Cranberry pollination and bumblebees

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Pollination assessment

The main cranberry flowering barely lasted for 20 days at two sites on the Pacific coast with 3 or more bumble bees per 10 square yards (0.33 per m(2)). With one bumble bee (or it's the combined equivalent in bumble bees and honey bees) per 10 m(2) produced 200 barrels per acre on one bog in 1993. The main flowering persisted for at least 30 days at two sites with less than 3 bumble bees per 100 m(2) and with high flower populations. Prolonged flowering is a first sign of inadequate pollination.

The best crops with over 200 barrels per acre had less than 20 % of the flowers unpollinated. Average crops had 20 - 30 % unpollinated flowers and bogs with a temporary shortfall of pollinators had 35 % or more of the flowers unpollinated. In 1993, it rained almost continuously for about 20 days during the first half of 'Stevens' flowering and 150 barrels per acre were harvested from an isolated two acre bog. This compared with a previous top yield of 380 barrels per acre.

Relative pollinator effectiveness

Sharing commercial bumble bee colonies between blueberries and cranberries should lead to more economic and so wider use of colonies. In 1994, 18 bumblebee colonies were shifted from late flowering blueberries in Oregon to cranberries at Long Beach, Washington. To shift hives growers must close the entrance after dusk to obtain as many of the foraging workers as possible. For safety, keep colonies in the open part of a pick up truck, where any 'leaking' bumble bees will not pose a hazard to the driver. Provided these precautions are followed there seems to be little justification for a business intermediary. From this two crop use of reared bumble bee colonies it seemed that an equal sharing of costs between growers is reasonable provided: **1.** blueberry growers do not introduce colonies appreciably earlier as has been advocated in this report to improve the rate of foraging on the crops 2. The weakest colonies are retained by the blueberry growers. Weakness can be determined by disturbing the colonies. If less than 20 workers are active on the top then the colony could be opened to verify the lack of workers, but let it settle down for a few minutes. 'Old' colonies of bumble bees (placed a month earlier in another field crop) are valuable to mix with freshly delivered colonies for the early flowering cranberry varieties, because their foraging has reached its highest level. "Old' colonies are of less value for late flowering cranberries, because the colonies become senescent and foraging declines.

Delivery of bees to the bogs

The introduction of honey or bumble bee colonies to the cranberry bog environment releases more bees around the bogs within the colonies flight range. However, colonies only deliver a proportion of the bees to forage (actually visit the cranberry flowers) on the bogs.

Three factors make the delivery rate of honey bee inferior to bumble bee colonies: **1.** Honey bees have a more extensive foraging range than bumble bees. 2. Honey bees communicate within the hive about the quality of the sources of food. However, each

bumble bee learns from experience and sampling what flowers yield resources best for them. Thus honey bees have the ability to shift to masses of better yielding flowers more rapidly than bumble bees 3. Honey bees forage freely from a wider range of flowers than the short tongued bumble bees. Hence competing pollen sources can be expected to be more important for honey bees than bumble bees. Put another way the main bumble bee species visiting cranberry flowers have a better preference for cranberry flowers.

In Washington, there was no consistent relationship between honeybee populations and the no of hives used per acre. For the early flowering 'Stevens' on average there were 3 (range 1 - 6.8) colonies per acre compared to 2.3 (0.9 - 5.6) at the final stages for 'McFarlin'. Despite the higher initial rate on 'Stevens' the overall rate of honey bee populations measured on 'Stevens' was lower than for 'McFarlin'

By contrast, consistent delivery of the differently colored southern Californian *B. occidentah* was measured from bumblebees colonies at 10 study bogs between 1992 and 1994. With a medium (4.5 bumble bees per 100 m²) feral bumble bee population and 0.6 commercial colonies per acre at best 5 -10 % of the bumble bees came from the commercial colonies. With 4.5 colonies per acre eventually the commercial bumble bees dominated the bumble bee complex. These studies show a provisional delivery of about 1 bumble bee per 100 m² for each colony of commercial bumble bees. An initial stocking rate of up to 4.5 hives of bumblebees per acre is suggested for them to be the main pollinators. Recommended changes to the timing of introduction of bumble bee hives may change this initial guideline.

If peak activity of the commercial bumble bee colonies is synchronized better with the main flowering in cranberries then results may be twice as good. Colony foraging during flowering can be maximized by bringing colonies to cranberry bogs as or even a week before cranberry flowering starts. This is about 10-20 days earlier than was achieved in 1993 and 1994. With this early introduction of colonies then feeders should be used before the cranberry starts to flower and then turned off unless it is raining consistently. Turn the feeders on again for the new queens as the cranberry flowering stops. 'Old' colonies of bumble bees (placed a month earlier in another field crop) are valuable to mix in with freshly delivered colonies. 'Old' colonies are suitable, because foraging has reached its highest level for the early flowering cranberry varieties. They are of less value for late flowering cranberry crops.

Protection of pollinators

The diurnal pattern of bee foraging indicates that longer exposure to insecticides at night may be possible without unduly harming the bees. Honey bees are more sensitive to insecticides. Monitoring for bee kill with honeybees is a practical way to know whether bumble bee populations may be being affected too. For pollination and to minimize fungal attacks prudent growers should irrigate early during daylight hours in the morning up until about 8 am.

In the Pacific North-West there are few residential hives of honey bees in the vicinity of bogs so risks of beekeeping losses are not high. Sprays before cranberry flowering on bogs with reasonably attractive flowers (notably white clover, lotus, fireweed, white sweet clover) in or within range of the sprinklers would tend to be more damaging than spraying after flowering. All the bumble bee species are either growing or are at their peak before cranberry flowers and so are vulnerable. Sprays after flowering

will have less effect on populations, whose colonies (notably ***B. perplexus, B. bimaculatus)*** have mostly completed brood rearing and have fed almost all new queens. The valued and common ***B. impatiens*** and ***B. affinis*** remain vulnerable at the end of cranberry flowering. A lower rate of Diazinon would perhaps be a better insecticide to use than Guthion or Lorsban, where there is an insecticide threat to bumble bees.

Guthion applied directly to 'McFarlin' bogs toward the end of flowering killed few bumblebee workers and queens directly in colonies. Still the most toxic insecticides could cause some subtle damage to bumble bee brood rearing unless the insecticide is washed off before the bumble bees gather pollen from the flowers.

RESIDENT BUMBLEBEE POPULATION MANAGEMENT

In Wisconsin, variation in resident bumblebee populations will probably be similar to the Pacific coast. Most bogs, especially the large complexes, will have low (less than 2 bumble bees per 100 m^2) populations of resident bumblebees and some will have medium populations (2-8 per 100 m^2). Low and medium populations can apparently fully service respectively less than 10 % and the first and last 10 - 40 % of the cranberry flowers by themselves. A few bogs especially with surrounding woodland and that were less than 5 acres had high resident bumblebee populations and did not need honeybees.

Woodlands and their fringes, and banks along cranberry bogs often provide a range of food sources and some hollow logs and bird nests for bumblebee to nest in. Without cultivation, hibernating queens are not disturbed and the ground retains convenient abandoned rodent nest or tangles of dense grass/goldenrod clumps for the bumble bees to start colonies in. Suburban areas may provide additional surface and aerial nest sites well protected from rain and some valued bee forage sources. Adjoining farmland with flowering crops, but not grass or maize will provide food for the bumblebee.

The main species in central Wisconsin are predominantly mid season emerging and short and medium tongue lengthed species. In sequence of importance these species will be ***B. impatiens, B. affinis, B. terricola,*** and near woodlands ***B. vagans*** and townships ***B. perplexus*** and ***B. bimaculatus.*** However, in the North of Wisconsin, the early active ***B. terricola*** and ***B. ternarius*** will be more important and so early flowering cranberry varieties may perform better on the smaller bog complexes.

The elements of field management of bumble bees are the provision of food, field hives for occupation by queens, and the need for protection against particular colony enemies.

Food supply

The 8 - 15 bumblebee species in each region emerge at different times in spring to early summer. This suggests that the sequence of local food supply has been one critical factor in bumblebee evolution. Differences the activity of their natural enemies is another factor. I view provision of the best food supply is possibly the most critical element to achieve the highest residential populations. This is partly because even if a colony has started in a hive it can fail. This happens more in the early growth phase, when there are few workers to seek the more distant floral sources. Even in well fed colonies 15 % of the queens (less than 20 % of their body weight is fat) will not enter hibernation. In colonies without food stores during maturity more than 50 % of the queens will not hibernate. After hibernation at least 5 % of the lightest queens die before colony formation. Poor

food sources up until about mid spring does not seem to be so critical, because the latest emerging queens of early emerging species and all queens of mid emerging species can still form nests. Hence, I have gained the impression that a favourable sequence of food supply around the period that mid and late season crops flower usually has the greatest impact on bumblebee populations. This is when the food demands for the colonies that have succeeded is greatest.

Bees need nectar from flowers or honey dew for sugar and water in their diet. Pollen provides the protein, vitamins and most of the fat and is absolutely essential for the development of the bees brood (larvae and pupae). Bumblebees prefer to use perennial flowers in most cases, because these plants produce either more nectar or do so more reliably than the more shallow rooted annuals. Open and upwards or outwards facing flowers tend to offer less reliable or poor nectar for bumblebees, because rain can readily dilute the nectar and prevent collection of pollen. Willows, Rosaceae (pip and stone fruits, blackberry), composites (sunflower, goldenrod) flowers are among the less reliable nectar sources. Flowers with narrower and deeper downward facing nectaries are protected from rain. Hence most Ericaceae (blueberries, ornamental ericas, lings, heaths), barberry, legumes (lotus, clovers, beans) and Labiatae, Scrophulariaceae, Boraginaceae are usually more reliable food sources (Table 2). Different plants cease nectar production at a lower critical temperature, which in red and Dutch clover tends to be 2-4°F above the limit of flight for honeybees.

The quality of the food source is important, because the area available for other flowers around buildings, banks, and waste areas is limited. Productive land put aside for bee forage has an opportunity cost apart from rates and other overheads, so plants in these areas must be the best.

Table 2. Quality and sequence of availability of some important food sources

	Quality	Flowering
	Before cranberry flowers	
Willow	Poor	March - early April
Barberry	Good	Mainly April
Rosemary	Good	Mainly April
Blue berry	Excellent	May mainly
	After cranberry flowering	
White clover	Fair	June - August mainly
Lotus	Good	July - August mainly
Golden rod	Good	July - August

Field hives

Field hives for bumblebees are occupied by feral queens, but if better natural underground sites are available then very few hives are used. Only a partial control of the species is possible by choosing to use aerial, surface or hives that at least simulate underground sites. Some further control is possible by choosing the time of the year, when the hives are available for the queens to form nests in. Still too many sites experience less than 20 % of the hives with colonies starting in them. This is too little

given the use of hives by unsuitable species for cranberry pollination and colony losses before they reach an adequate size. Hence it is suggested approach that a limited number of hives (about 10 per test site) are tried in what seem more favourable sites to find sites that trap searching queens. If the sites have no success after two years then the site is probably unsatisfactory. Then it is better to extend placement of the hives to sites where some occupation has been achieved. During my stay with you I will try to find such sites if some of you are willing to risk making some field hives to test.

In Washington, *B. occidentalis* populations were sensitive to rainfall 50 % or more above average during colony formation. Hence all four of the underground nesting all four species of underground nesting *Bombus* in Wisconsin (Table 3) may be similarly sensitive. Painted hives with overlapping lids, and a floor 0.5-l inch above the ground, but with 4-6 drainage holes around the side of the floor and an entrance level with the floor overcome much of the problems associated with wet hives. Wetness is undesirable for the queens, because she needs a dry site to help her keep her brood at 86 - 90 ° F , while she incubates and forages for the nest. Trials with field hives in Washington showed the importance of having dry hives that are either underground or above ground to simplify management.

Use upholsters cotton to line the hive or pink wall insulating material or wool. Wool and wall insulating are harder to check for colony establishment. Other materials can result in the workers and queen becoming tangled in them and dying of starvation.

The erratic use of hives at different sites, which at least partly linked to the adequacy of food sources as the colonies are being formed. Hence, put hives near attractive flower sources during nest formation or otherwise few if any hives may be used.

Table 3. Bumble bee biology related to cranberry varieties and habitat preference

	Cranberry varieties -flowering		Habitat and
	Early	Later	nest preferences
bimaculatus	decline	mainly inactive	Suburbs, mainly surface
perplexus	peak to decline	mainly inactive	Suburbs, surface-aerial
vagans	peaking	peak to decline	Woodland, underground-aerial
terricola	growing	peaking	North woodland, underground
ternarius	growing	peaking	North woodland, underground
affinis	growing	growing	Farmland, underground
impatiens	growing	growing	Farmland, underground

Limiting losses from enemies

Once a colony has been formed in a hive or commercial colonies are introduced to the crop, they may still experience losses in output due to various natural enemies. Deer mice *Peromyces maniculatus* mainly near woods and house mice *Mus musculari*s more in cropping land consume the brood and bees in founding colonies and those in the first week or so of colony growth. Little is left apart from the bees wings. As well, mice, may consume pupae of colonies in late summer as they approach senescence. Skunks, bears, raccoons and possibly opossums will consume full sized mature colonies for their

nutritious pupae. Prevent mice attacks with a metal hole of 7/16 of an inch to stop their entry, while stout hives keep out all but the bears.

Female *Psithyrus* destroy the eggs and young larvae of the hosts and lay their own eggs in the colony. Even the entry of one female tends to disrupt colony development especially during colony formation. *Psithyrus* females suppress the *Bombus* hosts queens egg laying too. Bumblebee queens of their own species or some subgenera related species may invade the colony at a similar stage in its development. If the colony has over 15 workers they usually succeed in killing invading queens, but two or more invading queens on average reduce colony production and 5-30 usually stop it. Limited Ontario and central USA studies suggest neither invading *Bombus* or *Psithyrus* are as serious as they are in New Zealand and southern Alberta respectively. A reduction in losses can be achieved with a few strategic inspections to remove *Psithyrus* and to apply a queen excluder. The commoner cuckoo bumblebees *Psithyrus ashtoni* (hosts *B. terricola, B. affinis)* and *P. citrinus* (hosts *B. vagans, B. impatiens, B. ternarius* are commoner near wooded areas partly because they hibernate there. *Psithyrus* tend to invade colonies that have a few workers or colonies with only a queen in areas with many *Psithyrus.*

The larvae of the bumble bee brood fly *Brachicoma* spp. reduce queen output in bumblebees if there are more than per colony and can prevent queen production if there are 30-60 per colony. Currently the only control method is to remove and squash the larvae and pupae mainly around the margins of the bumblebee canopy. Surface and aerial colonies are more severely affected. This year we want to develop better methods to restrict the impact of bumblebee brood flies and the wax moth from our studies.

Dried fruit moth *Vitula edmandsae* larvae act like the wax moths in honey bee combs. They consume pollen stores and the pupal cells and then pupae of bumblebee colonies from about peak colony development. Hence they disrupt colony food storage and effect the vigor of new queens. Initial trials were made with 2-3 dustings with *Bacillus thuringensis* (BT) at 14 day intervals from the onset of activity (August or earlier). This was coupled with removal of obvious moths, and these controls seemed to delay the onset of infestations until the colonies stop growing. No further control is possible from BT after colony growth has finished, because large wax moth caterpillars were not killed with this dust. Hence, 1995 studies in Wisconsin seek alternative insecticides to treat for it within the bumblebee hive.

CONCLUSION

Until we know the pollinating effectiveness of bumblebees and honeybees better, we can not be sure what management techniques warrant the effort and cost put into them. In the meantime it seems prudent to at least start to develop better techniques for the control of natural enemies. Also to achieve the best use of bumblebees there is a need to gather the basic information on the relative attractiveness and presumably value of food sources for bumblebees. This could become important if the Africanised honeybee increases the cost of colonies to you or even restricts their availability.