottschalk Foundation Gift, we have conducted some ***very preliminary*** work. The following are some observations.

- Cranberry plants do have bacterial endophytes in leaves/stems.
- We have observed about 120 individual isolates that look different but may not all be separate organisms. Work to identify them is now underway using modern genomic techniques.
- The endophyte population in cranberry plants growing in commercial beds versus native area appears to be significantly different.

So what? Considering what is known about endophytes, these results are not at all surprising. What our work will attempt to focus on is: "do these associations have any demonstrable positive effects on cranberry growth and productivity?" As an example, we conducted several very simple assays using only laboratory based techniques to explore if just one of these endophytes isolated from cranberry might affect the growth of a fungus involved in the field cranberry fruit rot complex. An example of the results is shown in Figure 5 below.

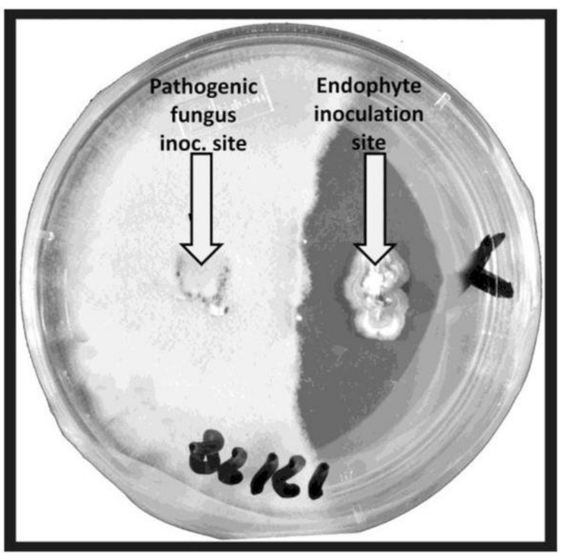

Fig. 5. Antifungal property of a cranberry endophyte. An endophytic bacteria isolated from cranberry was inoculated a few days before a fungus pathogenic to cranberry was, and the results viewed after five days. The fungus normally grows quite well on this medium, as evidenced by the left side of the petri dish. However, it was clearly inhibited by some factor produced by the endophyte on the right side of the dish. Endophytes may help plants with a number of factors, including resistance to pathogens, nutrient availability and tolerance to stress.

So now where do we head with this research?

- By developing endophyte-free cranberry plants and comparing their growth and productivity to cranberry plants with endophytes, will we see any differences?
- How stable and reproducible is the population of endophytes in cranberry fields?
- How important is the endophyte population to the success of new plantings?

- Can the effects of high populations of specific endophytes lead to modified BMPs?

If any of the above responses to the presence of endophytes in cranberry plants can be verified, should and how can this factor be incorporated into a cranberry breeding program? This is a really important question, because some of the past research working with other crops such as corn have shown strong interactions between the specific crop selections and specific endophytes; thus can we breed for the combined benefits of both organisms?

The 2050 Cranberry

So what will the leading cranberry cultivars of 2050 look like? We are betting that the themes of resiliency and positive microorganism associations may well be major factors. Bets anyone????

Thank You

The Cranberry Breeding Project thanks all the participants in the breeding program, including (among others) the Wisconsin Cranberry Board, Inc., Ocean Spray Cranberries, Inc., the Wisconsin State Cranberry Growers Association, the Wisconsin Alumni Research Foundation and in particular the cranberry growers of Wisconsin: without their major contributions both as collaborators and advisors, we would have been unable to be successful in our efforts to genetically improve cranberry.

2009 CRANBERRY FIELD PESTICIDE TESTING: SUMMARY REPORT

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Abstract

The mission of the 2009 program was to investigate fungicides, insecticides and herbicides for uses in Wisconsin cranberry production. Objectives were twofold:

1) investigate pesticides currently registered for use in cranberries to refine their use patterns and to further identify their spectrums of pests controlled, and
2) investigate pesticides not currently registered for uses in cranberries for their potential to address existing pest problems.

Thirty-nine field trials were conducted on fifteen Wisconsin marshes: 7 fungicide trials, 21 insecticide trials and 11 herbicide trials.

Fungicide Trials

In 2007 and 2008 late season *fruit rots* caused significant problems in Wisconsin cranberry production; in some marshes 30% of the harvested crop was lost to fruit rot. This disease complex generally affects mature beds that are in full production. In 2008 isolated incidents of *early rot* were consequential problems; losses of 50 – 100% of the crop were experienced. This disease complex and these losses generally occurred in 2–3 year old beds.

Fruit Rot

Five trials were conducted on three marshes that have experienced significant fruit rot problems in recent years. LaMunyon, Stevens and Ben Lear were the subject varieties. Fourteen treatments were evaluated. Treatments included various timings of applications of the registered products Bravo, Abound and Indar. Three non-registered products were also included. Disease pressure was heavy in the LaMunyon site, moderate in two of the Stevens sites and light in another Stevens site and in the Ben Lear site.

Bravo and Abound were the most efficacious products. Indar was less effective. The current recommendation is for two applications of a fungicide: at 50% bloom and at early post bloom. Additional applications at post-bloom or late berry set did not contribute significantly to enhancing disease control. None of the three candidate fungicides was significantly efficacious.

Early Rot

Two trials were conducted on two marshes that experienced significant early rot problems in 2008. Gryglesky GH-1 was the subject variety. Eight treatments were evaluated. Treatments included three applications of the registered products Bravo, Abound and Indar and one non-registered product. Each product was applied on two different application schedules.

Neither trial was productive as early rot disease did not occur. Although this was not the preferred outcome it might have been anticipated as this disease lessens in intensity with bed maturity. Weather conditions unfavorable to disease development were also a likely factor.

Insecticide Trials

Cranberry fruitworm, Sparanothis fruitworm, and blackheaded fireworm are the primary insect pests in Wisconsin cranberries. Most acres are treated at least once per season for one or more of these pests. Tipworm, loopers/spanworms and flea beetles are secondary pests; in any given season some acres are treated for these pests. Cranberry girdler and white grubs are also occasional pests; there are no efficacious insecticides for these pests.

Twenty-one insecticide trials were conducted in 2009: four for cranberry fruitworms, four for Sparganothis fruitworms, two for fireworms, two for loopers, six for tipworms, one for flea beetle, one for leafhoppers and one for white grubs. The number of treatments evaluated varied with the pest and the trial site. The recently registered insecticides Assail, Knack, Delegate, and Intrepid, the older standards Imidan, diazinon, Orthene, and Lorsban, and several unregistered products were evaluated both alone and in tank-mix combinations.

Since trial sites were selected based on existing or developing insect pest populations; all trials had moderate to heavy testable pest pressures.

All of the registered products performed much as expected. The older organo-phosphate products were broad-spectrum across most test pests and were generally efficacious as long as the pest was present at the time of the application. Efficacies ranged from acceptable to excellent. The newly registered products, particularly the insect growth regulator-types, were more pest-type specific. Lepidoperan pests were controlled well, tipworm less so and the other pests mostly not controlled. Although all of the newer products were generally equally efficacious, the timing of applications with these products was critical to performance. Late egg to early instar applications were efficacious whereas applications to later instars were significantly less effective; this is to be expected with these types of insecticides. Tank mixes of the newer products with the organophosphates lessened the necessity for precise timings of applications. One of the candidate insecticides was a stellar product.

Of special interest was a single trial conducted in a cranberry-abandoned site. Because of the heavy infestation of weeds, primarily grass-types, a heavy infestation of white grubs was present. The site received occasional irrigation but was not flooded. Granular formulations of diazinon, Lorsban, Imidan, Admire and two experimental turf grass products were evaluated. One of the tested products provided excellent control of grubs. Granular formulations of diazinon and Lorsban provided respectable suppression (ca. 70%) of grubs. Liquid formulations of diazinon, Lorsban and one of the experimental products were significantly less efficacious than their respective counterpart granular formulations. Admire and Imidan were not efficacious.

Herbicide Trials

The purposes of the 2009 herbicide trials were threefold:

1) investigate new post-applied products for possible uses in cranberries,
2) stay current with use patterns for Callisto (mesotrione) and
3) continue to investigate an unregistered product for dodder control.

New Post Product Trials

There are few new post applied products coming from industry. Most of the existing potential products have been investigated by us in previous years. Of those products, five have shown the greatest potential for uses in Wisconsin cranberries.

In our 2009 trials, two of the candidate herbicides caused discernable crop responses. With one, the crop response was detectable season long. With the other, the crop response was less long lasting but still unacceptable. Although the crop responses induced by either product did not result in significant yield reductions the visual responses were unacceptable. The visual crop response induced by a third candidate product was minor, however several tested treatments of this product resulted in significant crop reductions.

Two of the candidate products demonstrated good promise for use in Wisconsin cranberries. The weeds-controlled spectrums of both of these products would make these great companion products for Callisto as they provide good control of weeds that are weaknesses with Callisto. Neither of these products induced detectable crop response or negative effects on yields. One provided good control of St. Johnswort, a weed not controlled by Callisto, and yellow loosestrife.

Callisto Use Patterns

Commercial use patterns of Callisto were evaluated in small plot trials and monitored in commercial production situations. Observations are as follows.

1) Two applications of Callisto at 8 oz/acre may be excessive ($$). After several seasons of Callisto use, and once acceptable weed maintenance control has been achieved, 4–6 oz early followed by a second application, if needed, is appropriate.
2) Callisto is most efficacious when weeds first appear in the cranberry canopy. Later applications after the weeds are 6-8" tall are less efficacious.
3) Crop responses from Callisto applications can happen. Usually these responses are associated with cranberries under stress – cool temperatures, lack of moisture, etc. These responses are temporary and do not affect yields.

Some weeds that are not adequately controlled by Callisto, notably St. Johnswort, are beginning to be of concern. In recent years, pre-applications of Casoron, Devrinol and Evital have been deemphasized because of the effectiveness of Callisto. Growers need to keep in mind these products for the control of weeds not controlled by Callisto.

Dodder Trials

In 2008 we had successes with a candidate herbicide for the control of dodder. This product is pending registration for uses in cranberries. Although few marshes in Wisconsin are plagued with heavy dodder infestations, those that do have the problem are in dire need of help for the control of this parasite. In 2009 seven trials were conducted in two marshes to investigate use patterns of the candidate herbicide (rates, timings of applications, tank mixes) for dodder control. Four of these trials at City Point, WI had heavy dodder infestations and valid trials were conducted. Because of efficacious maintenance applications of Casoron, the three trials conducted at the Tomah marsh did not have testable dodder infestations.

The candidate product continued to be highly efficacious for dodder control; timing of applications is critical to good control. Applications need to be made when the dodder strands first begin to appear in the cranberry canopy. It is likely that this timing coincides with dodder seed germination or just before the vines abscise from the seeds. Later applications inhibited vines but did not prevent vine matting. The 8 oz/acre rate is more effective than the 5.3 oz rate; both rates represent the rate range on the proposed cranberry label. Callisto caused temporary chlorosis in the dodder but did not provide control. Combinations of the candidate product + Callisto did not provide control enhancements over comparable rates of the product alone. Neither of two other candidate products provided control of dodder.

Season Summary

The 2009 field testing season was productive. We have a greater understanding of how the registered pesticides perform, how to make them the most efficacious and what new products have potential for use in cranberries.

HOW MUCH POTASSIUM IS NEEDED?

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Potassium application to cranberries in Wisconsin is highly variable with some growers making many and large applications while others apply relatively less. Purported benefits of potassium (K) applications include increased yield, increased fruit size, improved fruit color, and improved winter hardiness. Long held practice is that cranberry vines are sensitive to chloride, so potassium should be applied in the more expensive sulfate rather than the less expensive chloride form. This research was undertaken to validate or invalidate these claims.

Objectives

1. To conduct small plot experiments where different rates of potassium fertilizer are applied with various timing schemes. A four week timing was compared to a two week timing.
2. To compare large late season K applications to a control.
3. To compare chloride and sulfate forms of potassium fertilizers at two rates.

Plots were established in commercial cranberry beds of 'Stevens' in central Wisconsin. One farm was upland and sand based and the other farm was wetland and peat based, but with a substantial sand lift. Plot size was 10 x 16 feet and treatments were replicated eight times. Fertilizer was pre-weighed and was applied by hand to individual plots. Plots received uniform rates of nitrogen (30 lbs/a) and phosphorus (45 lbs P_2O_5/a) in three split applications. Potassium was applied at various rates and timings as shown in Table 1. Tissue samples and soil samples were collected in late August and were submitted to the UW Soil and Plant Analysis lab for analysis. In September prior to commercial harvest square foot samples were collected for determining yield and fruit count. Fruit were collected for color analysis in late September. Total anthocyanin in 100 gram samples was measured by extracting the fruit in 0.2 N HCl using the standard industry protocol.

Table 1. Rates and timings of potassium fertilizer applied to plots in 'Stevens' cranberries in central Wisconsin during 2006. Rate is given as pounds of K_2O per acre.

Treatment number	Rate	Form	Timing
1	0	Sulfate	RN, BL, FS, August
2	50	Sulfate	RN, BL, FS, August
3	100	Sulfate	RN, BL, FS, August
4	200	Sulfate	RN, BL, FS, August
5	200	Chloride	RN, BL, FS, August
6	200	Sulfate	2 week schedule beginning at RN
7	400	Sulfate	RN, BL, FS, August
8	400	Chloride	RN, BL, FS, August
9	800	Sulfate	RN, BL, FS, Early Aug, Mid Aug, Sept.

RN = Roughneck, BL = Bloom, FS = Fruit Set

Results

Higher rates of potassium fertilizer application led to tissue K values that generally trended upwards with application rate. However, significant differences were found the first year in both locations and at the upland location for 2008 (Tables 2, 4). Even after three years of no application of K fertilizer the control plots were still within the sufficient range for tissue K.

Soil test K typically trended upwards with application rate (Tables 2, 4). For 2008 there were no differences in soil test at either location except that our 800 pound rate was higher than the remainder. It is likely this is a function of high amounts of K remaining in the soil following the large late season application, just prior to collecting our soil samples. At the highest application rate, soil test K exceeded what would generally be recommended for cranberry soil K. It is interesting that there is no clear relationship between soil test K and tissue K.

There were no significant differences in yield, count or size at either location across three years of research (Tables 3, 5). This is not surprising since we did not find significant differences in tissue K and since none of the samples were in the deficient range. In fact, all tissue samples are still in the mid-sufficiency range and in this range we would not anticipate finding treatment differences. This should provide very strong evidence for the cranberry grower community that yield and potassium fertilizer application are not correlated. I should also point out that yield and fruit count at the highest application rate is generally numerically lower than lower rates. Low replication and high variability did not allow us to fully support this statement. However, data from growers clearly showed a negative relationship between potassium application rate and yield.

Varying rates and timing of K fertilizer had no effect on fruit color in 2006 or 2007 (Table 6). Treatment and farm effects were not significant and there was no treatment by farm interaction. Thus, rates of potassium were not correlated with achievement of fruit color.

For all three years we did not find any difference in plant or soil response to application of potassium in either the sulfate or the chloride form. At the rates utilized (200 and 400 pounds K_2O per acre) we did not find that chloride posed any problems. We did not note any visual differences between the chloride and sulfate plots. Further, the 400 pound rate is higher than most growers apply, thus we believe that either form of potassium fertilizer is suitable for cranberry production if applied in split applications.

Conclusions from the Data

1. Fruit yield, fruit size, and fruit number were not affected by potassium fertilizer application over three years at 2 locations (six location/years). Applications of potassium fertilizer above maintenance doses does not appear warranted.
2. There was no effect of potassium rate or form on fruit anthocyanin concentration. Thus, adding potassium fertilizer does not improve fruit color.
3. At the rates we tested, there was no difference in response to fertilizer added as either the chloride or sulfate form. At reasonable rates either form appears suitable. Growers can save a considerable expense by purchasing the chloride (0-0-60) form.
4. Large applications of K fertilizer will typically increase tissue K.

Results similar to these were obtained in Massachusetts from a sister study.

Table 2. Effect of various rates, timings, and sources of potassium application to cranberry vines growing in a sand based upland bed in Wisconsin. n=8

		Tissue K			**Soil K**		
		% dw			*ppm*		
Trt #	Treatment*	*2006*	*2007*	*2008*	*2006*	*2007*	*2008*
1	Control	0.655 cd	0.633	0.46 a	47.9	112.5	30.5 a
2	50 # sulfate	0.740 bcd	0.70	0.51ab	50.4	82.5	32.5 a
3	100 # sulfate	0.615 d	0.70	0.52 ab	62.9	55.75	45.0 ab
4	200# sulfate	0.710 bcd	0.78	0.56 cd	77.4	54.25	52.5 abc
5	200# chloride	0.680 bcd	0.76	0.53 abc	73.4	74.0	57.8 bc
6	200# sulfate biweekly	0.678 cd	0.86	0.54 abc	85.0	50.5	59 bc
7	400# sulfate	0.840 ab	0.85	0.62 cd	101.4	43.3	71.0 c
8	400# chloride	0.783 bc	0.78	0.56 cd	98.3	65.3	76.0 c
9	800# sulfate	0.945a	0.96	0.68 d	210.4	103.0	130.3 d
	Significance	**	ns	**	***	ns	***

* Treatments are given as pounds of K_2O per acre. Fertilizer was supplied as either potassium sulfate or potassium chloride.

Table 3. Effect of various potassium treatments on yield, count, and fruit size of cranberries growing in a sand based upland bed in Wisconsin. n=8.

		Yield			**Count**			**Size**		
Trt #	Treatment*	*g/ft2*			*number*			*grams*		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
1	Control	183	149	267	118	98	159	0.645	1.52	1.63
2	50 # sulfate	193	181	248	125	111	179	0.647	1.60	1.37
3	100 # sulfate	227	174	204	141	111	156	0.620	1.56	1.31
4	200# sulfate	202	185	202	128	117	153	0.631	1.57	1.27
5	200# chloride	233	184	234	152	115	164	0.660	1.58	1.41
6	200# sulfate biweekly	200	166	224	128	106	166	0.640	1.55	1.35
7	400# sulfate	220	157	175	140	99	130	0.638	1.57	1.31
8	400# chloride	191	164	192	121	101	144	0.629	1.61	1.32
9	800# sulfate	222	135	171	142	91	131	0.638	1.49	1.26
	Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns

* Treatments are given as pounds of K_2O per acre. Fertilizer was supplied as either potassium sulfate or potassium chloride.

Table 4. Effect of various rates of phosphorus application to cranberry vines growing in a peat based wetland bed in Wisconsin. n=8.

		Tissue K			**Soil K**		
Trt #	Treatment*	*% dw*			*ppm*		
		2006	2007	2008	2006	2007	2008
1	Control	0.513 d	0.765	0.57	33.9	72	47 a
2	50 # sulfate	0.530 cd	0.590	0.61	46.3	70	45 a
3	100 # sulfate	0.648 bcd	0.658	0.62	46.3	54	42 a
4	200# sulfate	0.638 bcd	0.76	0.67	60.3	53	54 a
5	200# chloride	0.578 cd	0.59	0.63	57.3	51	52 a
6	200# sulfate biweekly	0.645 bcd	0.62	0.66	61.6	68	46 a
7	400# sulfate	0.735 b	0.66	0.75	84.9	44	51 a
8	400# chloride	0.655 bc	0.68	0.72	83.0	61	54 a
9	800# sulfate	1.040 a	0.76	0.66	131.3	73	121 b
	Significance	***	ns	ns	***	ns	***

* Treatments are given as pounds of K_2O per acre. Fertilizer was supplied as either potassium sulfate or potassium chloride.

Table 5. Effect of various potassium treatments on yield, count, and fruit size of cranberries growing in a peat based wetland bed in Wisconsin.

		Yield			**Count**			**Size**		
Trt #	Treatment*	*g/ft2*			*number*			*grams*		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
1	Control	193	98.1	166	131	61.6	115	0.68	1.60	1.45
2	50 # sulfate	199	78.6	163	133	50.9	112	0.67	1.56	1.46
3	100 # sulfate	180	108.9	139	119	69.4	93	0.66	1.58	1.49
4	200# sulfate	163	69.4	186	109	45.3	127	0.67	1.54	1.46
5	200# chloride	219	99.0	198	146	63.0	138	0.66	1.58	1.43
6	200# sulfate biweekly	150	77.7	186	104	50.4	132	0.69	1.55	1.41
7	400# sulfate	195	54.8	179	128	35.0	126	0.66	1.56	1.43
8	400# chloride	205	96.5	145	134	63.5	102	0.67	1.51	1.36
9	800# sulfate	181	79.4	180	130	55.1	121	0.71	1.46	1.48
	Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns

* Treatments are given as pounds of K_2O per acre. Fertilizer was supplied as either potassium sulfate or potassium chloride.

Table 6. Effect of rate of potassium fertilizer on total anthocyanin concentration in cranberry fruit at harvest. n=8.

Treatment	**Sand bed**		**Peat bed**	
	2006	2007	2006	2007
Control	30.6	34	31.5	30.4
200 lbs K_2SO_4	30.6	32.4	29.3	31.3
400 lbs K_2SO_4	32.2	32.6	28.0	31.1
800 lbs K_2SO_4	32.2	31	28.9	29.3
Significance	*ns*	*ns*	*ns*	*ns*

SUSTAINABLE CRANBERRY NUTRITION

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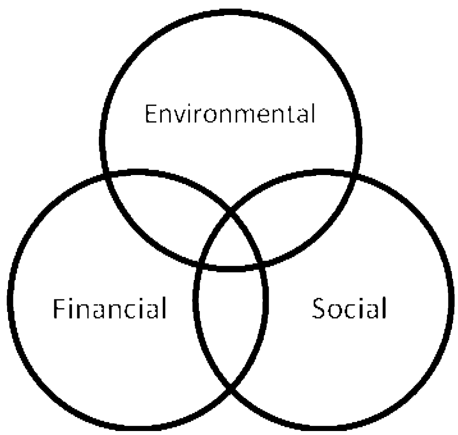
Sustainability has at its very core that future generations will be able to enjoy and utilize the systems and resources that we currently use. Further, decisions informed by sustainability look longer term than just the immediate future. Sustainable decisions look at least decades, if not centuries, into the future.

Sustainable cranberry production shares basic principles with broader sustainable agriculture. While some look broader than I will here, sustainability usually embraces at least three core principles: Environmentally sustainable, Financially sustainable, and Socially sustainable. These three core principles do not stand independently, but are interrelated as illustrated with a simple Venn diagram.



Environmentally Sustainable.

Cranberry nutrition that is environmentally sustainable does not pollute the environment, nor does it unduly deplete finite natural resources like rock phosphate, natural gas, and petroleum reserves. In this regard, nutrients that are required by a cranberry planting to ensure a full yield are provided in a timely manner and in a form so they can be utilized by cranberry vines. Nutrition is matched to vine genetics and known problems with a given bed. Sufficient nutrients are provided so that nutrient concentrations determined by fall tissue testing are in the sufficient range. Doing so ensures that mineral nutrients are not limiting yield. “Insurance applications” of fertilizer are not sustainable. Applying nutrients or other products that are not necessary (like gypsum) is not sustainable.

Financially Sustainable.

Practices that render a farming system unprofitable are not sustainable. Often these are considered more in terms of government regulations that require resources to meet. However, unnecessary applications of fertilizers reduce the profitability of the farming operation. Too often growers consider only the cost of the material to be applied and don’t consider the very real cost of application. In many, if not most, cases the cost of application exceeds the cost of the fertilizer material. About 10 years ago an ag economist estimated the cost of fertilizer application using a cantilevered boom at $25/acre. Since that time the cost of labor, fuel, lubricants, and depreciation have increased. I would not be surprised if the current cost were around $35/acre.

Fertilizer prices are intimately tied to the cost of petroleum and natural gas. As natural gas prices fluctuate so does the cost of fertilizer. We've seen tremendous increases in the cost of fertilizer in the last three to five years. I don't see this moderating in the near future.

Coffee shop talk in the fall centers around who had the highest yield per acre. This emphasizes the wrong metric. The question should be who had the highest net profit per acre. Of course, we are much less prone to share that kind of detail. The cost of squeezing that last barrel per acre out of cranberry vines costs substantially more than the first barrel or even the first 200 barrels. Thus your income per barrel declines at some point as more inputs are devoted to create high yields. This is not sustainable.

Socially Sustainable.

We live and work in communities with other people. Sometimes those people are negatively affected by the things we do. If we are careless with an insecticide and kill wildlife it affects our neighbors and we receive a fine for our carelessness. If we are careless and apply nutrients either where they don't belong or at rates higher than are justified we are polluting the environment. Phosphorus is a particularly good example. Excess phosphorus in fresh water leads to algae growth, reductions in oxygen in the water, which in turn leads to eutrophication of lakes, ponds, and streams. This is not being a good neighbor. Conspicuous consumption and flaunting our good fortune as growers also leads to increased scrutiny from the larger community.

Social sustainability usually requires that we treat our employees fairly and pay them a living wage and provide at least some benefits. Hiring excellent employees usually makes that easier to justify. Further, profits should be commensurate with the work and risk of growing a crop.

Increasingly the larger society wants to have a voice, and will have a voice, in how we manage our farms. Growers don't like this. They believe they take the risk and have made the investment and they should be able to manage their businesses as they see fit. Society sees that they are also at risk. Irresponsible management can pollute the environment in both the long and short term and society may bear the cost of cleanup. Society bears external costs such as resource depletion.

How to Manage Cranberry Nutrition Sustainably

The basics of sustainable cranberry nutrition are contained in the nutrient management plans that are currently being championed by the USDA-NRCS in cooperation with UW-Extension and WSCGA. The principles are as follows.

- Develop a plan that describes how fertility will be managed to ensure that mineral nutrients are never the limiting factor, but so that excess nutrients are not applied (whether or not they may ever leave the property).
- This plan is always based on tissue testing in the late summer to early fall. This is the primary source of data that justifies the need for fertilizer and provides a report card that previous applications were efficacious.
- The plan will set forth what fertilizer will be applied, how it will be applied, when it will be applied, and why it will be applied. It will also establish criteria that allow for deviations from the plan.
- The plan must be reviewed by an external group that does not stand to benefit from the plan (i.e. salespeople). Currently NRCS is providing that review.
- Follow the plan. If deviations from the plan are required those must be documented.
- Examine the data you have and fine tune the plan for subsequent years.

It is critical that this plan is data driven and that it generates data that continues to justify application of nutrients. These data protect you! You can also use these data to improve your operation if you will take the time to learn from it.

Current notions and practices that are not sustainable

1. *"Whatever actions I may take on my marsh are protected by the Wisconsin Cranberry Laws."*

Wisconsin's Cranberry Laws certainly protect your access to water, but they don't allow you to pollute at will. Cranberry growers are still subject to the provisions of the federal Clean Water Act. A recent lawsuit showed that cranberry growers can be subject to litigation. While the industry prevailed in this suit, it was not a resounding victory. Simply having fertilizer application records could have led to dismissal of the suit. In the absence of real data courts will accept reasonable proxy data. This lawsuit was a "near disaster" for the industry. If environmental litigation of cranberry growers becomes commonplace your liability insurance rates will skyrocket.

2. *"As I apply more fertilizer, yield will increase. Fertilizer is the primary limiting factor for yield. If I apply more fertilizer the concentration of the elements I apply will increase in the vines."*

None of these preceding statements is always true! Yield is influenced and limited by many factors that are not even distantly related to fertilizer. These include pest management, weather, water management, and genetics.

3. *"It is better to apply something than to do nothing."*

This notion leads growers to apply fertilizer and other products that are either not needed or useless. Gypsum is the best example. Gypsum will not reduce soil pH. Gypsum will not improve drainage of cranberry beds. Gypsum will provide calcium, but cranberries are not heavy calcium feeders. Gypsum is effective in the treatment of sodic soils, but Wisconsin has no sodic soils and is 1,000 miles away from substantial salt sources (seawater). Applying gypsum makes fertilizer salespeople rich and reduces the profitability of cranberry farms, not to mention the fuel and labor wasted to source and apply gypsum. Ask for efficacy data from your supplier. Testimony is insufficient justification.

4. *"Designing an effective nutrition program for cranberries is difficult, therefore, a consultant is required to ensure the fertilizer program works."*

Bunk. Fertilizing cranberry vines is not conceptually difficult. The principles are simple:

- apply enough fertilizer to ensure that mineral concentrations in tissue samples are in the sufficient range;
- make several small applications as opposed to a single large application;
- spread the nutrients uniformly over the bed surface and water them into the soil;
- watch the size of the crop and the amount of upright growth you get in the spring and adjust nitrogen to get the correct amount of growth.

5. *"Micronutrients are the key to high yields."*

This is also unsubstantiated by data. Cranberry vines require micronutrients in micro amounts. As long as the nutrients are in the sufficient range in tissue tests they will not be limiting. Micronutrients can become toxic when tissue concentrations are extremely high. I have seen boron toxicity in Wisconsin cranberry vines. This was a result of very poor advice provided by a consultant. In this case the nutrient application actually reduced rather than enhanced yield.

In Conclusion

Cranberry nutrition practices can be sustainable. However, to become so growers will have to rely on data and make data driven decisions. Thinking long term and not only for the current year will assist in making good decisions. For good or bad, society increasingly wishes to influence how agriculture is conducted. To some extent this can be pre-empted by setting some sort of standard agricultural practices and then having the proposed practices for individual marshes reviewed by an industry advisory committee with membership beyond the industry. This sort of "arms length" review will provide credibility to the larger community and should help prevent criticism and ultimately litigation.

The best measure of sustainability is to question if a practice will allow your children, grandchildren, and great-grandchildren to raise cranberries on your land if they wish. That is a metric that is easy to use and one that is almost infallible.

UNDERSTANDING HOW SOIL pH AND OTHER SOIL CHARACTERISTICS IMPACT NUTRIENT AVAILABILITY

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In soil science, pH is referred to as the master variable, as it controls many of the chemical and biological processes in the soil system. This is especially true when it comes to nutrient availability. Other soil properties, such as soil moisture and soil texture, also affect nutrient availability. It is important to understand the relationship between pH, soil properties and nutrient availability when developing or evaluating a nutrient management program for cranberry production. This paper provides an overview of these concepts.

How Plants Take Up Nutrients

Nutrients exist in soils as ions in the soil solution; bound to exchange sites on clay and organic matter; or as part of organic matter, microbial biomass, and minerals. Plants primarily take up nutrients available as ions in the soil solution, as they are easier to extract than are nutrients held tightly to soil exchange sites or attached to organic matter. Nutrients are often present in low concentrations in the soil solution; however, in natural systems, the soil nutrient pool is typically large enough to easily replace nutrients in solution when they are removed. In agricultural production systems, supplemental nutrient applications are required to maintain nutrient levels.

There are three ways that plants take up nutrients from the soil solution: (1) root interception, (2) mass flow and (3) diffusion.

1) *Root interception* occurs when the root grows toward and intercepts the nutrient. Roots come into contact with less than 1% of the soil volume, so root interception is not the primary uptake mechanism for most nutrients.

2) *Mass flow* occurs when the nutrient is brought to the root via movement or flow of water.

3) *Diffusion* occurs when nutrients move from areas of high concentration to areas of low concentration.

The relative contribution of each process varies from nutrient to nutrient (Table 1). The process that is most important for the transfer of the majority of plant nutrients is mass flow; however, diffusion is the most important process for macronutrients such as P and K.

Soil Moisture and Nutrient Availability

Soil moisture affects root interception, mass flow and diffusion. Low soil moisture can inhibit plant growth, leading to lower root biomass, and thus, lower ability for root interception to occur. Low soil moisture can also result in a breakdown of the diffusion pathway between the nutrient and the root. The diffusion process requires the plant and nutrient be connected by a water pathway. As the soil dries, more of the pathways are filled with air instead of water, resulting in the nutrient being cut off from the root or having to take a longer pathway to reach the root. A commonly cited statistic is that increasing the soil moisture from 10 to 28% increases the total K transport by 175%. Thus, it is important to consider your soil water management as it can heavily impact P and K uptake.

Table 1. Relative contribution of uptake/transport mechanism of macro- and micro-nutrients. [Adapted from Barber, Soil Bionutrient Availability (1984).]

	Percentage supplied by		
Nutrient	Root Interception	Mass Flow	Diffusion
	-------------------- % --------------------		
N	1	99	0
P	3	6	94
K	2	20	78
Ca	100+	100+	0
Mg	38	100+	0
S	5	95	0
Cu	10	100+	0
Zn	33	33	33
B	10	100+	0
Fe	11	53	37
Mn	33	100+	0
Mo	10	100+	0

Soil pH and Nutrient Availability

Low soil pH (acidification) occurs for a variety of reasons, including: acidic parent material, leaching of cations, plant removal of cations, addition of fertilizer and secretion of organic acids by plant roots. Low pH soils, while ideal for cranberry production, can limit the availability of some nutrients (Fig. 1). For example, phosphorus (P) is most available in a pH range of 5.5 to 7.0. Below pH 5.5, P gets "tied-up" with iron and aluminum oxides into forms of P that are not available to plants.

Nitrogen uptake can also be limited in low pH soils; however, this is not an issue for cranberry production. Low pH hinders the nitrification process (the conversion of ammonium to nitrate by microorganisms). In soils used for cranberry production, available nitrogen exists primarily as ammonium (as opposed to nitrate). Cranberries are well adapted to growing in low pH soils and actually prefer to take up nitrogen in the ammonium form. It is interesting to note that the nitrification process is an acidifying process. The microbial oxidation of ammonium releases H+ ions into soil solution, causing a decrease in pH. Nitrifying bacteria create an environment that inhibits their own productivity.

Soil pH also affects the amount of base cations (Ca^{2+}, Mg^{2+}, K^{+}) that are retained on soil exchange sites. At a lower pH, Al^{3+} and H^{+} ions are preferentially absorbed on exchange sites so the soil has less affinity to hold onto the cations that are important crop nutrients.

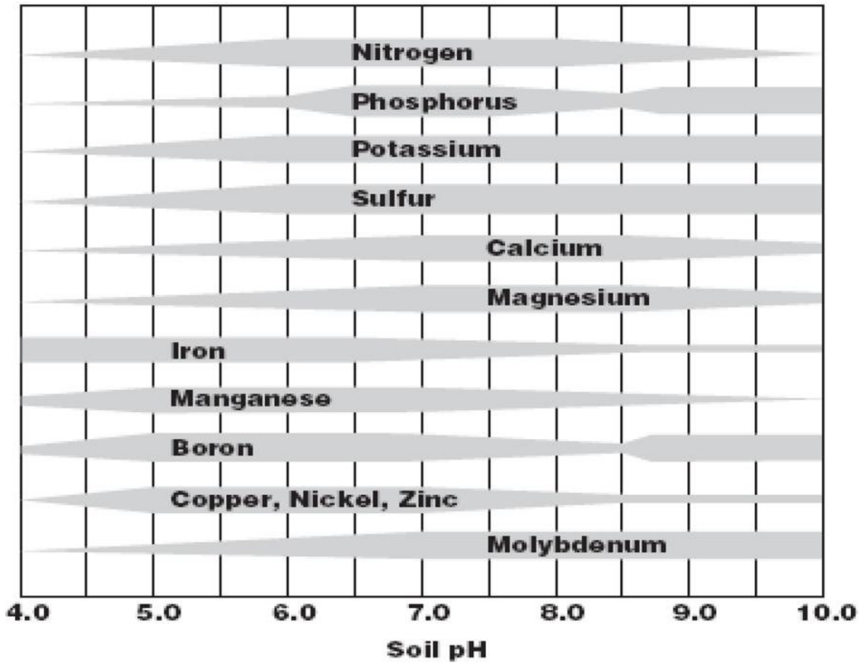

Figure 1. Conceptual diagram of the relative availability of crop nutrients across a pH gradient. A wider bar indicates greater availability. (From: Schulte et al. 2005. Management of Wisconsin Soils, UWEX A3588)

Soil Texture and Nutrient Availability

In general, soils with more organic matter or clay content are more "buffered" or resistant to pH change as compared to soils with low organic matter or sandy soils. The pH that is measured by a routine soil pH test is a measure of the active acidity; however, when we want to adjust the pH we also have to consider the reserve acidity. The diagram in Fig. 2 illustrates the relative reserve acidity in three different types of soil (organic, mineral, and sandy) with the same active pH. It will take more liming material to adjust to the desired pH in high organic matter soils as compared to mineral or sandy soils because of the additional reserve acidity. Table 2 illustrates that more elemental sulfur (S) would need to be applied to adjust soil pH as the organic matter content of a soil increases.

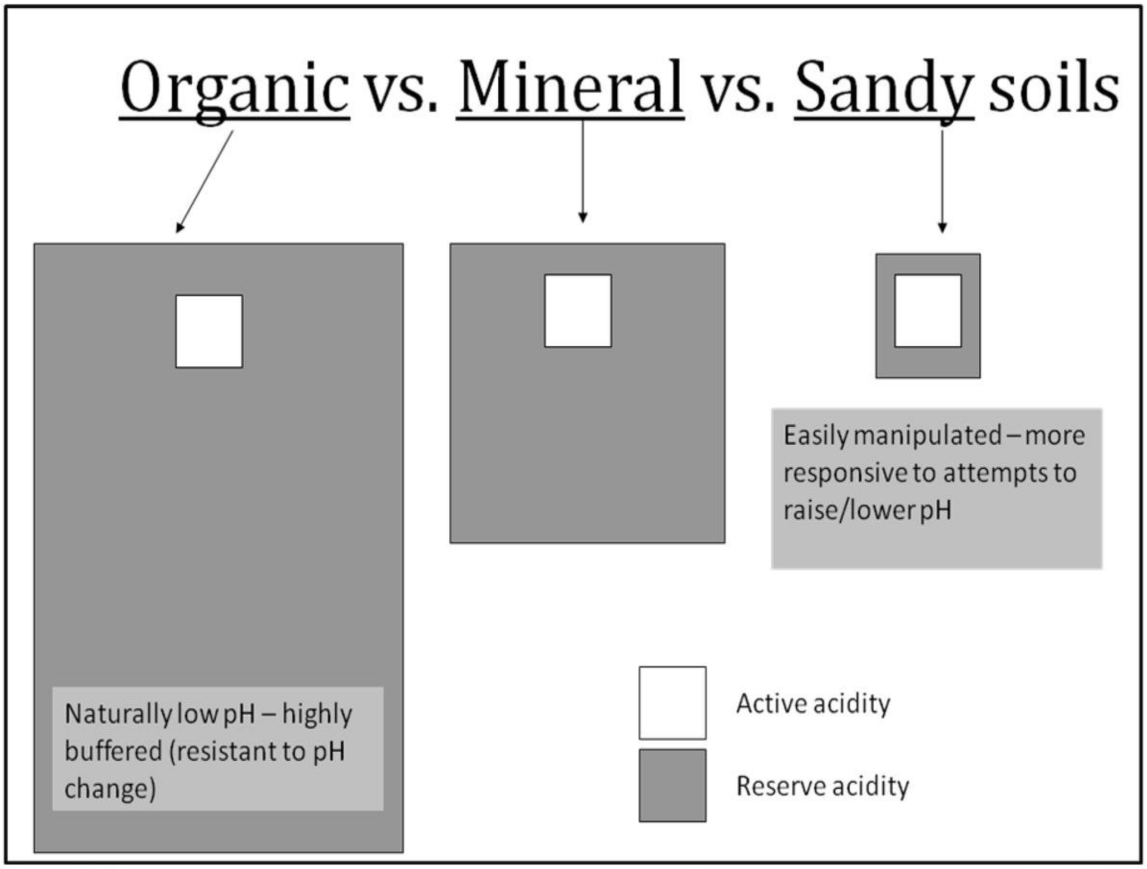

Figure 2. Example of the relative reserve acidity in organic soils (e.g. muck, peat), mineral soils (e.g. clay loams), and sandy soils.

Table 2. Amount of finely ground elemental sulfur needed to lower soil pH (adapted from Laboski et al. 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UWEX-A2809)

Reduction	Soil organic matter content (%)					
in pH	0.5-2	2-4	4-6	6-8	8-10	>10
		-------------------- lb S/1000 sq.ft.--------------------				
0.25	6	18	28*	40*	53*	62*
0.50	12	35*	56*	80*	106*	125*
1.00	24*	70*	112*	120*	212*	250*

*Do not apply more than 20 lb of S per 1,000 sq.ft. per year; retest between applications

Cation Exchange Capacity

Cation exchange capacity (CEC) is a measure of the soil's ability to retain cations (e.g. Al^{3+}, H^{+}, Ca^{2+}, Mg^{2+}, K^{+}, NH_4^{+}, Na^{+}). The CEC is a natural soil characteristic that can affect nutrient retention and nutrient availability. A soil's CEC is affected by the organic matter and clay content of the soil. As the organic matter and clay content of a soil increase, so does the CEC (Table 3). While CEC provides interesting information about the chemical and physical nature of the soil, it is not useful as a management tool.

Table 3. Examples of cation exchange capacity values across a range of soil textures.

Soil type	CEC (meq/100g)
Light color sands	3-5
Dark color sands	10-20
Loams	10-15
Silt loams	15-25
Clays and clay loams	20-50
Organic soils	50-100

Summary

- Managing soils to maintain water holding capacity and soil moisture will improve nutrient uptake (e.g. reduced compaction, timely irrigation), especially for those nutrients that rely on diffusion for plant uptake (e.g. P and K).
- In cranberry systems, maintaining a low soil pH is important for ensuring nitrogen is available in the plant-preferred ammonium form.
- A measure of soil organic matter content is required for proper elemental S application when attempting to maintain low pH levels.
- If nutrient deficiencies occur on your farm, it is important to know the soil pH and the soil organic matter content.

ASSESSING BIOLOGICAL IMPACTS OF IPM ADOPTION BY THE WISCONSIN CRANBERRY INDUSTRY: A PROGRESS REPORT

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Background

Since the initiation of the university's pilot Integrated Pest Management program in the 1980s, the Wisconsin cranberry industry has become a national leader in the implementation of IPM. Initially, IPM adoption meant using pest monitoring to make economically justifiable decisions on the need for controlling pests at any given time. Using this approach, growers substantially decreased the usage of broad spectrum insecticides. In more recent years, with the availability of more selective types of insecticides, many growers are going this additional step to reduce potential negative impacts associated with older broad spectrum materials. Overall, the adoption of these IPM practices has been beneficial to the industry. When reducing the use of broad spectrum insecticides, one of the expected benefits is the increase in beneficial natural enemies (such as predaceous and parasitic insects and spiders) that are important in biological control of pests.

Although the economic, environmental, and human health benefits of IPM are substantial and well documented in many types of crops, IPM adoption is not totally without risk. One occasional side effect resulting from significant reduction in broad spectrum pesticide use is the increase in numbers of "secondary" or "occasional" pests that had previously been inadvertently controlled. When such cases happen, the pest management program has to be modified to compensate. One possible example of such a situation is the recent reported increase in Massachusetts and New Jersey of bluntnosed leafhopper, a vector of the pathogen causing cranberry false blossom disease.

This progress report summarizes research that is assessing impacts of IPM adoption in Wisconsin cranberry production on populations of beneficial natural enemies. It also reports on a survey to detect the presence of bluntnosed leafhopper.

Methods

To assess the biological impacts of IPM adoption, 14 cranberry farms have been sampled during each of two field seasons (2008 & 2009) (1) to determine the abundance of natural enemies present and (2) to survey for the potential presence of bluntnosed leafhopper. Four of the farms were producing for the certified organic market and 10 were conventional farms. The conventional farms were spread along a continuum of degree of IPM adoption. Three sampling methods were used: (1) sweep sampling for insects and spiders within the cranberry canopy, (2) yellow sticky traps to sample insects flying just above the cranberry vines, and (3) pitfall traps to sample insects and spiders on the soil surface beneath the cranberry canopy. Sweep sampling was done every 1-2 weeks until onset of flowering; sticky trap and pitfall sampling was done season-long.

Growers provided their pesticide use records. Cornell University's Pesticide Environmental Impact Quotient program was used to assess "Natural Enemy Toxicity" scores (NETs) for each farm. Basically, the EIQ uses published research data to assess potential pesticide impacts vs. a diversity of study targets. One target group consists of beneficial natural enemies that are present in agriculture and that help control pest populations. Table 1 is an example of individual pesticide toxicity scores vs. beneficial natural enemies.

Table 1. Examples of pesticide toxicity scores to beneficial natural enemies.

Trade Name	Active Ingredient	Toxicity to Beneficials
Confirm	tebufenozide	12.2
Entrust	spinosad	14.9
Guthion	azinphos-methyl	44.8
Diazinon	diazinon	47.5

Individual toxicity scores for each pesticide for each farm are calculated based upon rates and frequencies of use, then all individual toxicity scores are grouped together to determine a seasonal total NETs for that farm. Total toxicity scores for all 14 farms for 2008 are shown in Table 2. Scores for 2009 are also shown for those farms that have reported and have had their data summarized. Scores were arbitrarily grouped into "Low", "Medium", and "High" categories for data analysis.

Table 2. Season-long insecticide natural enemy toxicity (NET) scores for each of the 14 farms. Organic farms are shaded in gray.

Year	Low						Medium				High			
2008	4	4	4.6	13	22	33	55	82	103	129	188	233	256	309
2009	NA	NA	NA	NA	39	30	31	NA	95	245	282	226	NA	NA

Results

Results to Date – Natural Enemies.

Natural enemy numbers for 2008, for each of the three sampling methods are summarized in Table 3.

Table 3. Seasonal total natural enemies, all three sampling methods combined, by farm, 2008.

	Conventional Farms										Organic Farms			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Sweep samples	12	41	36	16	6	15	31	44	24	37	49	65	37	54
Yellow sticky traps	1856	1121	1168	645	1035	1341	1011	1217	1033	975	831	1421	1235	998
Pitfall traps	437	670	154	110	97	492	215	303	278	122	119	780	595	1204
Total, all samples	2305	1832	1358	771	1138	1848	1257	1564	1335	1134	999	2266	1867	2256

For conventional farms, natural enemy numbers ranged from a low of 771 to a high of 2305 with an average of 1454. For organic farms, natural enemy numbers ranged from a low of 999 to a high of 2266 with an average of 1847. Organic farms averaged 27% more natural enemies than conventional farms.

Figure 1 shows the 2008 seasonal natural enemy totals collected per farm for each of the three toxicity categories (1=low, 2=medium, 3=high). The tops and bottoms of each of the three bars are the high and low farms, respectively, and the bold horizontal line is the average for all farms in the category.

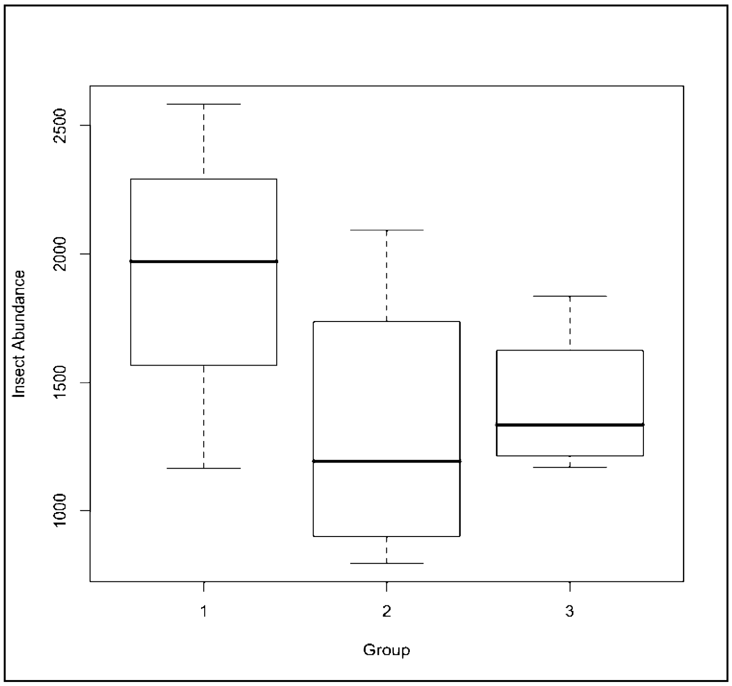

Fig. 1. Beneficial natural enemy abundance in 2008 on farms with low (1), medium (2), and (3) high natural enemy toxicity scores.

Although there is a trend for low toxicity farms to have more natural enemies than medium and high toxicity farms, statistically, there were no significant differences for the 2008 season. Therefore, sampling intensity was increased in 2009, and the counts are presented in Table 4.

Table 4. Seasonal total natural enemies, all three sampling methods combined, by farm, 2009.

	Conventional Farms										**Organic Farms**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Sweep samples	26	2	24	19	37	53	19	19	19	33	12	45	38	66
Yellow sticky traps	3972	4447	4666	6164	4194	3998	4423	5456	3461	5066	3534	7034	6950	5915
Pitfall traps	605	405	396	837	3578	501	1209	554	1453	734	611	3259	2098	2966
Total, all samples	4603	4854	5086	7020	7809	4552	5651	6029	4933	5833	4157	10338	9086	8947

Data analysis has not been completed for 2009 data. But to summarize, for conventional farms, natural enemy numbers ranged from a low of 4552 to a high of 7809 with an average of 5637. For organic farms, natural enemy numbers ranged from a low of 4157 to a high of 10,338 with an average of 8132. Again, it is interesting to note that organic farms had significantly more natural enemies than conventional, 45% more in 2009.

Results to Date – Leafhoppers.

Leafhopper samples for 2008 are summarized in Table 5. The most effective sampling method was yellow sticky traps but pitfall trap data are also presented. Most of the leafhoppers sampled were either potato leafhopper or aster leafhopper, both of which have a very broad host range. It is important to note that no bluntnosed leafhoppers, the vector of false blossom, were collected from any farm. Organic farms averaged higher numbers of leafhoppers (153) vs. conventional farms (122); this is to be expected with less reliance on broad spectrum insecticides.

Table 5. 2008 season total leafhopper counts from yellow sticky cards and pitfall traps, all species combined.

Conventional Farms										**Organic Farms**			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
84	148	253	18	78	98	141	181	124	98	98	190	250+	76
									Ave - 122				**Ave - 153**

In 2009, a total of 12,308 leafhoppers were collected; none were bluntnosed leafhopper.

Summary

Data from 2008 showed a trend suggesting that more beneficial natural enemies are on farms with lower Natural Enemy Toxicity scores, but statistically the trends were not significant. Therefore, a greater sampling intensity was used in 2009; data analysis is not yet complete.

For both years combined, over 13,000 leafhoppers were collected from sticky traps placed in cranberry beds; none of these were bluntnosed leafhopper, the vector of the pathogen that causes false blossom disease.