Demonstration of Bumble Bee and Indicator Plant Gardens

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Executive Summary

Cranberries are dependent on European honey bees for crop pollination. Previous studies suggest that native bumble bees have the potential to augment pollination in cranberries. Activities to increase native bumble bee populations around cranberry fields include targeted plantings of select plants (i.e. bumble bee gardens). Ideally these plants bloom prior to cranberries and after cranberries to provide bumble bee queens and workers with the necessary resources for the entire season. Lists of potential bumble garden plants have been developed but a hands-on demonstration site would provide the industry with data and experience so that growers can develop their own bumble bee garden plans.

A bumble bee garden was planted over the course of the 2014 field season at the BC Cranberry Research Farm. We sourced plants from local nurseries and used lists developed either specifically for cranberries or for the Fraser Valley in general. Bog rosemary, Ceanothus, and Rhododendron had the most bumble bee visits prior to cranberry bloom. Bumble bee visits to the demonstration garden during cranberry bloom were low. However, bumble bee visits to Himalayan blackberries, during cranberry bloom, was the highest observed in this study. Plants with high visitation rates post-cranberry bloom included Catmint (two varieties), Sedum (two varieties), a summer flowering Heather (var. Flamingo) and Salvia (one variety). The availability of these plants in combination with nesting and overwintering habitat for queens could help to support bumble bee populations adjacent to cranberry fields.

We also observed that three of the demonstration garden species (Ceanothus, Callicarpa, and Campanula) could be potential indicators for Dearness scale and cranberry fruitworm monitoring. Monitoring for the vulnerable stages of both these pests is intensive and having a reliable indicator of when to time monitoring could make monitoring more efficient.

Introduction and Objectives

Pollination of cranberry flowers is most efficiently done by bumble bees (Ratti *et al*. 2008, Macfarlane and Patten 1997). Commercial bumble bee hives are used in the greenhouse industry and are in development for outdoor use (http://www.thebugfactory.ca/news/). However, native bumble bees can potentially be abundant around agricultural fields. Bumble bees native to the Fraser Valley include *Bombus mixtus, B. melanopygus, B. flavifrons and B. vosnesenskii* and *B. occidentalis* all of these are potential pollinators of cranberries (Ratti *et al*. 2008, Macfarlane and Patten 1997). For other crops, the abundance and diversity of the native bee population has been shown to provide "pollination insurance" (Kremen *et al*. 2002, Ricketts 2004, Greenleaf and Kremen 2006). In other words, native bees provide additional crop pollination that can augment the pollination activity of European honey bee (*Apis mellifera*) from rented commercial hives. In years when conditions for honey bee pollination of cranberries are not favourable (e.g. rainy cool weather during bloom) native bees could mitigate some of the potential shortfall. Cranberry mass was found to be directly related to the abundance of bumble bees in cranberry fields during bloom (Ratti *et al*. 2008)

The challenge in using native bumble bees as pollination insurance for a specific crop however is to ensure that they are present in fields when the crop is in bloom and in large enough numbers (Macfarlane and Patten 1997). This may be possible if bumble bee queens overwinter and establish hives near fields (Williams *et al.* 2014). In order to do this queens (and workers) need pollen and nectar sources both prior to cranberry bloom and after bloom (Williams *et al.* 2014). While bumble bees can potentially utilize any source of pollen and nectar, they have clear preferences for certain types of plants (Williams *et al.* 2014) and not all types of pollen are of equal quality for bee development (MacFarlane and Patten 1997). In addition to food, shelter both for building hives and for queens to overwinter is needed. Plant material ideal for shelter includes bunching grasses for species that nest above ground (Williams *et al.* 2014). Information about building and establishing a bumble bee garden is widely available (e.g. Earthwise Society 2012). However, translating this information into a practical step-by-step process that cranberry growers can use to implement on their own farms is still challenging (Boss and Henderson 2000, MacFarlane and Patten 1997).

The objective therefore of this project, was to utilize the space and opportunity presented by the BC Cranberry Research Farm, to establish a bumble bee demonstration garden. The goal of this garden is to provide growers with a single site where they can observe the growth and appearance of various plants and to collect data on the activity of bumble bees in the garden before and after cranberry bloom. This study was a continuation of the work initiated by Boss and Henderson (2000), who developed a list of potential ornamental plants suitable for attracting and maintaining native pollinators in Fraser Valley cranberry fields based on commercial availability at the time. A secondary objective of this study was to determine if any of the species planted in the demonstration garden could be used as indicator plants to help time monitoring and/or sprays for some cranberry pests (e.g. first generation fireworm).

Project Activities and Methods

Demonstration garden construction and maintenance – Construction of the bumble bee demonstration garden began on April 11 and was completed on August 27. The garden was built as a raise (0.5-m high) bed with landscape ties used as edging and soil from the surrounding lands used as fill (Fig. 1). The garden was positioned along the south wall of the research farm building and was 2-m wide x 20-m long.

The garden was planted in two phases: the East portion was planted by May 15 and the West portion was planted by August 26. Plants were hand watered as needed and fertilized as per the growing instructions for the different plants in early November. The garden was hand weeded as needed each week. Plants for the bumble bee garden were purchased from both retail and wholesale nurseries (Table 1). We purchased the species that were available from the recommended bumble bee/pollinator plants lists developed by Boss & Henderson (2000), Williams *et al.* (2014), Anonymous (2011), Earthwise Society (2012), Macfarlane & Patten (1997) and expert advice (E. Elle, Simon Fraser University, Burnaby, BC, June 2014).

Figure 1. Bumble bee demonstration garden at the BC Cranberry research farm – April 11 (left) and August 26 (right).

Table 1. Summary of plant species, planting dates and bloom phenology for the main species planted in the bumble bee demonstration garden in 2014.

Plant	**Bloom Time**	**Planting date**	**Purchased from**	**Bloom start**	**Bloom Completed/or status on last observation date**
Cotoneaster dammeri	Pre-cranberry	April 15	East Richmond Nursery Inc.	Pre-bloom	June 3
Heather (Kramer's Red)	Pre-cranberry	April 15	East Richmond Nursery Inc.	In bloom at Planting	May 13
Rhododendron (PMJ Compacta)	Pre-cranberry	April 15	East Richmond Nursery Inc.	In bloom at Planting	April 26
Rhododendron –	Pre-	April 15	East Richmond	In bloom at	May 13

(White)	cranberry		Nursery Inc.	Planting	
Ceanothus (Victoria)	Pre-cranberry	April 11	Hanson's Nursery	Pre-bloom	July 1
Heather (Alba)	Pre-cranberry	April 11	Hanson's Nursery	In bloom at Planting	April 27
Rhododendron (PMJ Compacta)	Pre-cranberry	April 11	Hanson's Nursery	In bloom at planting	April 27
Bog Rosemary (Blue Ice)	Pre-cranberry	April 11	Hanson's Nursery	In bloom at planting	April 27
Callicarpa	Pre-cranberry	April 11	Hanson's Nursery	Pre bloom	July 15
Lavendar (Hidcote Bloom)	Post-cranberry*	April 11	Hanson's Nursery	Pre bloom	June 3*
Catamint (Dropmore Blue)	Post-cranberry*	May 22	Harris Nurseryland	In bloom at planting –	September 28
Campanula (Peachleaf bellflower)	Post-cranberry	May 22	Harris Nurseryland	Pre-bloom	July 22
Lupin	Post-cranberry	May 22	Harris Nurseryland	In bloom at planting	June 17*
Rhododendron (Red Eye)	Pre-cranberry	May 22	Harris Nurseryland	In bloom at planting	June 3
Blueberry (Early blue)	Pre-cranberry	May 22	Harris Nurseryland	Post bloom	N/A
Crocosima (Lucifer)	Post-cranberry	July 22	Aarts Nursery	In bloom at planting	August 5
Stonecrop (Cherry Tart)	Post-cranberry	July 22	Aarts Nursery	Pre bloom	September 28 (both live and dead flowers)
Stonecrop (Autumn Joy)	Post-cranberry	July 22	Aarts Nursery	Pre bloom	September 28 (50% bloom)
Skimmia (Rubella)	Pre-cranberry	July 22	Aarts Nursery	Post bloom	N/A
Rhododendron (PMJ)	Pre-cranberry	July 22	Aarts Nursery	Post bloom	N/A
Monarda (Bee Balm)	Post-cranberry	July 22	Aarts Nursery	In bloom	August 18
Arctostaphylos (Vancouver Island)	Pre-cranberry	July 22	Aarts Nursery	Post bloom	N/A
Salvia (Rose Queen)	Post-cranberry	August 12	Harris Nurseryland	In bloom	September 13
Heather (Flamingo)	Post-cranberry	August 12	Harris Nurseryland	Pre bloom	September 6
Veronica (Royal blue)	Post-cranberry	August 26	Harris Nurseryland	In bloom at planting	September 6

Catmint (Walker's Low)	Post-cranberry*	August 26	Harris Nurseryland	In bloom at planting	September 28 (dead blossoms)
Heather (Mediterranean Pink)	Pre-cranberry	August 26	Harris Nurseryland	Pre bloom	Did not bloom by September 28
Pennisetum (Little bunny)	Nesting habitat	August 26	Harris Nurseryland	N/A	N/A

* These species had flowers trimmed as their bloom period overlapped with that of cranberry.

Observations of bloom and bumble bee activity – Bumble bee activity in the demonstration garden was observed weekly from April 11 to September 28. The total number of bee visits to each of the different plant species during a continuous 15-minute interval was recorded. As our objective was to determine which plants were visited by bumble bees we recorded an individual bumble bee multiple times if different species of plants were visited during the 15-minute interval. During the 15-minute interval a single observer walked back and forth along a 10-m portion (i.e. East or West half) of the garden and observed all the plants in the 10-m long X 2-m wide portion. In addition to bumble bees we also recorded the activity of other pollinators, such as honey bees, syrphid flies, mason bees and solitary bees. Observations were done between 10 am and 5pm and not during rainfall or showers.

Finally, we also recorded bumble bee activity in the closest cranberry field (Field 1) during cranberry bloom (June 5, 11, 17 and 24) and in the adjacent margins of the research farm site when they were in bloom (June 11 to July 15). We flagged out our observation area in the cranberry field to approximately the same dimensions covered in a 15-minute observation period (2 m X 10 m). For each observation in the cranberry fields we pre-selected areas based on amount of bloom, thus we made observations in different areas each week. For farm margins we flagged out 10-m long transects along the East margin, adjacent to Himalayan blackberry bushes. As with the demonstration garden timed our observations along the margin and in the cranberry field for 15-minute intervals and recorded all pollinator activity in the observation area. Bumble bees observed were identified on site, however one or two bumble bees for each species observed were collected each week, to confirm field identifications. Tentative identifications have been made but confirmations are pending.

Results and Discussion

Bumble bee activity in garden pre-cranberry bloom – We only observed 18 bumble bee visits in the garden during the pre-bloom observations from April 11 to June 3 (Table 2). The majority of these bumble bees visits (10) were observed on the rhododendrons and five others were observed on Ceanothus (Table 2; Fig. 2). Many of these early blooming plants were in bloom when planted and most dropped flowers or ceased flowering within a week of transplanting. This was most likely due to transplant stress. Thus the data from this first planting season, are unlikely to be representative of the bumble bee activity around these plants in subsequent years. When the number of weeks with at least one bumble bee visit is compared to the total number of weeks that a species bloomed we see that some species had bumble bee visits during the duration of bloom (e.g. bog rosemary) (Fig. 3). This suggests that bog rosemary, if it can bloom for a longer period of time will attract bumble bees during most of its bloom. There were also some species that received no bumble bee visits during our

observations. This included Cotoneaster, Catmint (but see below), Potentilla and Spirea. Further, Potentilla and Spirea did not survive the drought at the end of May and beginning of June. Golden chain was visited by bees during each of its three weeks of bloom (data not shown) and was a preferred species for bumble bees in Washington State (Macfarlane and Patten 1997). However, this species has the potential to be highly invasive and for this reason we removed it from the demonstration garden and are not recommending it for cranberry farms in B.C.

Table 2. Summary of bumble bee visits to demonstration garden plants prior to cranberry bloom in adjacent fields at the cranberry research farm

Observation date	Species at 25% or more bloom	# of 15-minute observation intervals	Plant species and total number of bumble bee visits	Other flower visitors (across all species)
April 11	Rhododendron (PMJ and White), Bog Rosemary, Heather (Kramer's Red)	2	Rhododendron (PMJ) – 5 Bog Rosemary - 1	0
April 15	Rhododendron (PMJ and White), Bog Rosemary, Heather (Kramer's Red)	2	0	2 Calliphorid flies
April 22	Rhododendron (PMJ and White), Heather (Kramer's Red)	2	0	4 Syrphid flies 4 Calliphorid flies
April 29	Rhododendron (White), Heather (Kramer's Red)	3	0	3 Syrphid flies 2 Calliphorid flies
May 6	Rhododendron (White), Heather (Kramer's Red	2	0	3 Syrphid flies
May 13	Golden chain, Potentilla, Spirea	4	Golden chain - 1	5 Syrphid flies 1 Calliphorid flies 8 solitary bees
May 22	Golden chain	1	Golden chain - 1	3 Syrphid flies 1 Calliphorid flies
May 27	Rhododendron (Red Eye), Lupin, Cotoneaster, Ceanothus,	3	Rhododendron – 2 Lupin – 1 Ceanothus - 1	17 Syrphid flies 4 Solitary bees 6 Calliphorid flies
May 31	Lupin, Cotoneaster, Ceanothus,	3	Ceanothus - 1	23 Syrphid flies 7 Solitary bees

	Catmint			
June 3	Lupin, Ceanothus, Catmint	3	Ceanothus - 3	18 Syrphid flies 6 Calliphorid flies

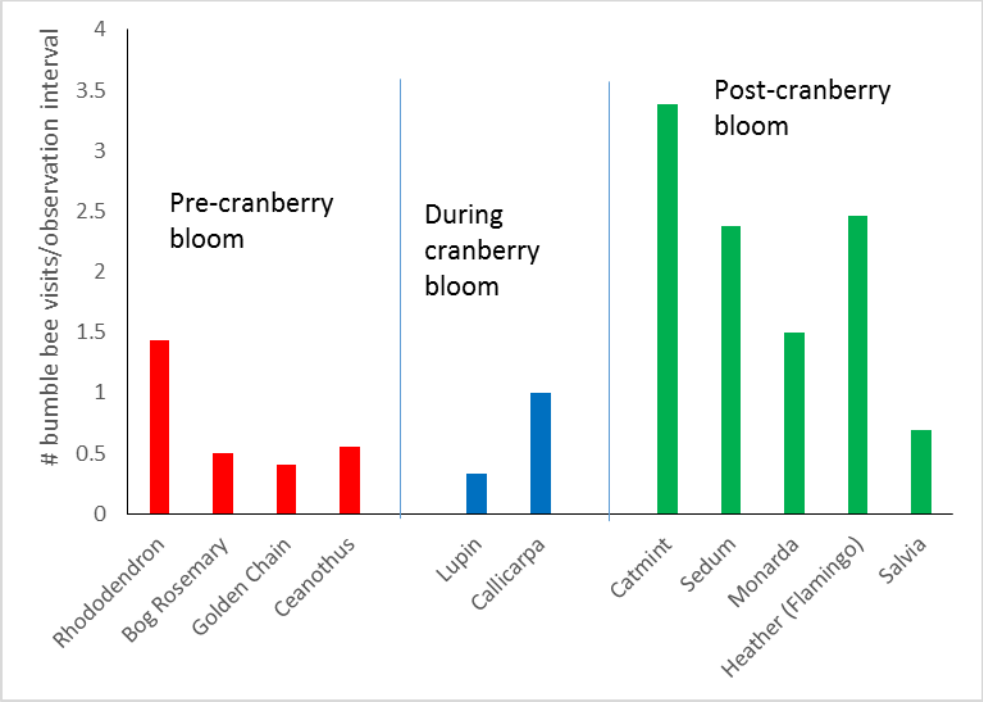

Figure 2. Summary of the average number of bumble bee visits/observational interval for different flowering perennials planted in a bumble bee demonstration garden. Averages were calculated only for dates when bumble bees visited the specific species.

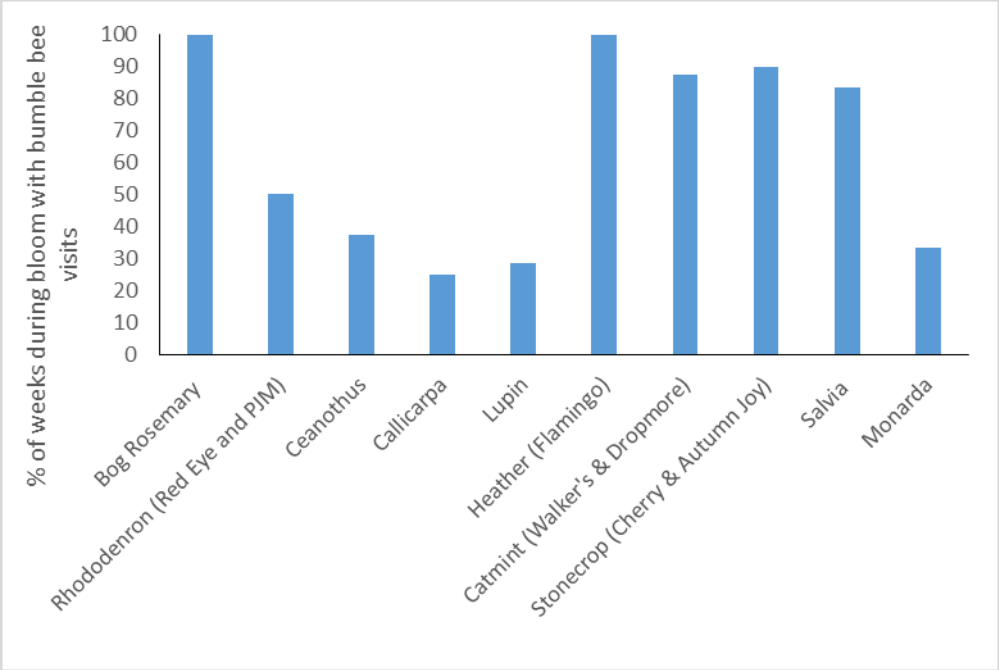

Figure 3. Summary of bumble bee visits for the different demonstration garden species. Data show the % of weeks during the bloom of each species when there was also at least one bumble bee visit observed. A value of 100% indicates that bumble bees were observed during all of the weeks that the species was blooming.

Bumble bee activity in garden during cranberry bloom – From June 5 to June 24 we only observed 3 bumble bee visits in the demonstration garden. These were found on Lupin and Callicarpa (Table 3). In addition to these two species Ceanothus, Campanula, Catmint and Lavender all bloomed during June and therefore overlapped with cranberry bloom. Mint and Lavender flowering stalks were trimmed and these species then set a later set of flowers for the remainder of the summer (see below). However, when Campanula and Lupin were trimmed in mid-June they did not produce a second set of flowers later in the summer. While trimming Ceanothus or Callicarpa flowers may be feasible when shrubs are small this will be less practical once plants establish. Further, flower removal may not result in a delayed bloom later in the summer. Finally, we did not find Lupin, Callicarpa or Ceanothus to be drought tolerant. Catmint on the other hand established well and was very drought tolerant.

While bumble bee activity was low in the demonstration garden during cranberry bloom, we observed the highest number of flower visits for this study in the blackberries growing along the east edge of the research farm. Between June 11 and July 8 a total of 58 bumble bee visits were observed during nine observation intervals (15 minutes each). Thus the bumble bee visitation rate on blackberries during this time was 6.44 bumble bee visits/15 minute interval. In contrast, the highest visitation rate for the demonstration garden plants was 3.5 bumble bee visit/15 minute interval (Fig. 2). During each of our nine observations in the blackberry edge we also observed a large number of honey bees (15+ for each observation interval). Since all of the beds at the cranberry research farm are still in the establishment phase we did not have uniform bloom throughout fields. Only six bumble bees were observed during our timed observations from June 11 to 24. These findings suggest that blackberries are potential

competitors with cranberries for pollinators, and the impact on activity of both bees and cranberry yield should possibly be explored further.

Table 3. Summary of bumble bee visits to demonstration garden plants during cranberry bloom in adjacent fields at the cranberry research farm

Observation date	Species at 25% or more bloom	# of 15-minute observation intervals	Plant species and total number of bumble bee visits	Other flower visitors (across all species)
June 5	Ceanothus, Catmint*, Campanula	1	0	2 Solitary bees 5 Syrphid flies
June 10	Ceanothus, Campanula, Lupin	3	Lupin - 1	6 Honey bees 12 Syrphid flies 2 Calliphorid flies 2 Solitary bees
June 17	Ceanothus, Campanula*, Lupin*, Lavendar*	2	0	4 Solitary bees 4 Syrphid flies 2 Calliphorid flies
June 24	Callicarpa, Ceanothus,	2	Callicarpa - 2	5 Solitary bees 11 Syrphid flies 3 Calliphorid flies

* These species had flowers trimmed on the corresponding date

Bumble bee activity in garden post-cranberry bloom – The most bumble bees visits to flowers in the garden occurred in the period following cranberry bloom (Table 4). However, this period of time also had the most weeks for observation – 15 weeks compared to four and nine for bloom and pre-bloom periods, respectively. Also, during this period of time we had three planting dates (Table 1) so that the number and variety of plants that were blooming was greater than in the pre- cranberry bloom period. We anticipate that in Year 2, the number and diversity of flowering plants in the garden prior to cranberry bloom will be quite high as eight pre-cranberry bloom species were planted this year. Also, some species of native bumble bee queens begin foraging as early as late February (Wilson et al. 2014, MacFarlane and Patten 1997) so our pre-bloom observation period will be longer.

Of the post bloom plants, Catmint (both Walkers Low and Dropmore) averaged 3.5 bumble bee visits/observation interval (Fig. 2) and had bumble bee visits for almost every week during bloom (Fig. 3). This species has a very long bloom period and although it started bloom in June, trimming flowers early did not impeded late bloom. Catmint has been recommended as a bumble bee forage crop by several recent authors (Earthwise Society 2012, Anonymous 2011). Some of the post-bloom species that were planted that did not have any bee visits observed were Corcosimia (Lucifer) and Campanula (Peachleaf bellflower). Monarda (bee balm) also had very little bee activity (Fig. 2) as did Veronica (Royal Blue) with only one bumble bee visit observed during the three weeks this species was in bloom; however both species are recommended on several lists (e.g. Williams et al. 2014), so they may perform better in Year 2. Corcosimia and Campanula did not appear to be drought tolerant so that may further limit their overall utility as bumble bee garden plants on cranberry farms.

Table 4. Summary of bumble bee visits to demonstration garden plants following cranberry bloom in adjacent fields at the cranberry research farm

Observation date	Species at 25% or more bloom	# of 15-minute observation intervals	Plant species and total number of bumble bee visits	Other flower visitors (across all species)
July 1	Ceanothus, Callicarpa, Campanula, Catmint	2	0	1 Mason bee 8 Syrphid flies
July 8	Callicarpa, Campanula, Catmint	2	Catmint - 9	1 Solitary bee 11 Syrphid flies
July 15	Campanula, Catmint	2	Catmint - 15	
July 22	Catmint	3	Catmint - 14	
July 29	Monarda Catmint Lavendar	2	Catmint – 11 Monarda – 3 Lavendar - 1	2 Solitary bees 2 Syrphid flies 1 Mason bee
August 5	Monarda Catmint Sedum (Cherry Tart), Lavendar	1	Catmint - 7	1 Syrphid fly 1 wasp
August 12	Monarda Catmint Sedum (Cherry Tart) Lavendar	1	Catmint – 3 Sedum - 2	3 Syrphid flies 3 Butterflies
August 18	Catmint Sedum (Cherry Tart), Heather (Flamingo)	3	Catmint – 4 Heather (Flamingo) – 5 Sedum – 2	24 Butterflies
August 23	Catmint Sedum (Cherry Tart), Heather (Flamingo), Salvia	2	Catmint – 2 Sedum – 1 Heather (Flamingo) – 1 Salvia - 1	14 Syrphid flies 8 Butterflies 1 Calliphorid fly
August 26	Catmint Sedum (Cherry Tart & Autumn Joy), Heather (Flamingo), Salvia	3	Catmint – 5 Sedum – 6 Salvia – 2 Heather (Flamingo) – 3	10 butterflies 2 Calliphorid flies 3 Syrphid flies
September 1	Catmint Sedum (Cherry Tart & Autumn Joy), Heather (Flamingo), Salvia	2	Catmint – 4 Sedum – 5 Heather (Flamingo) – 1 Veronica - 1	4 Syrphid flies 1 Solitary bee 3 Butterflies

September 6	Catmint Sedum (Cherry Tart & Autumn Joy), Heather (Flamingo), Salvia	3	Catmint – 8 Sedum – 9 Heather (Flamingo) – 22 Salvia - 4	9 Butterflies
September 13	Catmint Sedum (Cherry Tart & Autumn Joy), Heather (Flamingo), Salvia	2	Catmint – 5 Sedum – 4 Salvia - 1	4 Butterflies
September 21	Catmint Sedum (Autumn Joy)	3	Catmint – 11 Sedum – 11 Salvia - 1	
September 28	Catmint Sedum (Autumn Joy)	2	Catmint – 7 Sedum – 10	

Bumble bee species –The five most commonly observed species have been tentatively identified as *Bombus mixtus, B. melanopygus, B. flavifrons, B. morrisoni, and B. impatiens.* Of these *B. mixtus* and *B. melanopygus* are the short-tongued bumble bees which are most effective for cranberry pollination (Macfarlane and Patten 1997). Confirmation of identification is still pending. In their study, Ratti *et al.* (2008) found that bumble bee species diversity did not have an impact on cranberry yield. However, overall abundance of bumble bees was correlated with cranberry yield.

Other flower visitors – Other insects observed visiting flowers in the demonstration garden included solitary bees (such as Halticid bees), a few mason bees, and syrphid and calliphorid flies. We also observed butterflies visiting flowers in August and September. While there may be limited economic benefit to cranberry production from any of these species, the diversity of the arthropod community accessing the demonstration garden is another indicator of a functioning agroecosystem which bumble bees and other pollinators require in order to thrive (Williams *et al*. 2014).

Indicator plants – A secondary objective of this study was to determine if any of the plants used in the bumble bee garden could also be used as indicator plants to forecast the activity of cranberry pests. The timing of first bloom, 50% bloom or 95% bloom of ornamental plants are used as an efficient method to time insect control activities for ornamental and landscape IPM (Frank 2010, Mussey and Potter 1997). For example, euonymus scale crawlers have been shown to emerge at the same time that Oregon grape begins to bloom (Hodges and Braman 2004). Developing a reliable indicator plant-pest phenology tool requires three years of observation. Based on the first year of our study we suggest that Callicarpa, Ceanothus, and Campanula maybe good indicator plant choices for scale and cranberry fruitworm (Table 5). We were not able to use any of the information from our plants to obtain a tentative indicator plant for first generation fireworm, because many of our early plantings were blooming when we purchased and/or stopped blooming prematurely after planting. However, at the cranberry research farm we did observe that the native shrub elderberry was at 50% plus bloom during the same week that first generation fireworm larvae were observed at the research farm, and at an adjacent cranberry farm in Delta. These observations will need to be verified over at least two to three more years in order to determine if the industry can have more efficient timing for the start of monitoring for some pests.

Table 5. Observations of potential indicator plant and cranberry pest pairings, based on 2014 field season and pest activity at adjacent commercial cranberry farms.

Pest	Phenology and date	Plants	Phenology and date
Scale	Crawler emergence – June 5 (Richmond)	Campanula	First bloom – June 5
Scale	Crawler emergence – June 5 (Richmond)	Ceanothus	50% bloom – June 5
Cranberry fruitworm	Start seeing eggs on berries- June 23 (Delta)	Callicarpa	25% bloom – June 24
Blackheaded fireworm	First generation hatch – April 23 (Delta)	Elderberry (growing at BC Cranberry Research Farm)	50% bloom April 24

Summary – The primary objective of this work was build a bumble bee demonstration garden and to collect data on bumble bee activity. We observed that there are several plant species that bloom after cranberries that may be very beneficial for cranberry growers to consider adding to the landscape surrounding fields. These were Catmint (var. Dropmore and Walker's Blue), Sedum (var. Autumn Joy and Cherry Tart) and Heather (var. Flamingo). While we our pre-cranberry bloom findings are still preliminary, bog rosemary appears to be a promising choice for providing bumble bees with forage early in the season. Our findings also support the use of Rhododendron varieties PMJ and Red Eye for enhancing bumble bee activity. We also observed that several of the plant species planted in the demonstration garden may be useful indicator plants. In particular Ceanothus, Campanula, and Callicarpa phenology may match the timing of key event for some of the insect pests of cranberry. Interestingly, these Campanula, and Callicarpa were among the least promising as bumble bee forage after this first field season.

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