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DETERMINING THE POLLINATION POTENTIAL OF A HONEY BEE COLONY

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Introduction

With the price of cranberries at an all-time low and the price of honey at an all-time high, the interface between the beekeeper/pollinator and the cranberry grower may be at a critical juncture. For a beekeeper to decide to make cranberry pollination a part of his/her beekeeping activity, it has to be preferable to the production of a crop of honey, i.e., more profitable. We should realize that a Wisconsin beekeeper makes a conscious choice between these two activities every year.

Unlike the pollination of apples, almonds, and most other bee-pollinated crops, the relocation of a honey bee colony to the cranberry property usually removes it from a location at a time when leaving it there would have resulted in significant honey production. Wisconsin beekeepers anticipate and plan to produce their major honey crop between mid-June and mid- August, with only occasional small honey crops earlier or later. Thus, cranberry growers require that the beekeeper bring his/her bees to their properties for pollination at an inopportune time.

The current price for bulk honey packed in fifty-five gallon drums and sold in truck-load lots is about one dollar fifty cents per pound: that's one thousand dollars per drum or sixty thousand dollars per truck-load. Wisconsin beekeepers regularly produce about one hundred pounds of honey per colony; they can expect to gross one hundred fifty dollars per colony if the colony is simply left on its "permanent" location and supered adequately. Granted, there is no guarantee of a one hundred pound honey crop, nor is there a guarantee that the price will be one dollar fifty cents per pound.

What is needed to persuade a beekeeper to pollinate your cranberries is remuneration for the portion of the honey crop that has been sacrificed by the colony relocation, and also remuneration for the labor and out-of-pocket expenses for transporting the bees to and from the cranberry property. Other concerns of the beekeeper who rents bees for pollination include an increased risk from insecticides applied to the cranberry crop, or to nearby crops (if any), theft or vandalism of bees located outside the normal operating area of the beekeeper, exposure to bee diseases and/or bee parasites from the colonies of other beekeepers moving to the cranberries, and the wear and tear on the equipment and personnel trucking bees, often done under critical time constraints and during the night.

Granted, there are beekeepers that are doing their bee thing just for the fun of it, but they don't operate enough bee colonies to do most cranberry growers any good. Beekeepers operating enough bees to provide the pollination that you require are in the bee business to make money. For the most part, they are honest and hard-working businessmen and women. Unfortunately, there are a few exceptions, and you may even know one or two of these. I'll leave the evaluation of the beekeepers up to you, and we will now turn our attention to the evaluation of the honey bee colony.

Colony Evaluation

First we need to think of a honey bee colony as a dynamic and living organism. It begins life as a swarm (in nature) or as a package-bee-colony or as a colony "divide" or nucleus hive called a "nuc" (when produced under beekeeper management). These "newborn" colonies are not suitable for pollination rentals because most of their activity and energy is directed to the care and nurture of bee larvae to increase their colony's adult bee population as quickly and as efficiently as possible. We usually expect a productive colony from one of these new "starts" after two or three of their twenty-one-day brood cycles, i.e., forty-two to sixty three days; the actual duration dependent upon availability of bee forage and good weather and/or proper feeding by an astute beekeeper. It is such a young and populous colony that will provide you the desired pollination, if properly managed while on the crop. More mature colonies may become heavy and difficult to transport and may even be so overloaded with honey that their foraging activity declines.

Thus, you see, for a beekeeper to provide you the best pollination service possible, there needs to be advanced notice about what your expectations are so that the bees can be managed in anticipation of a move to the cranberries in late June. Honey producers that migrate south for the winter establish new bee colonies every year before they move to their summer locations in the Midwest. Several years ago I met with the North Dakota state beekeepers and was told that in that particular year, 350,000 honey bee colonies had been moved into their state for honey production. Such is the scope of commercial beekeeping in our country today. We might call the process that they employ as applied population control—and for the beekeeper, proper timing of colony initiation and population development is vitally important.

The most obvious criterion that you, the cranberry growers, have for a windshield inspection of what you have rented, is the number of "bee boxes" that you see on your property. However, such an assessment is only valid if you have a pretty good idea what is inside those boxes.

Colony Evaluation Field Experiment

About twenty years ago I designed and we conducted an experiment comparing single-story, double-story, and triple-story honey bee colonies in a pollination situation. These were all standard nine-and-five-eighth-inch Langstroth brood chambers with appropriate amounts of bees and brood and a young, laying queen. Each colony also had adequate storage space for honey in a six-and-five-eighth-inch Illinois-depth honey super with drawn comb placed on top of the brood chambers. The particular crop involved happened to be an onion seed field in full bloom and my experiment was conducted during two different years in Yuma County, Arizona.

Each bee colony in my experiment had its population estimated by counting frames covered with bees and then multiplying that total number of frames for each colony by 1,500, the number of bees we had found on average when bees were shaken from individual frames. To measure the relative number of foragers visiting our target crop (onion), we employed an animal behavior technique called capture and recapture.

Color-coded metal tags were glued onto the abdomens of foraging bees "captured" while visiting the onion flowers. These metal tags were then "recaptured" on magnets mounted above the hive entrances, thus recording those foragers that returned to every hive. Other data evaluated and presented here include the weight gained (honey, pollen, new bees, etc.) and the rate of flight at the entrances of these bee colonies.

The data (Table 1) clearly show that the numbers of foraging bees collected from the flowers of the target crop were proportional to the honey bee populations of the hives from which they had originated. The rate-of-flight data and the weight-gain data also were very much a function of the colony's populations. When the data are calculated on the basis of the numbers of frames of bees per total tags, pounds gained, or bee flights per minute, in all but one case there were no significant differences between one-, two-, and three-story colonies. The conclusion one makes from this is that it is the number of bees present that is important, and that they can be in colonies of various population sizes. Please note, however, that all of these colonies were provided with adequate storage space for incoming nectar and pollen, and they were not crowded for space when their populations increased.

Because the colonies were distributed in small apiaries adjacent to these fields, and because the metal tags were applied at six tagging sites uniformly distributed within these fields, we have data on distances traveled by colonies of three populations. On a seventeen-acre field with colonies placed on both sides of the field, half of the foragers went to the nearest tagging site sixty meters away (first-year study). On a ten-acre field with colonies only on one side, one-third of the foragers were tagged on the nearest tagging site thirty-six meters away (second-year study). Some have speculated that bees from the weaker colonies will not travel as far when they forage, as will the foragers from stronger or more populous colonies. There was no evidence of this behavior in our results.

Paying According to Colony Strength

The almond growers in California have a reputation for their insistence on quality honey bee colonies for pollination, as well as their willingness to pay a rental fee based on the hive inspection reports that they request and pay for. The present demand for pollination of California almonds requires about one million colonies every year in February. Thus, there is a mass movement of U. S. migratory beekeepers and their bees beginning as soon as the previous year's honey crop is harvested. Many beekeepers have learned the importance of fall feeding with syrup and pollen substitutes, so that their bee colonies will measure up to the almond growers expectations when inspectors evaluate colonies to determine the price to be paid for pollination rental colonies. Because the weather in February can be marginal for honey bee flight activity, almond growers have learned to be particularly harsh about weak colonies with small bee populations; they refuse to pay anything for such units.

For an unbiased assessment of the colonies you rent for cranberry pollination, I suggest that a beekeeper accompany you, but not the beekeeper who owns the rented colonies. You should have the beekeeper examine about ten percent of the colonies present at every location. Have someone record the information provided to you by the beekeeper as he tips every box back and tells you how many frames he sees that are fully covered with bees. A few frames should be removed for a close examination, especially if a colony appears to be particularly inferior to the majority of the hives that are opened. I emphasize the need to tip the hives back and look upwards into each box from the bottom. Often the bees on the topbars tell you little about the number of bees further down on the combs where the bees really count. Also, an experienced beekeeper can observe brood in the combs rather easily from the bottom, but the brood is nearly impossible to see when looking down between the thicker topbars.

Since I relocated back to Wisconsin in 1995, I have had occasion to visit cranberry properties and to inspect rental colonies nearly every year. I also assisted Dr. Marla Spivik, from the University of Minnesota, after I had recommended her to you when someone from your association requested help with some research on pollination of cranberries. I am a part-time bee inspector for the Wisconsin Department of Agriculture Trade and Consumer Protection (WDATCP). It is through my affiliation with WDATCP that, this past summer, I became involved with the examination of some colonies that had been rented from an out-of-state beekeeper for cranberry pollination in central Wisconsin

Using my method of tipping up every super and hive body to assess populations of bees, I and one assistant that the growers provided for recording the information were able to assess bee populations in 252 colonies on five properties in one day. Many of the colonies that we examined consisted of only one brood chamber and one honey super. Such a minimum hive would be all right if the brood chamber was more or less full of healthy brood and bees and the honey super contained drawn comb without much honey. However, many of these so-called story-and-a-half colonies had their honey supers already filled with combs of sealed honey, and there was no storage room for incoming nectar. In addition to overall populations, we were able to document some queenless or failing-queen colonies (3%), dead colonies (15%), and "plugged-out" colonies that could do little foraging owing to a lack of storage space (19%). Not including the dead colonies, our colony examinations showed that 90% had populations greater than 10,000 bees and that 75% had populations greater than 15,000 bees. Using the methods for colony assessment described herein, I would recommend that a minimum acceptable colony for remuneration be set at 15,000 bees when bees are rented for pollination. Such a minimum colony would have the equivalent of ten Langstroth deep brood frames covered on both sides with worker bees.

Further Reading

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Table 1. Colony size and honey bee foraging activity during two years in Arizona.

Brood Boxes Present	Average Hive Populations Frames	Average Hive Populations Bee No.	Bees Exiting Per Min.	Foragers Tagged Per Colony	Wt. Gain in Pounds Per Colony
			First Year		
1	8.5	12,750	---	28.4	9.8
2	16.1	24,150	---	40.1	14.8
3	23.3	34,950	---	55.0	21.9
			Second Year		
1	10.3	15,450	71.6	33.2	13.8
2	18.4	27,600	118.9	61.7	25.4
3	26.1	39,150	182.7	91.9	43.6

BUMBLEBEE CONSERVATION IN AND AROUND CRANBERRY MARSHES

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Introduction

Bumblebees as Cranberry Pollinators

As the most effective pollinators of the American cranberry *(Vaccinium macrocarpon* Aiton*),* bumblebees are valuable components of cultivated cranberry landscapes (Kevan et al., 1983; MacKenzie, 1994; Stubbs & Drummond, 1997). Since cranberry pollen is heavy and is not wind blown (Wyman, 1976), insects are necessary for adequate pollination. Cranberry growers, like farmers of many other agricultural crops, often rely on the European honeybee *(Apis mellifera* Latreille*)* for crop pollination because of the mobility and reliability of honeybee hives. Despite this dependence upon honeybees, however, these commercial bees are not ideal cranberry pollinators. Cranberry flowers are not particularly attractive to honeybees because they produce only small amounts of nectar and pollen (Kevan et al., 1983; Wyman, 1976). Bumblebees, on the other hand, are able to efficiently obtain pollen and transfer it between cranberry flowers (Free, 1993) because of their large size and use of sonication (i.e. "buzz pollination"), of which honeybees are incapable (Plowright & Laverty, 1987). Cranberries pollinated by bumblebees have higher yields, larger fruit, and more seeds per berry than those pollinated only by smaller insects (Mohr & Kevan, 1987). In addition, bumblebees work longer hours and in windier conditions than honeybees do (Williams & Christian, 1991). They also forage in the cooler periods of early morning and evening, when honeybees are typically inactive (Corbet et al., 1993; Free, 1955).

Risks of Relying on Honeybees

Better cranberry production is not the only reason to encourage wild bumblebee populations. Bumblebees are native pollinators; honeybees are not. In addition, a potential hazard of relying on honeybees is the risk of parasitic tracheal mites *(Acarapis woodi* Rennie) and Varroa mites *(Varroa jacobsoni* Oudemans) which are known to affect honeybees but have not been found to have an effect on bumblebees. The Africanized, or "killer" honeybee is another potential threat (Kevan et al., 1990; Thomson, 1993). If management practices were modified to better address the habitat needs of bumblebee populations, both cranberry growers and bumblebees could benefit by less reliance on non-native bees.

Bumblebee Population Declines

As a result of habitat destruction and pesticide poisoning (Kevan, 1975; Kevan et al., 1990; MacKenzie & Averill, 1995; Winston & Graf, 1982), bumblebee *(Bombus* spp. Latreille*)* populations have declined or gone extinct in some regions of Britain (Osborne & Corbet, 1994; Williams et al., 1991; Williams, 1986), Canada ((Plowright & Laverty, 1987), France, Belgium (Rasmont, 1988), Poland (Banaszak, 1995; Kosior, 1995), and Turkey (Ozbek, 1995). Although strong evidence for bumblebee population reductions in the United States has not yet been reported, researchers suspect that declines are occurring here as well (Tepedino & Ginsberg, 2000). It would be wise to take efforts to conserve these native pollinators.

Forage Resources in Agricultural Landscapes

In an agricultural landscape, the presence of an agricultural crop can provide an abundance of forage resources for a relatively short length of time. However, because bumblebees do not store up food resources for long periods of time, a single crop alone cannot sufficiently meet the forage needs of bumblebees. If the availability of forage is not continuous, the colony suffers. One way to address habitat needs of bumblebees is to manage the landscape within and around cranberry beds so sufficient and diverse foraging resources are available to bumblebees throughout the season (Banaszak, 1992; Corbet et al., 1994; Dramstad & Fry, 1995; Free, 1993; Macfarlane & Patten, 1997; Plowright & Laverty, 1987; Williams et al., 1991). A necessary step toward ensuring adequate forage resources is to discern which are most valuable to bumblebees.

Research Overview

Purpose

The purpose of this research was to determine which plant species and plant community types around cranberry farms are most valuable for bumblebee forage.

Methods and Study Sites

Data collection occurred during the spring and summer of 2001 and 2002. Transects were established and divided into sections according to plant community type. Flower abundance surveys and bumblebee surveys ("bee walks") were conducted.

The study sites were three commercial cranberry farms in northern Wisconsin. Native vegetation in uncultivated areas associated with these farms includes several ericaceous (heath family) plants in acidic northern bog communities. Ericaceous plants are mainly pollinated by bumblebees, which are adapted to cooler climates (Free, 1993; Mohr & Kevan, 1987). Conducting this study in the north increased the possibility of finding bumblebee-pollinated plant species in the landscape.

Another reason for conducting research in northern Wisconsin is that cooler temperatures sometimes lead to difficulties in using honeybee colonies (Plowright & Laverty, 1987). Therefore, northern growers in particular could benefit from enhanced habitats for bumblebees and other native pollinators. Also, cranberry farms in the northern part of the state are generally smaller than those in other regions. Native pollinator management strategies involving the surrounding landscape have higher chances of success there (Kevan et al., 1983; Mohr & Kevan, 1987) than in areas with greater flight distances to the center of the cranberry beds. Although it was logical to conduct this study in northern Wisconsin, the results of this research may still be applicable to cranberry farms in central Wisconsin. The following cranberry farms provided study sites for this research:

- Bartling's Manitowish Cranberry Company, Inc., Manitowish Waters area
- Lake Nokomis Cranberries, Inc., about midway between Bartling's and Tamarack Flowage
- Tamarack Flowage Cranberry Company, near Three Lakes

Results

Flower Abundance

In both 2001 and 2002, cultivated cranberry (*Vaccinium macrocarpon*) was the most abundant in terms of number of flowers for all sites. In 2001, the second most abundant was Labrador tea (*Ledum groenlandicum*), while in 2002 it was leatherleaf (*Chamaedaphne calyculata*). Although these plant species were most abundant, they did not receive the most bumblebee visits per flower or flower cluster. When bumblebee visits per flower were calculated, bull thistle (*Cirsium vulgare*) and raspberry (*Rubus idaeus* var. *strigosus*) received the highest number of visits in 2001, while fireweed (*Epilobium angustifolium*) and Joe Pye weed (*Eupatorium maculatum*) were the most frequented in 2002 (Table 1).

Table 1: Number of visits per flower or flower cluster for plant species on which bumblebees foraged during each research trip, all sites combined. Bumblebee visits per flower were multiplied by 100 for ease of interpretation.

Date	Plant Species	Common Name	# Bumblebee Visits/Flower * 100
5/29/01-6/12/01	*Ledum groenlandicum*	Labrador tea	0.12
	Rubus idaeus var. *strigosus*	red raspberry	15.15
	Vaccinium myrtelloides/angustifolium	blueberry	2.44
6/28/01-7/7/01	*Rubus idaeus* var. *strigosus*	red raspberry	6.25
	Vaccinium macrocarpon	large cranberry	0.06
8/11/01-8/16/01	*Aster* sp.	aster	10.00
	Cirsium vulgare	bull thistle	14.29
	Euthamia graminifolia	grass-leaved goldenrod	1.26
	Impatiens capensis	orange jewelweed	0.19
	Solidago canadensis	Canadian goldenrod	1.83
	Trifolium hybridum	alsike clover	0.31
5/21/02-5/28/02	*Chamaedaphne calyculata*	leatherleaf	0.11
6/25/02-7/2/02	*Hieracium aurantiacum*	orange hawkweed	0.24
	Rubus pubescens	dwarf red raspberry	0.38
	Vaccinium macrocarpon	large cranberry	0.01
7/23/02-7/30/02	*Epilobium angustifolium*	fireweed	41.67
	Vaccinium macrocarpon	large cranberry	2.96
8/13/02-8/19/02	*Anaphalis margaritacea*	pearly everlasting	2.50
	Aster pilosus	awl aster	0.34
	Eupatorium maculatum	Joe Pye weed	33.33
	Euthamia graminifolia	grass-leaved goldenrod	4.19
	Polygonum sagittatum	arrow-leaved tear-thumb	0.15
	Solidago canadensis	Canadian goldenrod	3.96
	Trifolium pratense	red clover	4.22

Plant Species before Cranberry Bloom

Early spring was a period when bumblebee forage resources were particularly scarce in the study areas. Leatherleaf (*Chamaedaphne calyculata*) was the earliest blooming plant on which bumblebees were observed to forage. Willow (*Salix* spp.), has been reported to be an important source of nectar and pollen for bumblebee queens in the early spring (Kearns & Thomson, 2001; Medler & Carney, 1963) and was the only plant species in bloom prior to leatherleaf. Bumblebees were not seen foraging on willows in this study; however, this may be due to the relative rarity of willows at the study sites or because the number of bumblebees foraging at the time willows were in bloom was quite low. Since the likelihood of bumblebees nesting near cranberry marshes may be increased by the presence of adjacent early blooming forage plants (Patten et al., 1993), availability of willows or leatherleaf at cranberry farms may help support bumblebee populations.

In early summer, prior to cranberry bloom Labrador tea and raspberry were both important forage plants in 2001. Although bumblebees were not observed to use either of these species in 2002, this may be explained by the timing of the research trips and the weather that year, which was cooler than normal in the spring.

Plant Species during Cranberry Bloom

During cranberry bloom in 2001, raspberry continued to be a useful forage plant for bumblebees. Although the number of visits to raspberry was much lower than the number of visits to cranberry, when the number of bumblebee visits was divided by the number of flowers available for each species, raspberry proved to be more valuable. Cranberry growers have differing opinions regarding plants that bloom concurrently with cranberries. Many growers attempt to eliminate all plants that have the potential to compete with cranberries for pollinators during cranberry bloom. Another less common perspective is that plants near cranberry bogs may help draw bumblebees and other pollinators to the area, where they then forage on those plants as well as cranberries, since cranberries alone may not supply sufficient pollen and nectar. Fireweed (*Epilobium angustifolium*) received a great deal more bumblebee visits per flower than any other species blooming at this time. In fact, the number of visits per flower was the highest of any forage plant species in the study. This plant could help attract bumblebees to cranberry crops if allowed to grow in the vicinity.

Plant Species after Cranberry Bloom

After cranberry bloom, there were more bumblebee forage plants in bloom than at any other time of the season. Grass-leaved goldenrod (*Euthamia graminifolia*) proved to be a very important bumblebee forage plant post-cranberry bloom. When data for 2001 and 2002 were combined, this plant received more bumblebee visits than *V. macrocarpon*. Joe Pye weed (*Eupatorium maculatum*) was another important food resource after cranberry bloom. This plant was second only to fireweed in terms of visits per flower.

Plant Community Type Preferences

Bumblebees foraged in 13 different plant community types in 2001 and 2002 combined (Figure 2). In early summer, 2001, foraging bumblebees used four of the available 12 plant community types. Bog edges were the most often visited plant communities at this time. During mid-summer (June 28-July 7 2001), foraging bumblebees were found in five plant communities. This was the period during which *V. macrocarpon* was flowering, and the number of visits in cultivated cranberry were greater than anywhere else. At the end of the 2001 season (August 11-16), six plant community types were utilized, with unplanted cranberry beds being most valuable.

In 2002, the number of plant community types in this study increased from 12 to 13; this occurred because, for the sake of this study, a cranberry grower did not mow a dike that had been mowed in 2001. During the first research trip of 2002 (May 21-May 28), bumblebees visited only two plant community types, bog edges and open bogs. Between June 25 and July 2 2002, bumblebees used seven different plant community types. The dry meadow received the most visits per 100 meters during this period, despite *V. macrocarpon* being in bloom. Although cultivated cranberry beds received the most bumblebee visits between July 23 and 30 2002, wet meadows were also important. In late summer (August 13-19 2002), the most heavily utilized plant communities were wet meadow and unmowed dike. Overall, unmowed dike and wet meadow were the two most valuable plant communities during the 2002 season, even when cultivated cranberry beds were included in calculations.

When data from both years were combined, it was evident that the unmowed dike attracted more bumblebees on a 100-meter basis than any of the other plant communities except cultivated cranberry (Figure 1).

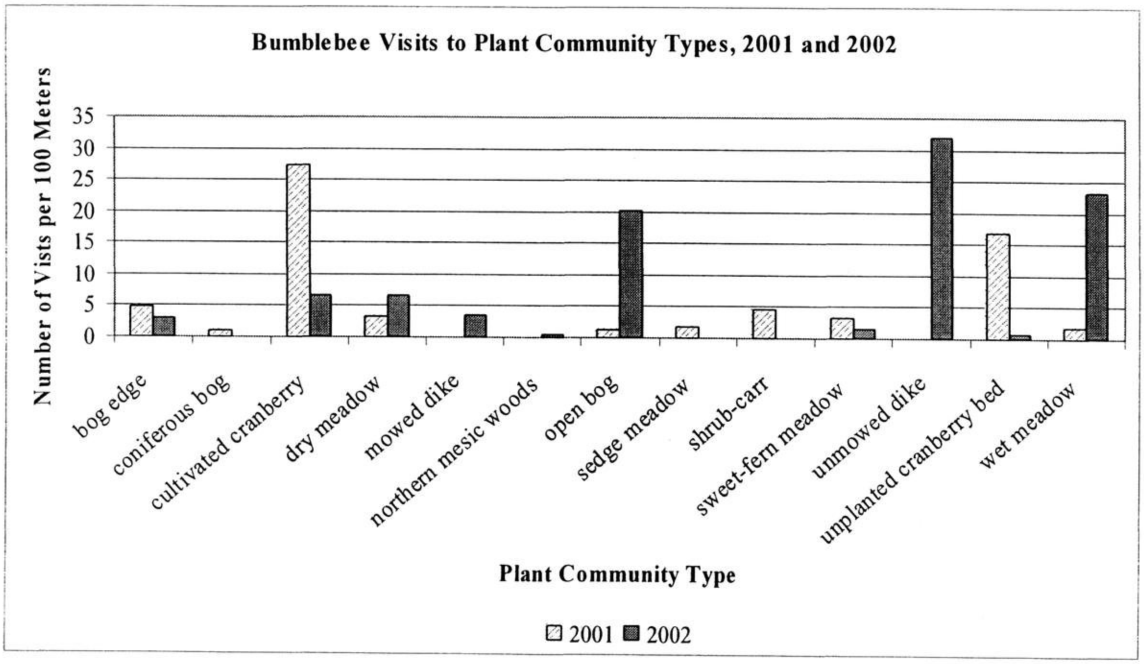

Figure 1: Plant community types visited by foraging bumblebees, all sites combined

Discussion and Recommendations

Diversity in Plant Community Types

This research suggests that diversity in plant community types is important for bumblebee habitat. Diversity is crucial because there is temporal variation in the value of plant community types. For instance, bog communities are important in the spring and early summer, while wet meadows and unplanted cranberry beds are valuable in late summer.

Importance of Perennials

Bumblebee forage habitat can be improved by managing land for perennials, which pollinators prefer over annuals (Corbet et al., 1994; Dramstad & Fry, 1995; Fussell & Corbet, 1991). Osborne (1994) states, "The most important factor in management for pollinators on farmland is to safeguard and extend areas of perennial herbaceous vegetation," including ditches and other areas usually considered wasteland (Fussell & Corbet, 1991). The results of this study support the claim that bumblebees prefer perennials to annuals: Eleven of the 18 plant species used by bumblebees were native perennial species, and an additional two species were naturalized invasive perennials. Some of the perennial species used by bumblebees in this study were shrubs, (e.g. *C. calyculata* and *L. groenlandicum*), but there was also a large herbaceous component. Perennial herbaceous vegetation corresponds to mid-successional plant communities, which are usually dependent on semi-regular disturbance regimes to prevent invasion by trees and shrubs (Dramstad & Fry, 1995).

Mowing Reduction

While infrequent mowing could act as a disturbance to help maintain perennial plant communities, it is typically done too often on cranberry farms to allow bumblebee forage plants to bloom throughout the season. To help support bumblebee populations on agricultural land, Corbet *et al* (1994) recommend not mowing large areas all at the same time. Infrequent, rather than regular, mowing is recommended to enhance bumblebee flowers (Fussell & Corbet, 1991). Data and observations from this study indicate that a reduction in mowed areas in cultivated cranberry landscapes could be beneficial to bumblebees and other pollinating insects. The most obvious example of the benefits of reduced mowing from this study was the dike that was mowed in 2001 and allowed to grow in 2002. This simple adjustment transformed this from one of the least used areas to one of the most valuable areas for bumblebees.

Enhancement Plantings

Besides managing the existing vegetation for bumblebees, another possibility is to establish enhancement plantings (Comba et al., 1999). The recent cranberry surplus has forced many growers to allow some cranberry beds to lie fallow. It may be possible to view this fallow land, as well as other uncultivated areas, as opportunities to create additional habitat for native pollinators. These areas could be allowed to regenerate naturally, or wildflower mixes could be planted (Osborne & Corbet, 1994). Comba *et al* (1999) suggest planting native species because they are evolutionarily adapted to coexist with native pollinators. The findings of this research support this view since almost all of the plants used by bumblebees were native species. Enhancement plantings would have to consist of plants that are attractive to bumblebees; that flower in uninterrupted succession through the season; that are hardy enough to thrive in Wisconsin; and that are reasonably easy to control. Plants meeting most of these criteria are already found in the landscapes at the cranberry farms in this study.

Suggested Plant Species

If forage plants are to be made available to bumblebees throughout the season by land management techniques, it is helpful to recognize which plants would best accomplish this goal. The following suggestions (Table 2) are based on the blooming periods of bumblebee forage plants and analysis of forage plant preferences obtained through this study. All of the suggested plant species are native to Wisconsin and are perennials. They are recommended only if they were found to be attractive to *Bombus terricola,* the primary cranberry pollinator at the study sites. The exception is *Salix* spp., on which no bumblebees were observed to forage during this study, but which has been previously documented as a valuable bumblebee plant in early spring. These species are suggested with the intent that if they already exist on land around cranberry farms, their growth should be encouraged. If they are not currently growing on the land, or if they are scarce, they could be enhanced with plantings. Reproductive mechanisms for each species (Lorenzi & Jeffery, 1987; Muenscher, 1980) are included in Table 2 and should be considered when deciding on planting locations or areas to reduce mowing. This table also includes information regarding the invasiveness of each plant species according to the USDA (USDA, NRCS, 2002).

Potential Risks

Knowledge of a plant's means of reproduction and invasive potential can help eliminate the possible problem of plants invading cranberry beds. For example, if a plant reproduces primarily through rhizomes rather than wind-blown seeds, it may not be problematic if allowed to grow in an area separated from cranberry beds by water. If reproduction is through wind-dispersed seeds, however, it would be important to allow for adequate space between these plants and cranberry beds or to ensure that the species could be easily controlled with herbicide. If a plant species is considered invasive, it is particularly important to keep in mind its ability to spread rapidly and compete with other plants for resources.

Table 2: Suggested plant species to encourage through enhancement plantings or other land management techniques.

Plant Species	Common Name	Blooming Period	Reproduction	Invasive?
Salix spp.	willow	Early Spring	seeds or fragments of shoots	no
Chamaedaphne calyculata	leatherleaf	Spring	seeds (wind-dispersed)	no
Ledum groenlandicum	Labrador tea	Spring	seeds or root suckers	no
Rubus idaus var. *strigosus*	raspberry	Mid-Spring to Mid-Summer	seeds or root suckers	no
Epilobium angustifolium	fireweed	Mid-Summer (blooms with cranberry)	seeds or root suckers	yes
Impatiens capensis	jewelweed	Mid-Summer to Late Summer	seeds	no
Eupatorium maculatum	Joe Pye weed	Late Summer	seeds	no
Euthamia graminifolia	grass-leaved goldenrod	Late Summer	usually rhizomes; sometimes seeds	no

Conclusion

Enhancement plantings or mowing reduction are ways in which cranberry growers could enhance habitat for bumblebees around their marshes. Although there are some risks involved with these methods, since there would be greater potential for plants to inoculate cranberry beds, these risks could be minimized by wise planning and some knowledge of the plants to be established. Improving habitat for bumblebees by ensuring a steady supply of forage resources would help reduce the devastating effects of habitat loss and fragmentation on bumblebee populations.

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ANSWERS TO COMMON NUTRITION QUESTIONS

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I. Nitrogen

A. *What is Nitrogen used for?* Nitrogen in the ammonium form is used in the formation of amino acids. Amino acids are assembled in appropriate order to form proteins. Enzymes that mediate plant metabolism and regulate uptake and movement through membranes are proteins. Proteins as enzymes are essential for energy capture and sugar formation via photosynthesis.

B. *Do N fertility guidelines vary by cultivar?* The optimum tissue level is the same. The optimum rate for Stevens is 20 lbs N/a [18 kg/ha]. The optimal rate for Stevens in Wisconsin research was different for different soils. A sand soil did best at one year at 40 pounds [36 kg] and a peat-based bed did best at 20 pounds [18 kg]. In all cases 20 pounds [18 kg] was better than 0 pounds N/a. Stevens appears to be a bit more forgiving of above optimal N than Searles.

C. *What is the optimum timing for N application?* Research in Wisconsin has shown that the best time to apply N on Stevens is: budbreak, peak bloom, fruit set, and preharvest. Data for Searles were inconclusive. The optimal rate for bearing beds was 20 lbs/A [18 kg/ha]. Interestingly, there were no treatment effects the first year as the buds for that crop were already in place. The treatment effects appeared in year 2 as a result of N fertilization in year 1. This is common in fertility experiments.

D. *How much N comes from thunderstorms?* In rural Wisconsin precipitation amounts to about 10-15 lbs N/A. However, this N is NO_3^-, not NH_4^+ and so is not useful for cranberries. Further, this natural precipitation is also present in all fertility studies, so this should not be counted as part of the 20 lbs N/A.

E. *After application how long does it take for the N to be in the young fruit?* Actually you don't want it in the fruit, you want it in the leaves so it can be used to make sugars that will cause the fruit to grow. In field studies using ^{15}N we can find ^{15}N in the uprights by 24 hours after application. It takes about 1 week before this levels off, depending on the air (soil?) temperature.

F. *Can I estimate N release from organic soils?* Mineralization, the process through which organic N is released as ammonium, is microbe mediated and therefore the process is temperature dependent. Further, the soils must not be "wet", just moist. During hot weather (>85°F; 30°C) postpone or eliminate N applications to peat beds as much N will be mineralized. There is no "formula" to determine mineralization.

G. *N released from peat below a 6-8" sand lift?* Cranberries are relatively shallow rooted. In my opinion little to no N would be available to cranberries under a 6-8" sand lift.

H. *Foliar applications*? Foliar N applications have their place. They are most effective when uprights are growing poorly or look pale. Foliar applications are expensive, but will "green" vines up in a short time. However, cranberry uprights cannot absorb sufficient N through the leaves to meet their full N requirement.

I. *Fall applications to enhance bud set?* A fall application is included in the best fertilizer timing protocol described above.

J. *What about drainage and leaching?* Ammonium N does not leach appreciably (but may leach or run off in surface water if a significant rain event quickly followed application). When pH is 5.5 or below there is no significant nitrification. Drainage is important because NH_4 uptake is energy dependent and oxygen is required for this process. When soils are saturated air is excluded and the root zone becomes anaerobic → no N uptake.

K. *What about slow release products for new beds?* We have done that research using Ammonium sulfate, SCU, MEU, Milorganite (biosolids) and composted chicken manure. All treatments were adjusted to provide the same amount of N, P, & K. Our results show that **none** of the slow release products performed as well as ammonium sulfate, not even close. We did not test osmocote as it is very expensive.

L. *At what soil temp does N uptake begin?* About 50°F [10°C].

M. *Are there guidelines for optimum growth of current season uprights?* Some of this work has been done in MA. We have not done that work in Wisconsin. My opinion is that it would be highly variable based on location, crop load, etc. However, the MA recommendations are:

Cultivar	Optimum growth before early bloom
Early Black	50-60 mm (2-2.5 in)
Howes	45-55 mm (1.75-2 in)
Ben Lear	55-65 mm (2-2.5 in)
Stevens	60-70 mm (2.5-2.75 in)

II. Phosphorus

A. *What is the role of P in cranberry plants?* P is very important to plant metabolism. P is a primary constituent of the genetic material of plants and animals (DNA). It is also critical in energy transfer (ATP→ADP). It is critical to transferring three carbon sugars from the chloroplast into the cytoplasm where it can be used for metabolism or growth or can be exported to other organs.

B. *Do we have guidelines about P timing?* There are some guidelines, but the research behind them is incomplete. The recommendation is no P until late spring, and then apply 20 lbs in 2-3 doses (I'd prefer 3). We also know that $H_2PO_4^-$ reacts readily with iron, aluminum and manganese ions in soils to form insoluble compounds and that these reactions occur rather quickly. Frequent light application of P is better than one or two large doses.

C. *About how much P should be applied during a year?* Research shows no response to added P fertilizer beyond 20 lbs P/a/yr [18 kg P/ha/yr]. This is about 45 lbs P_2O_5/a/yr [40 kg/ha/yr]. Sandy soils may need more P. I believe we are over-applying P by using fertilizers like 6-24-24. We recommend that cranberry fertilizers not exceed an N:P ratio of 1:2.

D. *Are there cultivar differences in P requirements or timing?* Not that I know of. There is no research in this area.

E. *Do sandy soils require more P than organic soils?* Because phosphorus is an anion (negatively charged) soil type is less critical. The current thinking is that sand beds will need more P than peat beds. The amount and availability of iron, aluminum and manganese are more important in my opinion. (But I also don't know of any way to alter the availability of these cations.)

F. *Should I worry about leaching or runoff?* Phosphorus does not leach and would not be any more likely to go through a sandy than a mineral or organic soil. Runoff is a concern if a significant rain event quickly followed a fertilizer application. There is some evidence (although not strong) that there is less P in outflow than inflow water. There is also some evidence that P can leach from uprights when a bed is flooded (as for harvest).

G. *Should P fertilizer be added after spring frost season?* Yes, that is the right timing, but irrigation for frost protection is only peripherally involved. P is released as soils begin to dry out but are still cool after the winter flood melts. Once the soils warm P is not released as quickly. It is coincidental that frost protection ending and soils warming occur at the same time.

H. *Do large levels of natural iron disrupt P uptake?* They don't directly disrupt P uptake, but rather the iron forms insoluble compounds with the P and makes it unavailable for uptake by cranberry roots.

I. *What available fertilizers contain P?* See the table below. Phosphoric acid can be used as a foliar P source, but should not be applied during flowering or on fresh fruit plantings. Rock phosphate is almost insoluble and is not a good P source.

Fertilizer	Chemical formula	Analysis	Solubility
Triple superphosphate	$Ca(H_2PO_4)_2$	0-46-0	87%
Diammonium phosphate	$(NH_4)_2HPO_4$	18-46-0	100%
Monoammonium phospate	$NH_4H_2PO_4$	11-48-0	100%
Ammonium polyphosphate (dry)	$NH_4H_2PO_4+(NH_4)_3HP_2O_7$	10-34-0	100%
Ammonium polyphosphate (liquid)	$NH_4H_2PO_4+(NH_4)_3HP_2O_7$	15-62-0	100%
Ordinary superphosphate	$Ca(H_2PO_4)_3 + CaSO_4$	0-20-0	85%
Phosphoric acid	HPO_4		
Rock phosphate			low

III. Potassium

A. *What is the role of K in plant growth?* Potassium does not have a direct role in plant metabolism. It is not involved in proteins or membranes. It is primarily used to balance charges and as an osmoticant (used to move water from place to place). K is important to stomata opening and closing and in the movement of sugars from one place to another.

B. *What is the optimum timing for K application?* Because K+ will leach it is important to have frequent light applications of K as opposed to 2-3 large applications at "critical" times. In Wisconsin research different timings for K fertilizer did not affect yield or rot.

C. *Do I need more K on sand than peat beds?* Probably. I don't know of research on this question, however.

D. *How much K is required annually?* Research showed yield differences related to K rate in only 1 of 4 years. There was no relationship between K rate and tissue K. Interestingly, yield was reduced at high K rates (240 lbs K_2O/a)[215 kg/ha]. 60-100 lbs K_2O/a/yr [55-90 Kg/ha] appears sufficient. High K was correlated with decreased Ca, Mg, & Fe. Apparently, high K applications exchanged other cations off the exchange sites in the soil. I would determine that through tissue testing in the late summer. If you know how much K you have applied and what the tissue concentration is then you can adjust up or down as needed the following year.

E. *Are there cultivar differences in K requirement?* Not that I am aware of. However, substantial amounts of K are removed in the crop so I would feed a heavy producing bed more K than a light producing bed.

F. *Can I minimize K leaching on sandy soils?* The only approach I know of is to be cautious with other cation nutrients (Ca, Mg, Fe) and then over time an organic duff layer will form. This layer will have more exchange sites and will hold onto K (& other cations) better than sand.

G. *What forms of K are available?* See J. Is one better than another on sandy soils or new plantings? In all cases potassium sulfate is preferred over potassium chloride.

H. *Can I optimize K uptake in soils with high Ca & Mg?* Frequent light applications of K would allow it to be more available than 1-2 heavy applications. K will compete with Ca & Mg for exchange sites. Overapplication of Ca & Mg will reduce K availability. However, see the answer in D above.

I. *Foliar applications of K during bloom & early fruit set?* Research shows no effect of timing on yield. Research also shows no effect of different products when applied at the same rate of K.

J. *What is the difference between 0-0-50 and 0-0-60?* 0-0-50 is potassium sulfate (KSO_4) and 0-0-60 is potassium chloride (muriate of potash, KCl). Cranberries are sensitive to chloride, so the sulfate form is preferred.

K. *Will early applications of 0-0-60 vs. 0-0-50 adversely affect production?* Since cranberries are sensitive to Cl, at high rates 0-0-60 may cause some injury. There isn't research to support this that I know of, but grower experience does. Choose the sulfate form. There are no data to support early application of potassium causing better fruit set or yield.

IV. Calcium and Magnesium

A. *What role does calcium play in cranberry production?* Calcium is known to be important in holding cell walls together in plants. It is also important in membrane integrity and permeability. Calcium is immobile in plants once it reaches its "final resting spot". A constant low level supply of calcium is important. Plants get calcium from other fertilizers (triple or ordinary superphosphate), water, and from the mineral fraction of soils.

B. *What does Magnesium do for cranberry production?* Magnesium is essential to create and maintain chlorophyll for photosynthesis and it is involved in several enzyme systems. Mg is required, but at low levels compared to N, P, or K.

C. *Will I see a yield response to added Ca?* One research project showed increased yield with applications of CaB at fruit set. However, they did not separate applications of Ca & B, so we can't tell which element caused the response. Boron is known to be critical for flower development and pollen germination and growth. In my opinion, B was the limiting nutrient in these studies. However, when we look at several years of tissue test results submitted to the UW soils lab we found very few samples that were below the critical value—suggesting that calcium is seldom a limiting factor. The same is true for magnesium.

D. *How much calcium and magnesium are required in a season?* There is not a good answer to this other than to say not very much. The requirement is likely met through water and other fertilizers.

E. *Will calcium applications during bloom increase fruit set?* See C above. I know of no research data suggesting that applications of calcium alone during bloom will increase fruit set or yield (fruit set ≠ yield).

F. *Is gypsum an excellent form of calcium and will it lower soil pH and enhance soil drainage?* 1) gypsum ($CaSO_4$) is an excellent source of calcium for cranberries, 2) gypsum will **NOT** lower soil pH, 3) gypsum will enhance soil drainage on sodic soils by exchanging Ca^{++} for Na^{+} ions on the soil. I don't know of any sodic cranberry soils in Wisconsin.

G. *What soils will benefit most from calcium applications?* Sodic soils. *What are the effects on soil?* Gypsum will enhance soil drainage on sodic soils by exchanging Ca^{++} for Na^{+} ions on the soil. This reduces soil clumping and opens channels through the soil. I don't know of any sodic cranberry soils in Wisconsin.

H. *What calcium forms are available?* See the table below. Which are cheapest? Lime is cheapest, but has the unwanted effect of raising pH.

Material	Formula	% Ca
Calcitic lime	$CaCO_3$	40
Dolomitic lime	$CaCO_3 + MgCO_3$	22
Gypsum	$CaSO4 \cdot 2H2O$	22
Ordinary superphosphate	$Ca(H_2PO_4)_3 + CaSO_4$	54
Triple Superphosphate	$Ca(H_2PO_4)_2$	14

I. *Is there an optimum timing for calcium and magnesium applications?* I know of no research data indicating an optimum timing for Ca or Mg application for cranberry.

J. *What options are available to supplement magnesium?* Dolomitic limestone is the cheapest, but has the unwanted effect of increasing soil pH. Epsom salts ($MsSO4 \cdot 7H2O$) or potassium magnesium sulfate (SulPoMag) are acceptable.

K *Does soil pH affect Ca or Mg availability?* Mg is less available as soil pH declines. If tissue tests indicate low or declining Mg in tissue you'll want to check the soil pH. If it is much below 5.0 you can make the Mg more available by applying a little bit of lime to increase the pH to 5.0 to 5.5.

V. Micronutrients

A. *Should I consider applying micronutrients such as zinc, manganese, copper and boron?* As the class name suggests, these elements are required in very small amounts. You should add them if a tissue test suggests they are low or declining. I have not seen tissue test reports showing deficiencies in any of these elements. The one exception may be boron during flowering to fruit set.

B. *Have there been any studies showing the benefits of applying the above micronutrients?* There is very little field research with micronutrients. It is difficult to do and unless replicated many times the effects are usually too small to find with the natural variability of cranberries. There have been some laboratory studies to determine the critical tissue value for these elements. These values are reflected in our current tissue test recommendations. We have also looked at toxicity of these elements and while they may become toxic, the concentrations that affect vegetative growth are ~100 fold higher than what we have found in routine tissue tests.

C. *About how much of these elements are needed for optimum crop production?* I'm not sure that is the correct question. Much of these elements are retained in the perennial portions of the vines and little is harvested with the crop. Further, our soils typically contain adequate amounts of these elements. The question isn't how many pounds per acre [Kg/ha], but how many ounces per acre [g/ha]. Further, if your tissue tests show sufficient levels of micronutrients adding micros probably is not necessary (with the possible exception of B).

VI. pH management

A. *When is the best time to apply sulfur for pH management?* Small doses of no more than 100 lbs/a [90 kg/ha] are best. These can be effective once soils have dried and warmed in the spring. Fall applications of sulfur would be less effective (depending on the length of fall and the temperatures after harvest) because the reactions that release H^{+} ions are microbe mediated and thus are temperature dependent. Early spring applications would not have an effect until the soils warm.

B. *Is there a general rule for calculating the number of pounds of sulfur per acre required to reduce soil pH by 1 point?* There are some general rules, but all of these are mediated by the soil type and carbonate concentration in the soil. The table that follows gives some guidelines.

Initial pH	Sand or Loamy Sand	Sandy Loam or Loam
	lb./acre	lb./acre
7.0	800	2500
6.5	650	2000
6.0	525	1500
5.5	350	1000
5.0	170	500

C. *How many pounds of sulfur per acre should I apply to maintain my current soil pH?* That depends on how alkaline your water supply is. If your water does not contain much carbonate it won't take much if any sulfur to manage pH. This question would need to be answered on a bed by bed and water source basis.

VII. General Questions

A. *Each season I see many small aborted berries at harvest time. What do I need to do to set more fruit & size these berries for harvest? Is there a problem with pollination, fertility (amount/timing), heat stress or blossom injury?*
While all of the above factors can affect fruit set and size, in my opinion it is not any of these that limits fruit set and production. My research clearly showed that most of the carbohydrates that support fruit set and growth come from leaves on the current season growth above the fruit. When we measure photosynthesis on these leaves through a season and then do some math it appears that on average, a cranberry upright produces enough carbon to set and grow to maturity, 2 fruit. Good overall management will give you the best chance of setting and keeping as much fruit as possible. Having enough, but not too much N is important. Good pollination is critical, as is frost protection. But none of these individually will increase production. In my opinion this phenomenon is not a fertility issue.

B. *Each season (especially hot, dry years) I see "yellow areas" appear in producing beds (mostly Stevens, sometimes Ben Lears), is this a sign of poor fertility, drainage, or leaching concern, heat stress or disease? What is suggested for treatment?* In my opinion this is not strictly a fertility issue, but is a sign of stress. I have also seen it in hot periods. We typically don't see the symptoms in spring or in cool years. Being careful with irrigation and using the sprinklers to cool the vines during the heat of the day can reduce the stress. Good drainage is also essential. However, time and cool weather are also effective at reducing symptoms.

C. *Have you ever heard of manganese deficiency on cranberry?* I have not. I don't recall seeing manganese deficient in tissue tests. *Is it possible and under what conditions?* It is possible. Conditions that would favor manganese deficiency are high pH and organic soils. The condition could be exacerbated by heavy doses of Calcium as the calcium would fill up the cation exchange sites in the soil and Mn could be lost. How do I know if I have it? By taking a tissue test.

D. *Growers in BC plant into sawdust. Is this a reasonable alternative? Will the sawdust hold water and nutrients better? Will herbicides work better?* BC growers use sawdust because it is cheap and readily available. This is aged softwood sawdust. In my experience it does not hold water or nutrients any better or worse than other organic soils. It might be useful for growers planting into alkaline soils, but in those sites the water is typically alkaline so I don't think this is a long-term solution. The biggest drawback to sawdust is keeping it from floating when beds are flooded. BC growers are in the process of sanding heavily to keep their bogs from floating. They don't flood to make ice in the winter. I don't know if herbicides would work better or worse.

E. *Why soil & tissue tests in Aug/Sept. rather than spring?* There are two reasons to take tissue tests in the late summer as opposed to spring. The first is that tissue concentrations of elements (particularly N) change rapidly in the spring. That means that the date or stage of development at which the sample is taken has a large effect on the tissue concentrations found in the uprights. In the summer these elements don't change much so the exact date or stage of development is much less critical. The second reason is that you should think of fertility as a July-to-July process rather than a May to August process. A fall tissue test tells you if your fertility program was effective for the year and points out areas where adjustments may have to be made for the following year. If you make this "paradigm shift" then the fall collection makes more sense than a spring sample.

F. *Should I irrigate after a fertilizer application?* I think it is prudent to irrigate after applying fertilizer, especially fertilizer with K (the possible exception being a foliar application of micronutrients that may be best absorbed through the leaves). About 1/10 of an inch [2.5 mm] of water should be sufficient to wash granules off the vines, solubilize the fertilizer and get it into the top soil layer, yet not enough to leach nutrients through the soil.

G. *Should I consider using blended rather than manufactured fertilizer?* Blended fertilizers are less expensive than manufactured fertilizers. The primary drawback is that blended fertilizers have different particle sizes/densities and some elements may settle out in shipping and they may behave differently in the pneumatic delivery tubes on booms. I think the cost savings exceed this minor drawback. Be careful that when a dealer blends a fertilizer for you that they use ammonium nitrogen and sulfate forms of potash.

Temporal and Spatial changes in soil pH of cranberry beds

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Cranberries are acidophilic. The optimum soil pH for cranberries is between 4.5 and 5.5. Growers have long been encouraged to take soil samples in the spring or the fall. However, no good research data supported this timing. This research was undertaken to document temporal and spatial changes in the soil pH of cranberry beds.

This research was conducted at five cranberry marshes in Wisconsin. At each location a 15 x 15 meter grid was established in a single bed and flags were set at the intersections. GPS readings were taken at each point so the identical grid could be taken the second year. Soil samples were collected monthly to a depth of six inches. Soils were air dried. Soils were mixed with equal amounts of deionized water into a slurry. Samples sat for 30 minutes then were measured for pH just above the soil:water line with a pH electrode. Data were subjected to spatial statistics that allowed inference to be made as to soil pH between the actual sample points. The work was continued into a second year.

Soil pH was found to vary both over time and space. The average pH for Wisconsin soils we sampled across both years was 5.47. The overall range of individual samples was between 7.55 at Marsh 4 in May of 2001 to 4.4 at Marsh 2 in 2002. With the exception of marsh 4, most of the samples were between 4.5 and 5.5.

The mean at each property varied over time (Table 1). The typical pattern was that spring and fall measurements were similar, but summer samples tended to be lower than the spring or fall samples. This supports the standard protocol of taking soil samples for pH in the spring and the fall rather than mid-summer. Samples taken in June and July may give artificially low readings.

Soil pH varied widely between properties at a given date (Table 1). This reflects the environments the marshes were created in. Properties one and two are older with well established beds that were created from wetlands. Water quality at these locations is excellent. Property three was created from an upland, but has good water quality. Property four was created from an upland and water quality is not as good as at other locations. Property five was created from a transitional area and has excellent water quality.

Soil pH also varied within a bed. Figure 1 shows changes in soil pH at one property over 2002. These figures were produced in color and unfortunately didn't translate well to grays. However, the spatial variability in soil pH is obvious. There is more spatial variability in soil pH in July and August than in May, June, or September. This also supports collecting samples in spring or fall. The variability encountered also underscores the need to collect samples from through a bed and not along one edge or in one corner. Doing so may give you poor data.

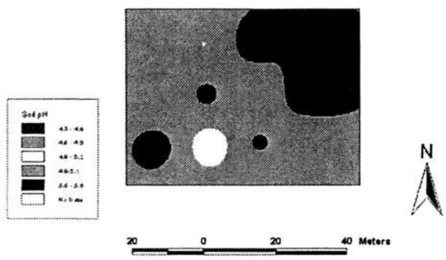
The results of this research show the importance of taking samples at the recommended time and to take samples randomly throughout an entire bed. The data also show the effect of parent material and water quality on soil pH and its management.

[1] I thank Armand Krueger and Bill Schmitt for technical assistance in this study and to Joan Davenport who did the spatial statistics and produced the figures.

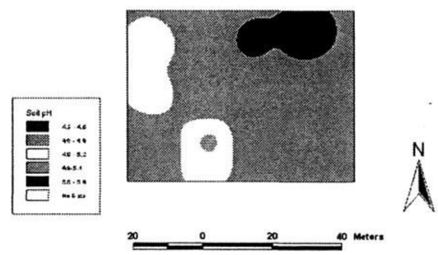
Table 1. Changes in soil pH at five Wisconsin cranberry marshes during 2001 and 2002.

Property	May	June	July	Aug	Sept
			2001		
1	5.29	5.22	5.06	4.98	
2	4.79	4.79	4.77	4.59	
3	5.47	5.35	5.00	5.10	
4	7.29	7.09	6.87	6.96	
5	5.3	5.15	5.08		
Mean	5.7	5.59	5.42	5.53	
			2002		
1	5.29	5.29	4.92	5.25	5.32
2	4.64	4.68	4.4	4.72	4.78
3	5.29	5.34	5.1	4.9	5.41
4	6.72	6.69	6.2	6.36	6.52
5		5.04	4.99	4.96	5.12
Mean	5.49	5.42	5.12	5.24	5.43

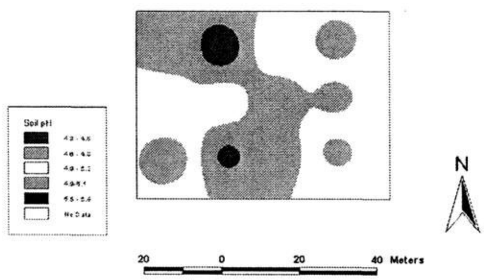
6" Soil pH May



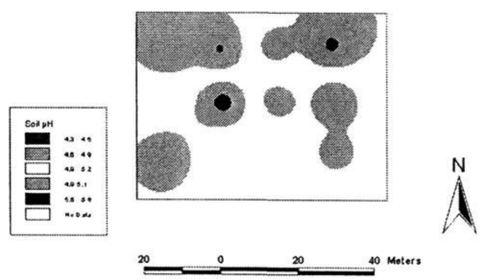
6" Soil pH June



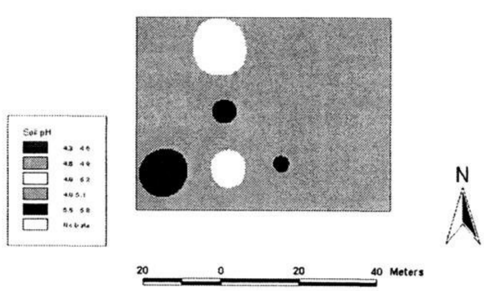
6" Soil pH July



6" Soil pH August



6" Soil pH September



Update on Stem Gall (Canker)

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Cranberry stem gall has erupted sporadically in Wisconsin for at least 25 years. The problem also has been reported from every other major cranberry-growing region. In 1998 and 2001 stem gall was especially common in central Wisconsin. Although stem gall commonly was called "canker" because of affected stems' rough, cracked surfaces, a close view of the symptoms reveals bumps and galls on uprights and runners. When the galls encircle the stem, all leaves, flowers, and fruit above the galled area die. Stem gall can range from being a minor nuisance to very ugly, affecting large portions of beds. Entire vines generally are not killed, and new uprights arise from the runners. However, it takes about three years before the affected areas regain full production. Also, weeds tend to crop up in voids left by dead uprights.

Stem gall often shows up in a somewhat linear pattern along the length of a bed and is sometimes worse near the bed ends. This suggests that mechanical injury might have a role, since beaters run the length of beds and can "rough up" the vines as they turn at the ends. Another form of wounding is low-temperature or "winter" injury, and gall symptoms have sometimes been noted in areas of the bed that were not protected by ice or snow, or where vines underwent freeze/thaw cycles. When woody plants recover from injury, they form callus tissue, which causes stem swelling. However, the galls that we've observed are different from callus. We do not believe that stem gall is merely a plant's normal, healthy response to wounding.

What causes stem gall?

Stem gall was a topic in the 1999 Cranberry School Proceedings (pp. 22-24). At that time, we suspected that the soilborne pathogen *Agrobacterium*, which causes galls on other plants, might be involved. While *Agrobacterium* may have a role, we think it's more complex than that. Our current thinking on stem gall is that it may not be caused by one pathogen, but perhaps by a collection of bacteria that produce indole acetic acid (IAA) which is an auxin type of plant hormone. Plants make their own IAA which is essential for cell elongation. However, many bacteria (including non-pathogens) found on plants and in soil also produce IAA. Usually production of IAA by non-pathogens has no bad effects on the plant. However, if they're present in large enough numbers and make enough IAA, bacteria can cause abnormal development of the vascular tissues needed for water and carbohydrate movement in cranberry plants. When we inoculate tissue culture cranberry plants with IAA-producing bacteria or with *Agrobacterium*, the plants develop galls. Applying synthetic IAA (purchased from a chemical company) also induces galls, suggesting that it's IAA and not the bacteria per se that causes symptoms.

To prove that bacteria are the cause of stem gall, we must reproduce gall symptoms on woody plants by inoculating with the suspected pathogens. So far we have not been able to reproduce symptoms on woody cranberry. This is somewhat troubling, because in the field it's the woody parts of stems that get galls. We've tried injecting woody stems directly and even dousing cranberry sods with high doses of bacteria, but galls have not developed. However, these experiments are ongoing—we haven't given up.

We think that bacteria have a role in stem gall, but it's clear that the environment plays an overwhelming role. The bacteria that make IAA and *Agrobacterium* are found in healthy beds as well as diseased beds; they cause trouble only under certain environmental conditions. What are those conditions? Anything that wounds stems and abundant water that allows bacteria to enter wounds. The winter that preceded the 2002 season was mild, with many freeze/thaw cycles and poor ice cover. This probably injured plants. At many sites where stem gall was severe, beds had been re-flooded during a late April cold snap. We think that during the re-flood, or perhaps even when irrigating for frost protection, bacteria entered through wounds. In the spring, when plants are breaking bud, the new vascular tissues are particularly sensitive to IAA. Microscopic evidence suggests that the abnormal growth that leads to stem gall starts as soon as plant growth resumes in the spring.

Managing stem gall

Managing stem gall depends on protecting plants from injury. So, take it easy with the beaters, and do your best to protect vines during winter. Also, if vines get too long (e.g., from lack of sanding), they tend to get lifted and ripped during freeze/thaw cycles. Even though copper is bactericidal, we do not recommend spraying copper. With bacterial diseases of other plants, copper is not effective when bacteria are actually inside the plant, as they are with stem gall. If you look at the labels for Champ, Kocide, and some other copper compounds, you will see that dormant sprays are recommended for control of "bacterial stem canker" of cranberry. This is puzzling, because our study of cranberry stem gall is the first aimed at identifying the cause. Apparently the fungicide manufacturers figure that if blueberry has a bacterial stem canker (which it does), then cranberry must have something similar. There simply is no data to support the label recommendations. Finally, stem gall occurs so sporadically and unpredictably, that you would waste a lot of money spraying it where the problem might never develop at all.