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ASSESSING BIOLOGICAL IMPACTS OF IPM ADOPTION BY THE WISCONSIN CRANBERRY INDUSTRY: FINAL 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 decisi ons 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 report summarizes research that assessed 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. It also introduces the concept that patterns of usage of land surrounding cranberry beds likely have an impact on the beneficial natural enemies found within the beds.

PART 1: PESTICIDE IMPACTS

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. Cornel 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 and 2009 are shown in Table 2. 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	5	13	34	47	55	82	103	129	188	233	256	309
2009	2	2	54	2	8	31	30	58	95	245	148	282	226	77

Results

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

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

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.

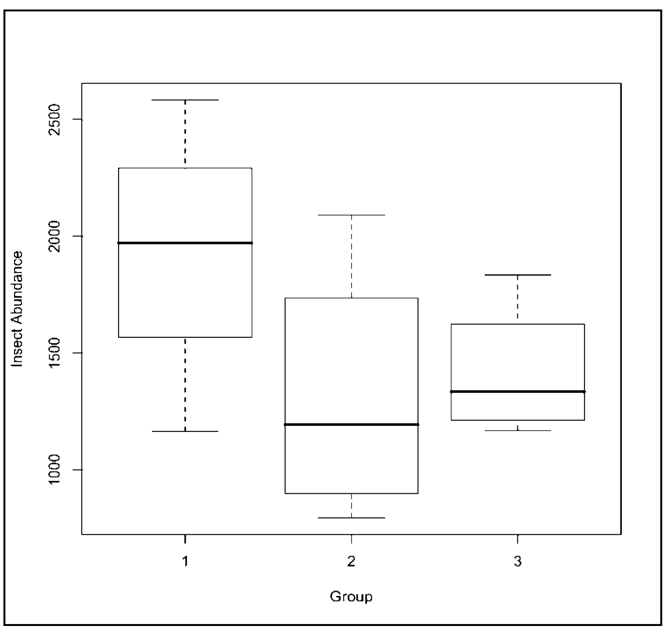

Fig. 1. Beneficial natural enemy abundance in 2008 on farms with low (1), medium (2), and (3) high natural enemy toxicity scores.

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

To summarize 2009 data, 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.

Natural enemy data analysis was conducted in numerous ways. When looking at the simple relationship between toxicity units vs. abundance and diversity of natural enemies, there were noticeable visual trends (such as Fig. 1) but few cases of statistically significant differences. Therefore, over 100 statistical analyses were conducted, each specific to over 20 natural enemy groups, and by sampling method and by year. Only four of these specific analyses showed statistically significant relationships between toxicity category and natural enemy abundance.

In addition to analyzing the data by total toxicity scores, we also looked at the relationship between the number of applications of broad-spectrum insecticides (oranophosphates and carbamates) and the abundance of natural enemies. Here we found that there was a strong statistical trend for fewer natural enemies on those farms that used more broad spectrum insecticides.

We also looked at the numbers of natural enemies present before an application of a broad-spectrum spray vs. after the spray. Again, we found solid evidence that numbers of natural enemies were lower in the samples after broad-spectrum sprays. However, we also found that natural enemy numbers rebounded fairly rapidly.

Results – Leafhoppers. Leafhoppers are very common plant-feeding insects. There are many different types and their feeding (host plant) preferences vary. In the two years of this study, over 14,000 leafhoppers were collected during our routine sampling for natural enemies. Most of the leafhoppers sampled were either potato leafhopper or aster leafhopper, both of which have a very broad host range, but are not known to cause any damage to cranberry. Two bluntnosed leafhoppers, the potential vectors of the false blossom pathogen, were found. This should not cause concern as the insect is native to Wisconsin and it is surprising we did not find more. We only need to continue to be alert for signs of false blossom and take action if necessary. Amongst our newer insecticides there are products known to be very effective in controlling leafhoppers, so pest management tools are already in place should they someday be needed.

Summary and Discussion of Pesticide Impacts

Large numbers of beneficial natural enemies are found on Wisconsin cranberry farms.

Annual marsh insecticide toxicity scores had a very broad range, from a low of 2 to a high of 309.

Toxicity scores varied substantially from year to year on some beds, presumably resulting from actions needed to respond to IPM scouting information.

Surprisingly, there were relatively few statistically significant relationships between total insecticide toxicity and natural enemy numbers.

However, there were fewer natural enemies on those farms using more broad-spectrum insecticides (in the organophosphate and carbamate classes). This suggests that broad-spectrum materials are more damaging to natural enemies.

Also, there were often significant declines in natural enemy numbers in those samples taken following a broad-spectrum application. However, natural enemy populations tended to rebound quickly, suggesting that other environmental factors on cranberry farms may be acting to maintain high levels of natural enemies (see **PART 2**, below).

Two of over 14,000 leafhoppers collected were bluntnosed leafhopper, indicating that the insect is present, but at very low numbers and not requiring attention other than continued vigilance.

PART 2: THE LAND USE HYPOTHESIS

Background

The large numbers of natural enemies found during our survey, and the ability of the natural enemy community to rebound quickly after insecticide applications, suggested to us that other factors might be important in maintaining natural enemy numbers on cranberry farms.

Research in many cropping and natural systems has shown that land use patterns adjacent to croplands can have a significant impact on the abundance and diversity of natural enemies within the crops. This primarily relates to the needs that natural enemies have to survive as living organisms:

- many predaceous insects will starve or leave the area when pest species are in low numbers; therefore alternate types of prey, that live on alternate (non-crop) plants, can serve as essential food resources for predators when pest species are scarce;

- the adults of most parasitic wasps that attack pests need to feed on alternate food sources that provide energy while they are searching for pests to parasitize; important alternate food sources are nectar and pollen derived from flowers; these floral resources need to be present throughout the growing season;

- both predaceous and parasitic natural enemies require undisturbed habitat where they can seek shelter from storms or other adversity, rest during their normal daily activity cycles, and be protected from harsh winter weather in appropriate overwintering sites.

We therefore conducted a preliminary study to determine if there were relationships between natural enemy numbers in cranberry beds and the types of potential natural enemy habitat surrounding those beds.

Methods

Satellite imagery was used to identify the cranberry farms participating in this study and the specific beds sampled. Geographic Information System (GIS) software was used to categorize the habitat surrounding each of our specific sample sites in radii of 500 m and 1000 m. Land use was classified into three categories: (1) agricultural (crop land, including cranberry), (2) non-habitat (hardscape (buildings, roads, parking lots, etc.) and water), and (3) natural enemy habitat (pasture, forest, herbaceous cover, vegetated wetlands, etc.). The numbers of natural enemies from our samples were statistically compared with the amount of natural enemy habitat adjacent to the sample sites.

Results and Discussion

On average, 65% of the area surrounding our sample sites was categorized as natural enemy habitat. This is a very high value compared with many other cropping systems; in some other crops, as little as 2% of surrounding land can be considered ideal natural enemy habitat. Certain statistical relationships between natural enemy abundance and amount of good habitat were found. For example, there were significant relationships for spiders (general predators), the parasitic wasp family Trichogrammatidae (parasites of the eggs of moths and other insects, including some cranberry pests), and the parasitic wasp family Platygastridae (some species in this family parasitize tipworm larvae). Therefore, we feel that natural enemies are favored by the abundance of “natural” habitat land surrounding cranberry farms, and therefore the natural existing biological controls likely are important in our Integrated Pest Management programs.

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CRANBERRY DISEASES AND FRUIT ROT CONTROL

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Fungal diseases are an important component of cranberry culture. The crop is susceptible to a wide variety of diseases that range in impact from severe to benign (Table 1). Some diseases, such as cranberry leaf gall, are extremely rare and when they occur may have little or no economic impact. Other diseases can flare up in certain years and disappear the next. This is certainly the case with cranberry fruit rot in Wisconsin. It is important to understand that although many diseases described on cranberry are found in all growing regions, some diseases such as fairy ring are more limited in distribution (Table 1). Other diseases such as Valdensinia leaf spot have not yet been reported on cranberry but represent a significant threat. As stakeholders in the cranberry industry we need to be aware of the micro-organisms that travel with our crop and take precautions not to introduce novel pathogens into areas where they do not currently exist. Valdensinia leaf spot is a prime example of such a disease.

Table 1. Some economically important fungal and fungal-like diseases of cranberry and the distribution of those diseases

Disease	Causal Agent	Distribution
Phomopsis Upright Dieback	*Phomopsis vaccinii*	WA,OR,MA, NJ, WI, MI
Fairy Ring	*Helicobasidium species*	NJ, MA
Valdensinia Leaf Spot	*Valdensinia heterodoxa*	BC, WA, OR, NS, NB, ME (on blueberry and other Ericaceae)
Cottonball	*Monilinia oxycocci*	OR, WA, MA, WI, ME, AK
Rose Bloom/Red Leaf Spot	*Exobasidium* species	MA, WA, OR
Phytophthora root and runner rot	*Phytophthora* species	MA, NJ, OR, WA, BC, WI
Fruit Rot	See below	See below

Many diseases have a unique causal agent and some diseases such as fruit rot may be caused by more than one pathogen. Since each pathogen has unique characteristics in terms of life cycle, sensitivity to pesticides, and response to environmental parameters, each one must be managed using a series of recommendations that are developed specifically to that disease and causal agent. Each set of recommendations is developed for a specific geographic region and applying recommendations outside of that region is risky and may not provide the expected results. Therefore each time a disease is introduced into a region time and money must be spent learning how to manage the disease, and during that time, potential yield will lost.

One of the most important first steps that should be taken in developing disease management programs is diagnosis. Improper diagnosis can lead to wasted time and expense. For example, there are several species that can cause Phytophthora root and runner rot. Each species has distinct temperature optima and fungicide sensitivity and therefore one recommendation does not cover all species. It is often critical to know exactly which pathogen species is present.

Cranberry fruit rot

Cranberry fruit rot is caused by a complex of several fungal species that, with the right environmental conditions, can act individually or in combination to destroy up to 100% of fruit in a cranberry bed. In Wisconsin, prior to about 2003, fruit rot was rare, and fungicides were used by only a few growers. In the past few years, however, fruit rot has become more common and severe, with reports of 20-40% rot at several marshes. Why is this happening, and what can we do about it?

In Wisconsin we have the same set of pathogens that are present in New Jersey, where they would have annual crop failures if fruit rot were left unchecked. We plant many of the same varieties, although perhaps in different proportions. What differs between Wisconsin and New Jersey is the environment. Wisconsin generally has cooler, less humid summers and shorter growing seasons than New Jersey. The 2010 season was an exceptional one in Wisconsin. The month of April was the second warmest on record, which advanced plant phenology, and therefore the growing season, by 3-4 weeks. Although the summer days were not terribly hot, the nights were warmer than usual. In many parts of central Wisconsin, frequent and heavy summer rains left berries underwater for several hours, or at least left beds wet for prolonged periods. ***Taken together, fungal pathogens had ideal conditions to rot cranberry fruit, and they had an extra month to do it!***

The weather is the first thing that we think about when discussing “environment.” However, cultural practices also strongly influence environment in a cranberry bed. The open canopies of newer beds tend to be warm, and that may be why diseases such as early rot (*Phyllosticta vaccinii*) are worse in newer beds than in established beds. In the past decade growers have been demanding more from new and older beds alike. New plantings are being pushed hard with nitrogen. This results in plants with lots of leaves that are supported by small root systems. More leaves are favorable for fungi, since the fungi like leaves every bit or more than they like fruit. More leaves means more irrigation is required. Lots of water on a warm, sandy bed with soft, rank runners is the perfect storm for disease. In established beds the new “norm” is 400+ barrels per acre. Such heavy crops mean that berries are packed together deep in the canopy where they remain wet for most or all of the day. In addition to creating an environment ideal for disease, fungicide coverage is more difficult as cultivation practices become more intensive to support a canopy that feeds high yielding beds.

Recommendations for fruit rot management

The current recommended control measures rely on five fungicides: ferbam, mancozeb, chlorothalonil, azoxystrobin and fenbuconazole. All of these fungicides work best when applied before infection occurs, and the key to effective fruit rot management is accurate timing of the fungicide applications. We have found that phenology of flowering is the best indicator for timing applications. In Fig. 1 you can see how rapidly control is lost by delaying the first fungicide application. Applications initiated during bloom perform consistently better than those initiated after bloom. In New Jersey the period where fungicide applications are critical range from early to mid-bloom until three weeks post bloom. Maintaining a fungicide residue on the fruit surface during this time will reduce the incidence and risk of fruit rot.

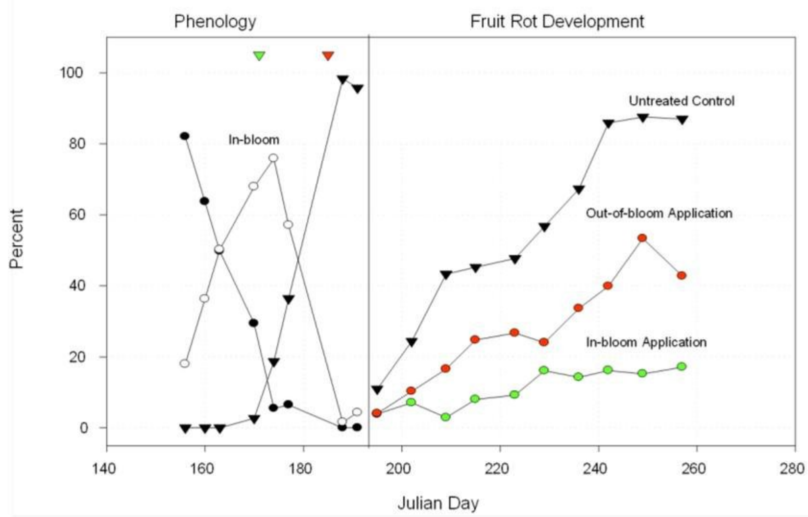

Fig. 1. A comparison of fruit rot development under different treatment timings and an untreated control. Each treatment consisted of two applications of chlorothalonil made 14 days apart. The start date is indicated by a triangle on the phenology side of the chart. The chart demonstrates the

Each of the registered fungicides displays different properties and should be used in a manner that optimizes efficacy and minimizes phytotoxicity. In Table 2 we have summarized the characteristics of each fungicide as it applies to cranberry fruit rot use and control.

TABLE 2. FUNGICIDE USE RECOMMENDATIONS FOR CRANBERRY FRUIT ROT				
Fungicide*	**REI**	PHI	**Maximum amount permitted**	**Suggested use**
Abound	4 h	3 days	92.3 fl.oz product	Use at early bloom in combination with Indar. Narrow spectrum fungicide with low efficacy to *Coleophoma*.
Chlorothalonil*	12 h	50 days	3 applications	Use after full bloom. Very effective broad spectrum fungicide. Can be phytotoxic to flowers and scar fruit.
Ferbam Granuflo	12 h	Note**	5 applications	Use during early bloom. Moderately effective broad spectrum fungicide.
Indar 2F	12 h	30 days	4 applications	Use at early bloom in combination with Abound. Narrow spectrum fungicide with low efficacy to *Colletotrichum* species.
Mancozeb*	24 h	30 days	See label	Use during mid –late bloom. Broad spectrum fungicide; can inhibit color.
Mankocide	24 h	30 days	96 lb	Similar use pattern as mancozeb.
Copper products				Not useful for fruit rot control.
*Additional trade names: **Chlorothalonil**: Bravo 90DG, Bravo 720, Bravo Ultrex, Echo, Equus, Ensign 720, Supanil 720, Terranil 6L, Terranil 90DF. **Mancozeb**: Dithane DF, Dithane F-45, Dithane M-45, Manex II, Manzate DF, Penncozeb DF or WP, Maneb 75DF, Maneb 80, Maneb + Zinc F4. ****Ferbam** PHI is 28 days post mid-bloom				

Trouble shooting disease management failures

In 2005 a survey was conducted in New Jersey to determine the magnitude of losses due to cranberry fruit rot. In that survey 200 samples were collected from 31 beds planted to the cultivar Stevens. The total area sampled was 130 acres and the total average yield was 412 bbl/acre. Of that yield there was an average of 24% fruit rot which amounted to 9000 bbl. This result demonstrated that the management strategies were not working and required significant revision. Most of the recommendations were developed using small research plots to test chemical types and timing to optimize a spray calendar. When scaling up from plot work to commercial fields there are several factors that can lead to control failure. In the table below is a checklist of issues to help troubleshoot disease control failures.

Table 3. Factors that can reduce efficacy of a fungicide spray program for cranberry fruit rot	
Chemical type and properties	Does the fungicide spectrum of action cover all of the target species? Some fungicides have limited spectrum of action (see Table 2) and will only control certain species. It is important to know which pathogen is causing the disease and if that pathogen is sensitive to the fungicide. Was the interval between applications too long? Each chemical will dissipate at a different rate. This property dictates how frequently a fungicide must be reapplied to maintain the appropriate concentration on the plant surface.
Application	Is the application calibrated to deliver the correct amount of active ingredient per acre? This is a very common mistake. Calculating the size of the area to be treated is sometimes miscalculated and can lead to undesirable effects. If chemigation is being utilized is wash-off time excessive? A general rule of thumb is that if chemigation time allows water to flow off the foliage and wet the ground, wash-off is occurring.
Timing	Was the application timed correctly and based on crop development? Applications made too early will dissipate before the pathogen is present. Applications made too late have minimal effect since the pathogen has penetrated plant and cannot be contacted by fungicide.
Pathogen	Is the pathogen you are attempting to control the one that is causing the disease? This is a situation where diagnosis can be critical. Since cranberry fruit rot can be caused by many species of fungi as well as abiotic causes, proper diagnosis is critical.
Distribution (in canopy)	Was the fungicide distributed within the canopy? Applications are sometimes made that do not penetrate the canopy. In those cases, fungicidal control is greatly diminished in the area where the crop is concentrated.
Distribution (in field)	Was the chemical applied uniformly to the field? Depending on the equipment being used applications can be extremely variable. This can lead to some areas with excessive residues and others with insufficient residues.
Chemical stability and compatibility	Is the chemical stable in the diluent being used? Are the other components in the tank compatible with the fungicide being applied? For example, Abound should not be mixed with emulsifiable concentrates or silicon based adjuvants since these mixtures may promote phytotoxic responses.

Conclusions

Fruit rot control is a critical component to producing healthy, profitable crop. High levels of fruit rot can affect yield as well as quality and create many problems during harvest and delivery. In some regions fruit rot is problematic every year, whereas in other areas such as Wisconsin fruit rot occurs occasionally. It is evident that the fungal load is sufficient in Wisconsin to cause significant loss; however, the environment dictates if it will be a “bad” fruit rot year or not. It is likely that significant expenditure on fungicides and crop loss to fruit rot could be avoided if the threat of fruit rot could be predicted. Such a predictive scheme could likely be implemented through research.

ADDRESSING SUSTAINABILITY IN U.S. AGRICULTURE:
BACKGROUND AND A WAY FORWARD

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While sustainable agriculture certainly is not a new topic, the use of "sustainability" as a marketing concept is. Despite recessionary times, the interest in sustainability continues to grow at a rapid pace, yet from producers to consumers much confusion exists about the meaning and value of such efforts. With this in mind, it would be prudent for agricultural producers to become engaged in sustainability discussions and take ownership of a way forward that addresses local values, manages economic risk and reduces environmental impact.

Background of sustainability and current efforts in agriculture:

The vast majority of consumers are either unaware of sustainability efforts or are confused by them. While "green," "eco-friendly," "fair," "sustainable" and other terms are very popular within marketing groups, consumers aren't necessarily engaged at a similar level. A recent International Food Information Council (IFIC) consumer survey indicated that 50% of consumers knew nothing at all about the concept of sustainability in food production, while 23% knew a little (IFIC, 2010). Consumers that are aware of the concept are often confused by it, to the point where the Federal Trade Commission (FTC) is now releasing a revision of their Green Guides – a document that provides guidance on appropriate use of the aforementioned terms in product marketing – for the first time in over a decade. According to FTC chairman Jon Leibowitz:

"In recent years, businesses have increasingly used 'green' marketing to capture consumers' attention and move Americans toward a more environmentally friendly future. But what companies think green claims mean and what consumers really understand are sometimes two different things." (FTC, 2010)

Thus far, sustainability in food production doesn't add value – it is an expectation. Much of the effort around sustainability in agriculture adds cost to production, such as additional labor costs that result from increased scouting to the actual process of documenting sustainability and enhancing biodiversity through non-crop habitat improvement. Unlike industrial processes (see below), these efforts often have a poor if any return on investment. Consumers even expect "sustainable" products to be cheaper given that they ideally would require fewer inputs to produce. Authors of a recent Deloitte/Grocery Manufacturers Association (GMA) consumer survey on the subject concluded that:

"…most shoppers would like green products to be price competitive. They often don't understand or buy into the rationale that a green product should be more expensive. Shoppers don't understand why a green product should cost more if it was manufactured with less packaging or it was transported less distance." (GMA/Deloitte, 2009)

This survey and others suggest that there is a strong difference between what consumers say they will purchase and what is actually in their grocery carts in the checkout lane. In the 2009 Deloitte/GMA survey, 95% of shoppers indicated that they would buy green but only 22% actually did so. Furthermore, only 2% were committed to buying green.

Similar consumer responses were observed in marketing challenges with the Healthy Grown Potato Program in Wisconsin. The program is the result of a unique collaboration of organizations, including growers through the Wisconsin Potato and Vegetable Growers Association, University of Wisconsin, Michael Fields Agricultural Institute, World Wildlife Fund, International Crane Foundation, and Defenders of Wildlife, among others. Research that provided the basis for the standards began in the early 1980s. The developed standards are rigorous and involve all aspects of potato production from seed through crop harvest and storage. They restrict pesticide use, require the adoption of integrated pest management (IPM), and require ecosystem services beyond the agricultural fields that are designed to preserve biodiversity in the landscape. By 2005, IPM adoption among program participants increased 30 to 40% compared to the first certified crop in 2001. In fact, the standards are so rigorous that not all fields enrolled in the Healthy Grown Potato program pass - in 2006, only 35% of the fields enrolled passed the minimum bar for certification. The Healthy Grown certification process is conducted by Protected Harvest, a third-party organization hired by the growers. The investment in research and rigor of the standard have not gone unnoticed - in 2003 the collaborative team received the **USDA Secretary Honor Award for Maintaining and Enhancing the Nation's Natural Resources and has since been the recipient of several other accolades.** While it may “feel right” to grow potatoes this way, it certainly isn’t cheap. Alternative pest management and production practices are often more expensive, the certification process requires employee time and a hired third-party organization, and growers are required to invest annually in the ecosystems services component of the standard.

An award-winning collaboration among academics, environmental advocates and growers, a rigorous science-based standard that has been documented to improve IPM adoption and preserves ecosystem services - so what’s the problem? First, consumers aren’t convinced about paying for environmental conservation, particularly in this troubled economy. Second, the potato growers have invested in a significant amount of market research and implementation into the project. After hearing about the Healthy Grown story, 70% of consumers indicated that they were more likely to purchase Healthy Grown potatoes. Moreover, of those that were interested in purchasing the product, 88% indicated that they would be willing to pay 25 cents more per bag. In 2004 and 2005, however, just over 1% of product sold was actually sold as Healthy Grown, and certainly not at a value-added price.

Sustainability is measurable in industrial processes, but isn’t easily quantified in agricultural production. Many of the inputs in industrial processes (including food processing) that pertain to sustainability, such as water, energy and fuel use can be measured as easily as reading the utility bill. The impetus is often “measurement leads to management,” and efficiencies or alternative sources are employed that have a rapid return on investment. Regardless of the input, such strategies save money. Cyber communication and monitoring technologies have made this process quite feasible and affordable. In fact, inputs are often monitored by the minute, with a red flag raised when they exceed goals. This technology also allows for direct communication with and participation by consumers. In food processing, for example, the Kettle Brand® web site (www.kettlebrand.com) includes a link to an online public monitoring system that reports electric generation from wind turbines on the roof of their Beloit potato chip plant by the minute. This alternative energy generation is then equated in terms that consumers understand, such as gallons of fuel saved.

The description of these successes in industrial and food processing is not meant at all to belittle sustainability efforts – but rather to highlight them. The use of technology to improve efficiencies is good for the manufacturer, for the consumer, and for the planet. Unfortunately, we have not been able to report such success stories when it comes to agricultural production. The sustainability parameters of interest, such as biodiversity, soil health and water quality, cannot be measured with a simple meter – they require expensive and cumbersome monitoring. Additionally, agricultural production is extremely variable by crop, production region and season, thus the one-size-fits-all approach is inappropriate. Agricultural sustainability efforts often focus on a practice-based approach given the challenges in measuring outcomes. In other words, while practice-based sustainability programs may not measure soil sediment in water, they instead ask producers about tillage practices. The National Organic Program is an example of such an approach. The challenge here is that practices may not relate directly to outcomes, or in some cases this relationship is poorly understood.

At some point, a buyer or consumer value system guides choices around sustainability. Agriculture is a complex biological system, confounded by broad seasonal variation and overlaid with management systems that vary by farm. Actions taken to improve an individual sustainability metric often affect several other parameters – and not always in a positive manner. For example, reducing herbicide use in favor of increased cultivation may reduce overall pesticide use but may also increase risk of soil erosion.

Greenhouse gas emissions in agriculture provide a striking example of the potential role of consumer values in sustainability metrics. Weber and Matthews (2008) compared the greenhouse gas emissions associated with food production with that of food distribution. They reported that 83% of the household carbon footprint associated with food is in production and only 11% in what is considered "food miles." Four percent of the greenhouse gas emissions were associated with transport from producer to retailer. Furthermore, the authors report that red meat production is about 150% more greenhouse gas-intensive than chicken or fish. The authors conclude that:

"…dietary shift can be a more effective means of lowering an average household's food-related climate footprint than "buying local." Shifting less than one day per week's worth of calories from red meat and dairy products to chicken, fish, eggs, or a vegetable-based diet achieves more GHG reduction than buying all locally sourced food."

There currently exists a wide gap between high-altitude metrics programs designed to capture change on a national scale and local, practice-based sustainability efforts. Several national efforts are currently underway that are developing programs that will capture broad change, such as at the watershed level, in typical sustainability parameters such as land and water use, energy and carbon footprint. These programs have made great headway in recent years and will be critical in the efforts to communicate advancements in agriculture to regulators, environmental advocates and the general consumer. They do not, however, instigate local engagement and change at the field level, as the intention has never been to advise someone on how to farm or develop "best management practices." Local change requires local grower engagement, regionally- and crop-appropriate best management practices and prioritization of efforts around values that are locally important. For example, 75% of the economic impact from potato and vegetable production in Wisconsin is enabled by irrigation, thus water is held as a high value by the agricultural community. In contrast, labor constraints are of relatively less concern given the mechanized nature of production in this area. The downside to local, practice-based sustainability programs is that the impact of such efforts is often not captured or communicated beyond agriculture. Additionally, the multitude of local sustainability efforts in various crops, by several entities (public and private) and without a consistent framework or process has led to challenges in duplicative programs and messaging (i.e. one production region is unintentionally put forward as "more sustainable" than other regions for the same crop, further confusing all involved) .

A way forward

Future sustainable agriculture efforts should be based in the context outlined above: consumer confusion and lack of engagement when filling the grocery cart will likely persist, sustainability programs of some sort will be an expectation and not generate a price premium and local change will require local grower action. While this seems like a lot to ask of agriculture, a reasonable way forward exists that will not be overly burdensome (economically or time-wise), will capture ground-level change and report through respected high-level communication channels and will result in regionally- and crop-appropriate best management practices.

Components of a way forward. Three pieces are necessary in a successful framework: high-altitude, outcome-based metrics and communications programs, a set of rigid guiding principles that frame and facilitate *all* local sustainability programs and regionally- and crop-appropriate best management practice (BMP) sustainability workbooks (Figure 1). The high-altitude outcome-based metrics programs are far down the road of development, are well-respected and will be integral players in this way forward. Local, practice-based (BMP) sustainability workbooks are also in development or in use in several situations. The local effort represents the appropriately nimble piece in this way forward, but would benefit greatly from the currently missing third piece – the rigid guiding principles that create common ground among programs.

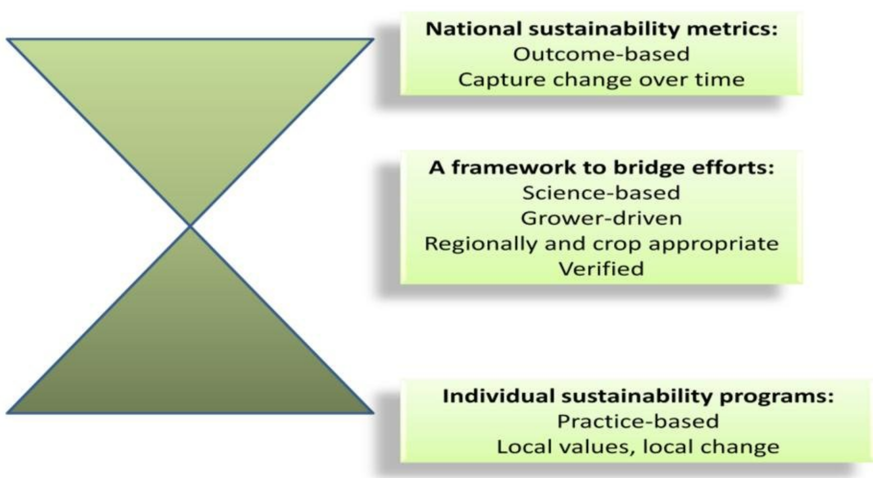

Figure 1. A way forward for sustainable agriculture efforts that combines existing or developing national sustainability metrics, a framework to bridge efforts across common ground and individual sustainability programs.

A framework of guiding principles to bridge local sustainability programs and national sustainability metrics. The rigid framework of guiding principles would be relatively simple and the result of a transparent process of agricultural producer involvement. As such, the guiding principles certainly aren't set, but could likely include:

Regionally- and crop-appropriate BMPs that are incorporated in workbooks that will guide producer decisions and provide educational materials on alternative practices. Such BMP workbooks should allow for internal or local agricultural community self-scoring, allow for local sustainability values to be emphasized and engage growers, academics and appropriate NGOs. It is reasonable that the BMP workbooks will drive education and change that could later be captured in the national metrics programs. It is important to note that the guiding principles will require BMP workbooks but will not create them, due to the focus on locally-appropriate practices.

Grower involvement in the creation of BMP workbooks in a manner that protects the economic well-being of future farming, while reducing any associated environmental risk. This local agricultural community involvement is absolutely critical given the myriad of players and interests in the sustainability arena.

While grower-involvement in the creation of local sustainability programs is critical, the efforts must also be defendable and verifiable. There are several mechanisms that should be explored, ranging from appropriate environmentally-oriented NGO involvement with groups that appreciate food and agriculture to third-party certification to a simple affidavit of responsible participation.

Local efforts must be science-based. BMPs should be based on repeatable and peer-reviewed research and not on anecdotes or irrational pursuits. Science-based BMPs currently exist or are in development in many crops and regions and would involve cooperation with appropriate land-grant institutions and other agricultural research entities.

Individual local sustainability programs will drive local engagement and change. The efforts of local and national grower organizations should be directed not only to participation in the development of the guiding principles but also in the facilitation of appropriate BMP workbook development. It is not appropriate to dictate what exists in each of these workbooks on a broad scale; that should be based on local values, issues and opportunities. This isn't to say that local efforts should ignore the parameters included in national metrics as most of these will be commonly held among crops and regions, but the specific manner in which these parameters are addressed should be a local decision. It is important to recognize and avoid potential pitfalls in the development of BMP workbooks:

Choose initial partners wisely. It is important to have a broad portfolio of interests at the table that will take ownership of the process and lend credibility (see "green-washing" below) but also have a strong appreciation for agriculture and food. Everyone has their own "agenda," openly broadcast or not, but it is important to share a common goal from the beginning of the process.

Avoid the perception of green-washing. From the outside, potential signs of green-washing might include: complete avoidance of tough issues, the attempt to simply document what agriculture has historically done without the hint of positive trajectory or change, lack of scientific basis for practices and lack of involvement from outside traditional agricultural producers.

Include practices that are defensible and science-based. Avoid anecdotal practices unless they are documented to improve the given parameter, such as "more bird boxes seem to attract more important bird species."

Recognize that taking several smell steps to improve sustainability in a given area may be just as important as one large step and that these actions are often not independent. As such, avoid the strict ranking of best management practices (such as 1 through 5, with 5 being best), as this pigeon-holes participants into a single "gold standard." Instead, offer points for a list of acceptable best management practices, allow multiple practices to be selected within a parameter and total the score in that area.

Test-run the BMP workbooks with a few producers to gauge their understanding of the questions, the appropriateness of the answers and the level of commitment required to complete the process. It is important that these documents are modified through time based on new data and growers' experiences.

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Cranberry Canopy Management

Rebecca Harbut, Department of Horticulture, University of Wisconsin-Madison

Canopy management is an important part of perennial fruit crop production. All high-value fruit crops utilize cultural practices and invest significant resources focused on canopy management. The objective of canopy management is to manipulate the canopy to achieve optimal conditions for fruit production. This includes ensuring adequate aeration to reduce disease pressure, opening the canopy and creating an even canopy to improve penetration of light and chemicals, and stimulation of new, fruitful growth. Without any canopy management, cranberry beds can develop a thick layer of unrooted runners which leads to an increasing amount of vegetative growth relying on a limited amount of roots to take up sufficient water and nutrients. Additionally, there will be reduced stimulation of new upright growth, which is critical for fruit production and a dense canopy can lead to conditions that favor disease development. Management practices used by Wisconsin growers to manage canopy growth include; nutrient management, sanding and pruning.

Nutrient Management. Nutrients, especially nitrogen, play a key role in managing the amount of vegetative growth. Increasing amounts of N application to the crop result in increased biomass accumulation (Sandler and DeMorranville, 2009). Over application of N can result in excessive vine growth, reduced reproductive uprights (Sandler and DeMorranville, 2009), increased fruit rot, and reduced yield. Tissue analysis and visual assessment of vine growth are critical to ensure that excessive N is not applied to the bed.

Sanding. Sanding is, by far, the most common practice used by Wisconsin cranberry growers on a regular basis. Every 2-5 years a layer of sand 0.5-2” thick is spread on the ice during the winter and allowed to settle on the canopy as the ice melts. As the sand settles on the canopy, it anchors runners and covers bare wood at the base of uprights, resulting in rooting and stimulation of new uprights. In addition to stimulating new root and shoot growth, sanding can provide other benefits to cranberry production. Application of sand buries leaves which increases the rate of organic matter breakdown and can burry fungal inoculum. If the application of sand is sufficiently heavy, there can be some reduced insect and weed pressure, although the effectiveness of this is dependent on a heavy, even application across the bed. A newly sanded bed can benefit from more rapid warming of soil in the spring. This cultural practice is particularly critical in new bed establishment in order to ensure adequate rooting.

While there are many benefits to sanding, there are some drawbacks. After the application of sand there is often a reduction of yield for 1 or 2 years following the application. The severity of the yield reduction depends on how heavy the sand application is (DeMoranville and Sandler, 2009). A heavy application of sand can result in uneven settling of the subsoil and it can be difficult to ensure the uniformity of the sand distribution across the bed. The cost of sanding can be significant especially if the sand is not readily available on site. Despite these drawbacks, the practice of sanding has been an important part of maintaining the productivity of cranberry beds.

Pruning. Pruning is a technique used to manage the canopy by removing vegetative growth to optimize the canopy conditions for production. In most fruit crops, pruning is the most important practice to manage the canopy and stimulate fruitful growth. The adoption of pruning as a regular practice is variable among WI cranberry growers with some using it as a regular part of a management routine and other growers that have never pruned. Cranberries are perennial vines and if left unmanaged a cranberry bed can develop uneven growth and excessive amounts of vegetative growth leading to dense canopies. The objective of pruning is to remove excessive runners, stimulate new upright growth, even out and open up the canopy to improve light and chemical penetration and air flow. Heavy pruning is also done to provide cuttings to establish new plantings.

The earliest studies on pruning were conducted in New Jersey and showed improvements in yield in the first or second year after pruning (Chambers, 1918). A more recent study showed that a light pruning (250-500 lb/Acre) had a positive effect on yield and all levels of pruning severity resulted in the same or higher yields compared to sanded beds (Table 1). Pruning of more than 1 ton/acre can result in a yield reduction of 10% or more in the following year, however the stimulation of new fruitful growth can lead to increased yields in later years (Sandler, 2010).

The benefits of pruning may vary depending on the characteristics of the bed. More fertile soils and vigorous vines may benefit the most from regular pruning. Pruning can also be beneficial if the growing conditions during the season led to excessive vegetative growth, as was the case in WI during the 2010 season. Despite reducing the amount of nitrogen applied to the crop, many growers observed excessive vegetative growth resulting in dense, uneven canopies. If the runners are left on the canopy, the fruiting zone will have reduced light penetration, aeration, and poor penetration of chemicals. A light to moderate spring pruning can remove a significant amount of the runners with minimal impact on uprights.

Table 1. Yield of cranberry beds in the year of treatment (2006) and the following year (2007). Treatments were control (no treatment applied), light, moderate and heavy sanding and pruning. (Table adapted from Suhayda et al, 2009).

Severity of Treatment	**2006 Yield** (bbl/Acre)		**2006 Yld of Pruned vs Sanded beds**	**2007 Yield** (bbl/Acre)		**2007 Yld of Pruned vs Sanded beds**	**Net Yield of Pruned vs. Sanded Beds**
	Pruning	Sanding		Pruning	Sanding		
Control	232	209	**+23**	166	202	-36	**-13**
Light	349	292	**+57**	215	215	0	**+57**
Moderate	216	137	**+79**	140	102	+38	**+117**
Heavy	177	109	**+68**	154	60	+104	**+172**

There has been a growing interest in using pruning as a complementary practice to sanding, particularly in MA where sand is often required to be transported to the cranberry marsh. When the cost of transporting sand is considered, pruning is a significantly cheaper alternative (Table 2). Although the economic benefit may not be as significant if sand is in close proximity to the marsh, it may present a cost effective compliment to sanding as it can be more effective than sanding in evening out growth in the canopy. In addition, pruning can provide income if the cuttings are sold or used on the marsh to establish a new bed or fill in poorly established areas.

Table 2. Economic analysis of pruning vs. sanding in the year of treatment (2006) and the following year (2007). (Table adapted from Suhayda et al, 2009)

Treatment Severity	**Cost of Treatment** ($/Acre)		2006 Net Value ($/A @ $38.50/bbl) Pruning vs. Sanding	2007 Net Value ($/A @ $43.40/bbl) Pruning vs. Sanding	2 Year Net Value ($/A) Pruning vs. Sanding
	Pruning	Sanding			
Control	0	0	+ 903	- 1,545	**-642**
Light	179	1,291	+ 3,341	-25	**+3,316**
Moderate	385	2,414	+ 5,129	+1,658	**+3,471**
Heavy	537	3,535	+ 603	+4,054	**+4,657**

Pruning provides growers with a technique to help manage the canopy with more controlled measures than sanding can provide. While pruning can not fully replace the role of sanding as it does not provide additional rooting medium, adding pruning into a regular canopy management program could provide growers with a technique that would improve the productivity of the bed and increase the grower's ability to precisely manage the crop.

There are several types of mechanical pruners used by growers but there are a few principles that apply regardless of the equipment (Sandler, 2010):

- Sharpen the knives and conduct regular maintenance on the pruners
- Prune water harvested beds in the spring prior to bud break
- Avoid pruning wet vines as the blade does not cut as well and vines tend to drop more leaves
- Prune in the same direction vines are growing
- If picking fresh fruit, prune at the same time as harvest

Canopy management is not a new concept in cranberry production. Early literature makes reference to the practice of mowing and burning beds that had become "dense, clumpy and tangled" (Darrow et al, 1924) to rejuvenate the productivity of the bed. Pruning was a regular part of production when cranberries were dry harvested to manage runner growth that interfered with the harvest scoops (Darrow et al, 1924). Later, machines such as the 'Furford' were developed to harvest and prune at the same time (Furford, 1959). In recent years, the focus of canopy management has been on sanding and nutrient management. Pruning offers a cost effective management technique that could significantly improve the canopy environment for producing a crop, especially in beds that tend to have uneven growth and in years like 2010 when conditions resulted in excessive vegetative growth. In these conditions, there may be benefit to including a light pruning in the regular management of the crop.

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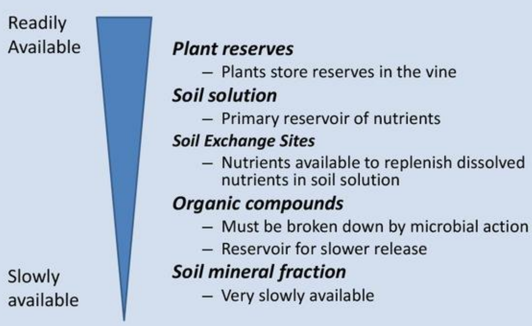
ROOTS, SHOOTS AND BOOTS:
THE NUTRIENT MANAGEMENT TRILOGY

Rebecca Harbut, Dept. of Horticulture, University of Wisconsin-Madison

Cranberries are native to low nutrient environments and have evolved strategies which allow them to be efficient at taking up and utilizing nutrients. Compared to other fruit crops, the nutrient demands of cranberries are relatively low. By utilizing diagnostics tools such as soil and tissue analysis and combining these tools with observations and experience, nutrient management plans can be developed to allow for efficient use of applied nutrients that ensures optimal crop productivity.

Nutrient Sources

Figure 1. Pools of nutrients in the cranberry bed and availability for plant uptake



The soil in a cranberry bed contains different 'pools' of nutrients that differ in regards to the availability to the plant (Fig.1). The most available nutrients are those that the plant has stored in its own tissue; this is a critical source of nutrients for the early spring growth. All nutrients that are taken up by the plant must be dissolved in the soil solution. When a fertilizer, which is in the form of a salt, comes into contact with the soil solution, the salt dissolves into its ion form. Every nutrient ion has a charge, those that have a positive charge are called 'cations' and those with a negative charge are 'anions' (Table 1). Therefore when a nutrient is taken up by the plant it is taking up an ion that is dissolved in the soil solution. There are three main mechanisms that these nutrient ions move through the soil to come into contact with the root surface to be taken up:

1) Interception – the root comes into contact with the nutrient as it moves through the soil profile, this is a minor contribution of plant nutrient uptake

2) Mass flow – the movement of ions with the flow of water. This is most important for N, Ca and Mg

3) Diffusion – the movement of ions from an area of high to low concentration. This is a slower movement of nutrients through the soil profile and is the primary transport mechanism for P and K

Table 1. Ion forms of nutrients

Cations (+ charge)	Anions (- charge)
Ammonium (NH_4^+)	Nitrate (NO_3^-)
Potassium (K^+)	Phosphate ($H_2PO_4^-$ and HPO_4^{-2})
Calcium (Ca^{+2})	Sulfate (SO_4^-)
Magnesium (Mg^{+2})	Borate (BO_3^-)
Manganese (Mn^{+2})	Molybdate (MoO_4^{-2})
Zinc (Zn^+)	
Iron (Fe^{+2})	
Copper (Cu^+)	

Part 1: Roots

Understanding the soil environment is essential to effectively manage nutrients. Four key factors play a critical role in determining the availability of nutrients to the cranberry plant: soil pH, soil composition, soil moisture and aeration and soil biology.

Soil pH. Cranberries evolved in low pH environments and require a soil pH between 4.2 and 5.5 for most efficient uptake of nutrients. If the soil is outside of the ideal conditions the nutrients are not in a form that is available to the plant. Under these conditions, a nutrient deficiency may not be corrected by adding fertilizer if the problem is due to poor availability of the nutrient, rather than presence of the nutrient in the soil.

Soil composition. A newly constructed bed is composed primarily of sand but as the bed ages, layers of organic material accumulate and the profile of the bed changes dramatically. As organic matter accumulates in the bed, there is an increased amount of nutrients supplied by decomposing organic matter and an increase in the cation exchange capacity (CEC). Soils with high CEC can hold nutrients on exchange sites that are readily available for the plants. Therefore, a soil with low CEC (ie. a new bed) will require smaller and more frequent applications of fertilizer compared to an established bed that has higher organic matter. As the bed matures, there will also be an increasing amount of nutrients that are supplied from the decomposing organic material and the soil profile will be able to retain a large amount of nutrients.

Soil moisture and aeration. As previously mentioned, all nutrients that are taken up by the plant must first be dissolved in the soil solution. Managing soil moisture is a critical component of nutrient management. A constant supply of water is important to ensure the plant can take up nutrients when needed. However, if the soil is too saturated, root growth will be negatively impacted and will reduce the ability of the plant to effectively take up nutrients. Soil moisture probes can be a valuable tool to ensure that appropriate moisture levels are maintained in the bed.

Soil Biology. Cranberries have developed symbiotic relationships with mycorrhizae, which are fungal organisms that live within the roots that benefit the cranberry plant by increasing nutrient uptake. As the bed ages, the number of cranberry roots infected by mycorrhizae increases. A new bed (2-5 years old) has about 5-10% of the roots infected with the mychorrizae, whereas a bed that is 32-38 years old can have over 80% of the roots infected with these beneficial fungi (Scagel, 2003). As the infection rate increases, the plants become more effective at taking up nutrients from the soil. In addition to mychorrizae, there are other soil bacteria that break down organic matter which provides a source of nutrients to the plants. It is important to manage the soil moisture, avoiding excessively dry or wet conditions and ensure that the bed has adequate aeration to encourage mycorrhizal and bacterial populations.

Soil Analysis

Soil analysis is an important part of nutrient management and should be conducted every 3-4 years. Soil analysis can effectively monitor soil pH, CEC and can help identify trends in soil nutrient levels, such as P accumulation or depletion. There are however some limitations to soil analysis in cranberries. Most extraction methods used by the labs are not designed for low pH soils, so the amount of nutrients available to the plant is often overestimated by soil analysis. Therefore, soil analysis and tissue analysis are often not well correlated in cranberries. Despite these limitations, the analysis provides valuable information about soil characteristics such as pH, organic matter content, and nutrient content which can help identify long-term trends. Be sure to keep your records and every time you conduct a new analysis, take out your previous reports and look for changes that may have occurred.

Part 2: Shoots

Tissue Analysis

Tissue analysis is the most accurate way to determine the nutrient status of the vines and is a critical component of a nutrient management plan. Extensive research has established sufficiency ranges for nutrient levels in the tissue during the sampling period (mid-August to mid-September), there is no benefit to having tissue nutrient levels above the sufficiency range. Annual samples should be collected to inform nutrient management strategies for the following season. When collecting tissue samples, it is important to collect samples from distinct 'management blocks', areas that you manage in a similar way. Be sure to track the changes that may occur in your tissue analysis by looking at previous years reports and record the relationships between nutrient status and crop performance. Keeping good records will allow you to evaluate the impact changes in your nutrient management may have on crop performance. Remember that the tissue analysis is only as good as the sample you collect!

While tissue analysis is perhaps the most important tool for nutrient management, the information provided by the report should not be the only source of information used when making decisions. Consider the results together with soil analysis, previous experience, observations in the field and crop performance.

Part 3: Boots

While soil and tissue analysis are extremely valuable tools, there is nothing that can replace time spent in your boots walking the beds and observing the vines. There is a great deal of complexity in the cranberry system and cranberry vines will perform differently from year to year, across a marsh and sometimes across a bed depending on factors such as weather, soil type and water status. It is critical to have good records of your observations throughout the season so that you can best utilize the information generated by the soil and tissue analysis. For example, in 2010, many tissue analysis indicated that vines had low nitrogen levels. However, if you took one step into many beds the growth of the vines clearly indicated otherwise!

Summary

- When making nutrient management decisions, consider the WHOLE story: roots (soil conditions), shoots (tissue nutrient status) and boots (observations from the field)

- Be sure to collect tissue and soil samples properly – the data is only useful if the sample was collected properly
- Keep your tissue and soil reports from previous year and take them out every time you get a new report – this will help you track trends
- Consider the impact of environmental conditions – you may have to make in-season adjustments to your plan based on weather conditions and your observations
- Monitor the soil moisture status in the bed to ensure optimal conditions for nutrient uptake and microbial activity
- Spend time with your vines!

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UW-MADISON CRANBERRY BREEDING PROGRAM HIGHLIGHTS

Brent McCown and Eric Zeldin, Department of Horticulture, University of Wisconsin-Madison

Over the past several years and expected to continue into the next several years, our program has focused on a number of initiatives:

- Support 'HyRed' growers
- Facilitate scale up and release of new cultivar 'Sundance'
- Work with grower/cooperators to scale up and evaluate other promising selections
- Perform and evaluate a limited number of new crosses aimed at enhancing resiliency in response to climate change
- Continue to evaluate how to handle tetraploid cranberry
- Other assorted more risky activities including the association of cranberry and naturally occurring bacteria.

This brief article will focus on the new introductions.

<u>Hyred planting status</u>

The number of growers planting HyRed continues to slowing increase:

Year and location	# licenced growers	Total acres on record
2009	30	120
2010	37	200+
% in WI	75	80

Encouragingly, we have not received any information of major problems in the last two years.

<u>New release status:</u>

In 2010, WARF filed a patent application for A-X14, commonly called 'Sundance'. Details can be seen in the patent application that is attached to this article. In summary, the traits claimed include:

- Excellent yearly bud set
- Large berry size (early and late berry bulking)
- Color development ahead of 'Stevens'
- Very good vigor that results in uniform plantings
- High tolerance to low and high N fertilization
- Reliable and performance over multiple seasons

With these traits, 'Sundance' promises to duplicate 'Stevens' in flexibility and reliability but be an improvement in yield, fruit size, and earlier coloration. Over 14 acres have been planted for propagation purposes and availability of planting stock is anticipated in 2012.

‘Sundance’ Patent Application

PATENT WARF:101US, APPLICATION FOR PLANT PATENT for Cranberry Variety Named WI92-A-X15 by ERIC ZELDIN and BRENT McCOWN

BACKGROUND OF THE INVENTION

Latin name of the genus and species of the plant claimed: *Vaccinium macrocarpon* Ait.

Variety denomination: WI92-A-X15.

The present invention relates to a new and distinctive cranberry clonal variety having significantly higher yields, larger fruit size, more favorable bud set traits, tolerance to high levels of fertilizer, high red pigmentation and ability to produce excellent crops at an early age as compared to the leading commercial cultivar, ‘Stevens’.

The American cranberry, *Vaccinium macrocarpon* Ait., is a small fruit grown commercially in the temperate regions of North America and Chile. The United States is presently the major producer of cranberries, with the combined Wisconsin and Massachusetts harvests accounting for the majority of U.S. and world annual production. Currently Wisconsin produces over half of the U.S. crop.

The American cranberry is well known for its tart flavor and its red pigment. The importance of adequate pigment content (measured as total anthocyanins or Tacy, and expressed as mg per 100 grams fresh fruit) is recognized by most processors as they are known to give a reduced value to poorly colored fruit. Cranberry selections widely grown today have generally not experienced the extensive breeding as seen in other fruit-bearing species. Many selections were derived directly from native areas or from managed beds of mixed origin. For example, ‘Ben Lear’ (unpatented) is a cranberry selection taken directly from the wild in Wisconsin in the early 1880’s, and is widely grown in short-seasonal areas due to its early fruit development and high color content. The U.S. Department of Agriculture undertook, in cooperation with state experimental stations, one generation of breeding in an attempt to improve U.S. cranberry cultivars. The breeding resulted in the introduction of the ‘Stevens’ (unpatented) variety in the 1950. The ‘Stevens’ variety is today the most widely grown cultivar and is characterized by dependably good yields, but only moderate color development, especially in short-seasonal regions such as Wisconsin.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to a new and distinct cranberry variety. The variety is designated “WI92-A-X15” and was produced through controlled breeding performed in 1990 at the University of Wisconsin-Madison. Cranberry variety “W192-A-X15” is derived from a controlled cross of the ‘Stevens’ variety and a selection designated “Boone’s BL8” (originally derived from an open-pollinated population of seedlings of ‘Ben Lear’).

“W192-A-X15” cranberry was initially selected based on large berry size in August of 1992 and was clonally propagated for field trials planted in 1994. “W192-A-X15” demonstrated continued production of large berries and favorable bud set traits, including both good fruit bud set in general and excellent bud set on fruiting stems (‘uprights’) specifically. “W192-A-X15” was been compared to ‘Stevens’ both in plots within common beds (2004 and 2009 data presented below) and in full beds utilizing a 0.66 acre dedicated bed planted in 2006 and on a 2 acre portion of a larger bed planted in 2007. In late September of 2009, four years after planting, the 0.66 acre bed was harvested and in mid-October of 2009, three years after planting, the 2 acre bed was harvested. The yields were compared to established beds of ‘Stevens’ harvested in the same time period (Table 1).

“WI92-A-X15” exhibits significantly higher yields (up to approximately two times higher than variety ‘Stevens’), larger fruit size, more favorable bud set traits, tolerance to high levels of fertilizer, earlier and higher red pigmentation, and an ability to set excellent crops at an early age as compared to ‘Stevens’.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1. WI92-A-X15 uprights with fruit, Monroe County, Wisconsin, Sept. 30th, 2009. Note the large size and good pigmentation of the fruit and the presence of flower buds on the fruiting upright tips.

DETAILED BOTANICAL DESCRIPTION

The distinctive characteristics of the new “WI92-A-X15” variety are shown in Tables 1 and 2 and described in detail below.

Visual analysis of “W192-A-X15” cranberry samples taken between early September and early October 2009 demonstrated fruit color development and fruit size exceeding that of parent cultivar ‘Stevens’. “W192-A-X15” fruit from the four-year-old, 0.66 acre bed and the three-year-old, 2 acre bed were harvested at the beginning of October and mid-October of 2009, respectively, and comparison ‘Stevens’ was harvested over the course of several weeks in October. Yields from each “W192-A-X15” bed were compared to established beds of ‘Stevens’ over the whole farm and specific beds as indicated (see Table 1 for harvest dates). Yield is expressed as barrels per acre or B/a, 1 barrel =100 lbs. As shown in Table 1, cranberries from the four-year-old “W192-A-X15” bed out-performed the established variety ‘Stevens’ by about two-fold, yielding 476 B/a versus a farm average of 243 B/a for 66 acres of ’Stevens’. Examples of individual beds of ‘Stevens’ show a range from 217 to 278 B/a. The three-year-old “W192-A-X15” had a yield similar to that of established ’Stevens’ with 242 B/a. In contrast, the yields produced from two beds of ‘Stevens’ planted in 1995, produced 153 and 156 B/a as three-year-olds, respectively, and 192 and 204 B/a as four-year-olds, respectively (data not shown).

“W192-A-X15” was not only able to produce higher yields, but the fruit color was favorable when compared with ‘Stevens’. The 0.66 acre bed of “W192-A-X15” was harvested eight to fifteen days earlier than the ‘Stevens’ beds listed, yet had nearly equivalent fruit color (Table 1). The 2 acre area of “W192-A-X15” was harvested only a few days later than the ‘Stevens’ beds, yet had fruit color approximately 50% greater.

Table 1. Yield comparison of "W192-A-X15" and 'Stevens' cranberry varieties in 2009 at a commercial cranberry farm in Wood County, Wisconsin. Data are based on Ocean Spray receipts of usable berries and are provided courtesy of Rocky Beigel, Dempsey Cranberry Co., Wisconsin Rapids, WI .

	"W192-A-X15"		'Stevens'					
				Specific 'Stevens' beds (all at least 10-yr-old)				
	4-yr-old	3-yr-old	Overall	A14	A18	A6	A20	A24
Yield (B/a)	476	242	243	217	236	278	248	229
Size (acres)	0.66	2.00	66	3.17	4.59	2.27	4.06	3.58
N applied (lbs/acre)	74	74	42	42	42	42	42	42
Harvest date	10/1	0/17	-	10/10	10/9	10/15	10/12	10/9
Tacy (mg/100g)	26	47	-	29	27	30	28	27

High rates of nitrogen can cause excessive vegetative growth, or "overgrowth", resulting in numerous non-fruiting stolons growing over the top of the canopy. 'Stevens' is particularly susceptible to such nitrogen induced overgrowth, which can be associated with reduced yields. Unlike 'Stevens', "W192-A-X15" displays little overgrowth, no reduced yields, and no changes in berry size or upright average growth when treated with high levels of nitrogen; instead "W198-A-X15" displays an increase in flower bud set under high nitrogen fertilization. The tolerance of cranberry variety "W192-A-X15" to high levels of fertilizer can be seen in Table 2. The effects of increased fertilizer and the tolerance thereto displayed by "W192-A-X15" is also demonstrated in Table 1 as the yields shown for "W192-A-X15" were not adversely affected by the significantly higher units of nitrogen applied than what was used for 'Stevens'.

In early October of 2009 the tolerance of "W192-A-X15" to increased nitrogen was evaluated at a testing site near Tomah, WI. Plots of "W192-A-X15" were fertilized with nitrogen levels used throughout the bed or received additional fertilizer from three extra applications of ammonium sulfate as well as a slow release fertilizer. Table 2 shows the resulting effects of nitrogen treatment of five samples of "W192-A-X15". In particular, the high nitrogen treated plot of "W192-A-X15" did not display overgrowth, reduced yields or differences in berry size or upright average growth; instead a slight increase in yield and a large increase in flower bud set was observed.

Table 2. Effects of low and high nitrogen (N) fertilization on yield and other characteristics in "W192-A-X15" cranberry variety in 2009 near Tomah, WI. (numbers in parentheses denote standard error)

Treatment	Units N (lbs/acre)	Yield (B/a)	Avg. berry weight (g)	Avg. upright fresh wt.(g)	Flower bud set (%)	Shoot N content (%DW)
Low N	32	559 (36)	1.65 (0.05)	0.11 (0.01)	28.5 (5.7)	0.87 (0.04)
High N	66+	612 (27)	1.64 (0.03)	0.10 (0.01)	57.8 (8.0)	1.16 (0.08)

The red pigment of cranberry is located almost entirely in the epidermal layers of the fruit. One factor which can to contribute to high extractable fruit color in cranberry is small fruit size, due in part to the influence of surface area to weight ratio on the total pigment content for each fruit. A negative correlation between yield and fruit color has also been suggested. However, "WI92-A-X15" demonstrated better coloration in combination with increased fruit size and greater yield potential. Thus, "WI92-A-X15" appears to be able to produce high yields and large fruit size simultaneously with good fruit coloration (Table 1 and Figs. 2-4.).

Thus, "WI92-A-X15" appears to be able to develop high levels of extractable pigmentation simultaneously with increased fruit size and yield.

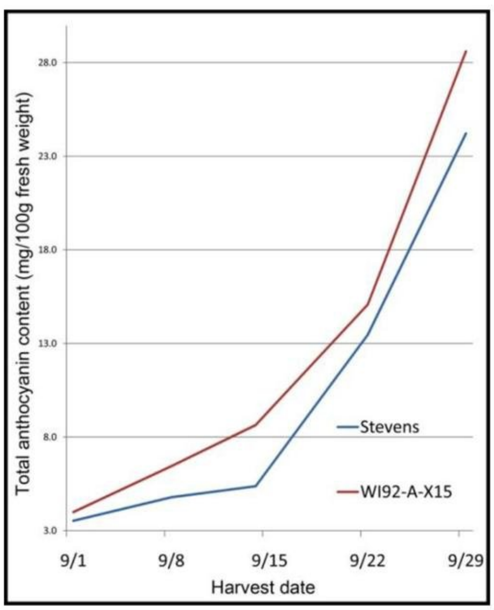

Fig. 2. Fruit color (anthocyanin) accumulation in fruit from plots of 'Stevens' and "WI-A-X15" during the late growing season of 2004 in a common bed in Wood County Wisconsin. "WI92-A-X15" pigmentation is consistently above 'Stevens'. Data presented is the average of six replicates for each time point for each variety. Data courtesy of Dr. Rodney Serres, Ocean Spray Cranberries, Inc.

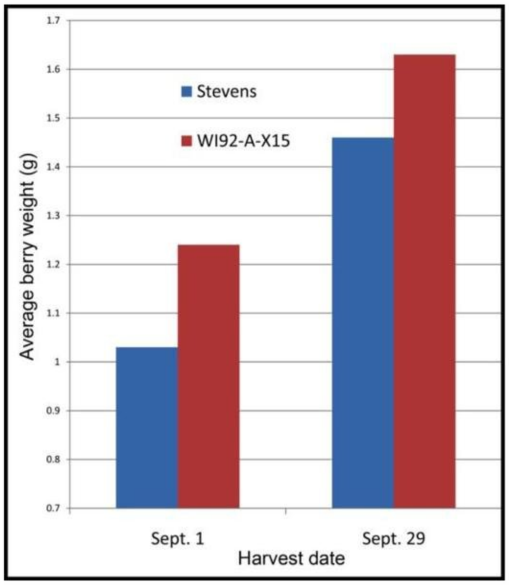

Fig. 3. Average berry size of fruit from plots of 'Stevens' and "WI-A-X15" at two points of the growing season of 2004 in a common bed in Wood County, Wisconsin (same plots as Fig. 2). "WI-A-X15" displays both early and late berry bulking that leads to a larger berry size compared to 'Stevens'. Values are the average of six replicates for each harvest date for each variety.

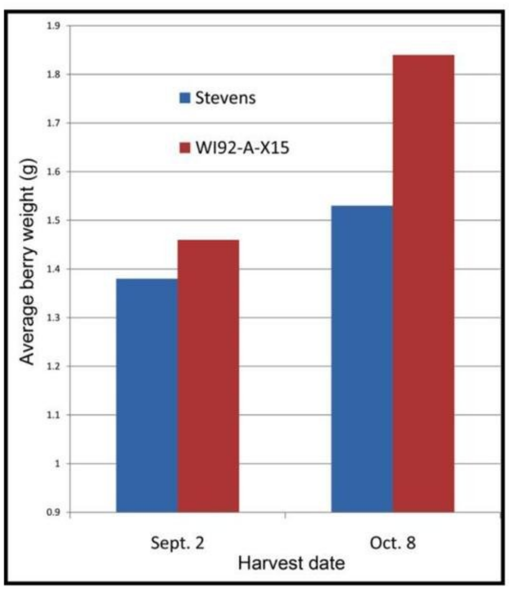

Fig. 4. Average berry size of fruit from plots of 'Stevens' and "WI-A-X15" at two points of the growing season of 2009 in a common bed in Wood County, Wisconsin (different location from Fig. 3). "WI-A-X15" uniformly has larger average berry size than 'Stevens', consistent with its original selection. Values are the average of three replicates for each harvest date for each variety.

The combination of the above "WI92-A-X15" characteristics easily differentiates "WI92-A-X15" from both its parents. The above characteristics also provide the "WI92-A-X15" variety with benefits not recognized in other commercially grown and established varieties. For example, the increased yield and flower but set of "WI92-A-X15" provides the potential to increase both the current year's crop and the next year's crop through fertilizer regime. "WI92-A-X15" additionally provides beneficial and distinct aspects over other cranberry cultivars as evidenced by its high yields. For instance, the observed approximately two times greater yield than the most planted 'Stevens' cultivar demonstrates a great advantage of the "WI92-A-X15" variety.

Scientific name: *Vaccinium macrocarpon* Ait.

Parentage: The variety is a cross of the 'Stevens' variety and a selection designated "Boone's BL8", which was derived from an open-pollinated population of seedlings of 'Ben Lear'.

Reproductive structures - The cranberry variety has both asexual (stolons) and sexual reproductive (fruit) structures.

Propagation - Cranberries can reproduce both asexually and sexually. For instance, stolons readily root when contacted with soil or reproduction may occur from seeds. Cranberry cultivars are propagated asexually through rooting of stolons and vertical shoots. Cranberry growers typically reproduce cranberries with either rooted or unrooted cuttings, or vine prunings that are broadcast and then pressed into the soil surface.

Productivity - "W198-A-X15" has out-yielded 'Stevens' by two-fold. In a four-year-old, 0.66 acre bed "W198-A-X15" yielded yielding 476 B/a while 'Stevens' produced a multi-bed farm average of 243 B/a. In a three-year-old, 2 acre bed "W192-A-X15" yielded 242 B/a, which was comparable to the yield observed for the established much older 'Stevens' beds, but yields were greater than from three and four-year old beds of 'Stevens' planted which produced an average of 154.5 B/a and 198 B/a, respectively. Yield data shown in Tables 1 and 2.

WHAT IS CLAIMED IS:

1. A new and distinct variety of cranberry plant named "W192-A-X15" herein described and illustrated.

ABSTRACT

A new and distinct cranberry variety "W198-A-X15" is described. The variety is distinguished by significantly higher yields, larger fruit size, more favorable bud set traits, tolerance to high levels of fertilizer, higher and earlier red pigmentation, and ability to set excellent crops at an early age as compared to 'Stevens', the most widely grown cranberry cultivar. "W198-A-X15" was derived from a controlled cross of the variety 'Stevens' and an open-pollinated seedling selection of the variety 'Ben Lear' designated as "Boone's BL8".

DRAWINGS