

Bumblebees as Pollinators and Management Options

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BUMBLE BEES AS POLLINATORS

The value and effectiveness of bumblebees should be compared to honeybees to keep their practical use in perspective. Almost all of the pollinator force on cranberry crops is from honeybees and bumblebees. These pollinators and a few wasps and solitary bees provide cranberries with the pollination they need. Flower populations (yield potential) and actual yields in response to increases in the pollinator force must be known to determine how many bees are required on the bogs. Then we can derive the bees value to the grower.

Efficiency

On many crops, bumblebees (*Bombus* species) are 2-4 times more effective pollinators per bee than honeybees (*Apis mellifera*) and solitary bees such as the alfalfa leafcutter (*Megachile rotundata*). This is due to a 50-200% faster flower working rate and an average of 50 or more % longer hours worked each day. The importance of the working day remains underappreciated, and it is virtually unquantified worldwide. The greatest differential in average working days between bumblebees and honeybees occurs in wetter and cooler regions (e.g. coastal pacific Northwest North America) or seasons during crop flowering. The least difference occurs in consistently warm dry climates e.g. parts of California.

For a few crops, bumblebees can be 10-20 times more effective pollinators per bee than nectar collecting honey bees. This is either because bumblebees either contact the stigma more consistently on cranberries, blueberries, red clover, some vetches or their larger bodies contact much more of the stigma e.g. cucurbits (pumpkins, squashes, melons, cucumbers), cotton, kiwifruit, cranberries, feijoa. As well they may carry about twice as much pollen on their body hairs for transfer to stigmas.

Pollinator role of bumblebees

In Wisconsin and eastern North America, feral (unmanaged) populations of short and medium tongued species of bumblebees (notably *B. impatiens*, *B. affinis*, *B. terricola*, *B. vagans*, and *B. perplexus*) provide backup pollination that adds an element of reliability to pollination of other crops. These crops include lotus, Dutch, alsike clovers, sunflower, buckwheat, *Phacelia*, chicory, pip and stone fruits and berries. The honeybee is an effective and economic pollinator of most of these crops except for some major sunflower cultivars. Long tongued bumblebee species (*B. fervidus*, *B. pennsylvanicus* and the rarer *B. borealis*, and *B. auricomus*) prefer other flowers to cranberries. They are affective pollinators of red clover, many vetches, faba or tick and runner beans, blueberries, cherries, and cucurbits.

Bumble bees tolerate a wider range of insecticides than honeybees and solitary bees (alkali bees *Nomia melanderi*; alfalfa leafcutter bees; and perhaps mason bees (*Osmia* spp). *Osmia lignaria* (American) and *O. cornuta* (Japanese) in USA are of potential value for fruit pollination.

Colony characters and development

Commercially reared colonies of bumblebees will always tend to be expensive compared to honeybees. This is partly, because bumblebees are used only for pollination and adverts and can never be kept for honey production. Honeybees have potentially perennial colonies, because they can be requeened and so only colonies lost to disease and enemies need replacing. As well, all temperate species of bumblebee colonies last for 3-5 months. Colony formation takes about 4 weeks, colony growth (3-10 weeks - workers and males reared), maturity (2-4 weeks - new queens emerge) and senescence (2-4 weeks - brood rearing has ceased). Species with large colonies last

about twice as long as species with small colonies (20-50 active bees per colony). Even the American species with the largest colonies (*B. impatiens*, *B. affinis*, *B. occidentalis*, *B. vosnesenskii*) only last at peak pollinating activity for 6-8 weeks. During this time the colony approaches and then passes through maturity. Hence year round production of glasshouse tomatoes requires several colonies per year.

At their peak each colonies of commercially reared species can have 200-400 bees including the non stinging males. Maximum foraging averages 2-3 bees entering or leaving per minute. During summer a honeybee colony has 20-50,000 bees and the better colonies have 100-150 bees foraging from them per minute.

In spring, the queen (the large bumblebees) forms a colony, before the 6-8 workers (small, main stingers) from the first brood take over foraging for nectar and pollen for the colony. Usually, 10-30 % of the colonies that produce workers mature provided field conditions are reasonable (an adequate sequence of food supply, lack of major parasitism, bee poisoning, predation). Species with large or medium-large (*B. terricola*, *B. perplexus*, and perhaps *B. ternarius*) colonies produce an average of 60-200 queens per colony. Variation in total seasonal output between mature colonies within commercial species is quite large (800-3,000 bees and 1-900 new queens). Eventually there should be less variation when a few key pathogens have been eliminated and the more productive lines have been bred.

This output of new queens allows considerable potential for dispersal of overwintered queens to sites with more favorable food. For each queen this can occur over 2-3 weeks in spring before she starts her colony. Spring dispersal is usually within 2-3 miles, but can be as much as 10 or more miles. The high queen output allows for population recovery after unfavorable seasons. New Zealand and 1993-1994 Washington studies with two *Bombus* species confirmed that most (over 70%) of the new queens do not survive to emerge next spring from soil hibernation sites. However, if colonies are well fed during the production of new queens then at least 2 times as many enter hibernation. Hence, at Washington, queens from commercial colonies were overwintered artificially. Overwintered queens emerged for 30 days. In 1994, a sheltered cage (within a shed) was tried in an attempt to improve overwintering.

CRANBERRIES AND POLLINATOR EFFECTIVENESS

The following results were obtained on 60 cranberry bogs on the Pacific coast during 1993 and 1994. Half the virgin cranberry flowers visited once by honey bees formed berries. Two pollen collecting honey bees = one bumble bee based on working rate and a 30 % longer working day for bumble bees. On a favorable, 10 hour day one bumble bee would visit 6,000 flowers and on an average 4-5 hour day 2,500 - 3,000 flowers will be visited. Pollen collecting honey bees are 10 times more effective in pollen transfer than nectar collecting honey bees. This is based on working method (contact with the stigma) and pollen on parts of the body that contact the stigma.

Foraging and delivery to bogs

The rate of entrance activity of honey bees varied considerably between locations as well as with temperature and during the day but it did not change much throughout cranberry flowering. The general average of 80 entrances per minute for honey bees, was only marginally below the rates recommended for pollinating colonies. Foraging activity of *Bombus occidentalis* colonies direct from the producer 'Bees West' upon release produce about 0.5 entries and exits per minute. Within 30 - 50 days foraging builds up to the maximum of 1.5 - 2.0 per minute. Hence honeybee hives had 40 -160 times greater activity than bumble bee colonies.

The introduction of honey or bumble bee colonies to the vicinity of the cranberry bogs releases more bees into the environment around the bogs. However, only a proportion of the bees

that forage from the colonies are delivered (actually visit the cranberry flowers) to the bogs that are within the flight range of the colonies.

Three factors make the delivery rate of honey bee inferior to bumble bee colonies: 1. Honey bees have 2-3 times the average foraging range of bumble bees except in adverse weather. 2. Honey bees communicate within the hive about the quality of the sources of food, while each bumble bee determines from what flowers are yielding resources best from experience and sampling. 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 are 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. The rates were an average of 3 (range 1 - 6.8) colonies per acre for the early flowering 'Stevens' 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, responses in the bumblebees densities from commercial hives were apparent, although in three seasons data had been accumulated for 10 bogs. The ability of commercial bumble bee colonies to deliver bees onto cranberry bogs has been derived as an initial reference for stocking at up to 4.5 hives per acre. Recommended changes to the timing of introduction of bumble bee hives may change this initial guideline.

Irrigation, weather and bee activity

On cranberries, honey bee populations were reduced to 10 % of normal levels while the bog remains wet, but bumble bee populations remain at 80 % of normal on wet crops. Wetting the crops can discourage bee foraging by diluting the nectar and making the pollen temporarily unavailable for collection. Honey bee populations decline by more than a half once winds exceed 6 - 7 mph. Bumble bee foraging is not so readily affected by these winds, but declines beyond 7 mph.

Honey bee populations increased 70 fold on cranberries between the onset of foraging at 59 - 60°F and 71°F. Medium and high bumble bee populations increase 9 fold from about the onset of foraging at about 54 - 55°F and 71°F. At about 80°F bumble bee populations will level off and then decline in the middle of the day as temperatures extend into the 80's. Partly this is because honeybees deplete the nectar resource of the crop faster at high temperatures. In addition, bumblebees can only cool their colonies by fanning, which diverts workers from foraging. If the wax melts and larvae are exposed then bumblebee workers throw the larvae out, so overheating can be a problem. Bumble bee colonies try to keep at around 86-90°F. Honeybees bring water in to evaporate, which controls high temperatures better.

Consequently honey bee populations using cranberry flower are volatile to changes in the weather. As well only a few hours per day produce most of the foraging.

Most (80 %) honey bee foraging occurred between 11 am and 4 pm, while for bumble bees 85 % of the foraging occurred between 10 am and 7 pm. Foraging of bumble bees and honey bees on cranberries is a best low before 10 am even when temperatures above 65°F allow for adequate flight. This is presumably due to the time needed to replenish nectar in for new pollen to become available from newly opened flowers. With honey bees the relative percentage of cranberry pollen being gathered during six parts of the day was examined with the pollen traps over two days. Over 80 % of the weight of cranberry pollen was collected by honey bees between 12 am and 4 pm. This implies that much of the pollination done by honey bees is actually achieved during only four hours per day in the Pacific North-West.

Honeybee pollen collection

Honey bees collect cranberry pollen freely for about 7 - 10 days. There is steady decline in the percentage of pollen collecting honey bees on cranberry bogs as the season progresses. Hence better honey bee pollination should be achieved with early flowering varieties compared to later flowering varieties. Honey bees took 5-10 days to start to collect pollen freely after introduction to the bogs. The variation may depend partly on the attractiveness of other flowers close to the bogs. Honey bees were relatively slow to come onto a bog, where the colonies had been resident for all the year and learnt about their environment. This indicated that they were collecting pollen more from other sources such as scotch broom before the mass of cranberry flowers provided an attractive enough source of pollen to foragers. The effect of shifting hives in 10- 12 days later for bogs with mainly late flowering areas should be investigated judging from the seasonal trend in pollen collection. Final pollen gathering from cranberries was low while the majority of pollen come from blackberry (increased to 60 %). Catsear (false dandelion) with 15 - 30 % of the pollen, which was mainly gathered around mid day, was another major competing flower for honeybees. In British Columbia, white sweet clover seemed to be an important competing pollen source.

REARED BUMBLEBEE FIELD MANAGEMENT

The advent of extensive (100,000 colonies per year) commercial production of bumblebee colonies (*B. terrestris* - Europe, New Zealand; *B. impatiens*, *B. occidentalis* - North America) primarily for pollination of glasshouse tomatoes between 1987 and 1992 opened up new avenues for their field use and the resultant new queen progeny. However, the three large and at least seven lesser firms in all these areas have only just begun the sale of colonies for field crops. For North America, sales began in 1993/1994. To be frank these firms tend to be a "little green" at the best in dealing with colonies in the field. In a few years you should get better pollination service from more professionally handled colonies.

In Washington and British Columbia colonies not protected by an electric fence were eaten by bears even when placed on a high solid pole. The continued supply of sugar to foraging colonies is dubious or probably the wrong approach. I consider, the feeder should be shut off during pollination of the crop to ensure surplus nectar is used up within the colony. Only mature colonies accumulate food stores beyond daily use. Bumblebees are diligent foragers, because each day they must replenish food stores daily or temporarily starve, and they start foraging each day before honeybees can reduce the amount of accumulated nectar per flower. So far nobody has measured how much effect this contrast in feeder management has on foraging from the entrance, but perhaps extra food cuts foraging by half at least initially. The feeder can be reapplied along with the closing of the entrance for a day if harmful insecticides are applied, where any cranberry crop within 0.5 miles still has more than a trace of flowers. The feeder provides handy food for any colonies taken into a screen cage for new queens to be extracted for overwintering. No provision of a small (OS -1 inch wide) entrance landing and with entrances in the same direction caused workers to drift into lower colonies. Bumblebees and their social parasites (cuckoo bumblebees, *Psithyrus* spp) at least use a marking pheromone (virtually distinct for different *Bombus* subgenera) to assist females to find the colony entrance. The colonies produced by one of the major firms for tomatoes pollination are great for inspection and rapid control of wax moth operations. However, these hives have insufficient space for the largest colonies and inadequate ventilation and drainage for the fecal output. This tends to accentuate overheating problems and cause more ejection of larvae to make enough space for the bees. Colony foraging from commercial hives will benefit from shaded hives in old pumphouses, sheds, special shelters. Hives within 2 feet of each other should have the entrances facing in different directions to aid orientation.

Few bumblebees forage beyond 1/3 of a mile and with commercial colonies at least in the first 2 weeks foraging was concentrated within 1/6-1/10 of a mile (100-200 m). This is based on limited measurements on foraging from feral colonies in Nebraska, and hived colonies in New Zealand and Washington. Hence, when commercial bumblebee colonies are used in combination with honeybees, then place the commercial bumble bee colonies in the more central bog locations about 50 yards or more away from honeybee colonies. Keeping the bees apart and shutting of the feeders will lessen the risk of the honeybees robbing the bumblebee colonies. Let the honeybees and feral bumblebees look after the marginal flowers on bog complexes.

FERAL POPULATION MANAGEMENT

Management options

Management of field populations of bumblebees has barely extended beyond the planning stage anywhere in the world. In theory, more bumblebees may be obtained from the collection of overwintered queens or colonies started in field hives from a “wild or suburban area”, where bumblebees are not needed and then shifted to the grower. Trapping of colonies in field hives in a suburban setting in Christchurch, New Zealand and the sale of colonies over 60 miles away began the commercial use of bumblebees in the world in 1982. Eventually these sales to red clover, kiwifruit and alfalfa growers stimulated the European implementation of extensive commercial colony production by *Biobest* in 1987. In practice, release of bumblebee queens in two contrasting areas of Canterbury in New Zealand lead to population increases during that season at a dry cool continental area. Where queens have been consistently released since 1982, populations have increased even although hives placed out on the farm did not encourage any colony formation. This grower has planted strategic small comers of bee forage and has increased his range of nectar bearing crops so it now includes *Phacelia*, chicory and lotus in addition to Dutch and red clover.

In early summer, some urban dwellers especially need colonies removed when the owners come across them in their gardens, garages, sheds and house walls. However, only some of these colonies merit collection. Some are unavailable (in or under concrete, structural walls, roofs - that can not be reassembled). Others are too small or too far spent (tunnel activity less than 0.5 per minute) or with are species with a fierce temperament (mainly long tongued species) or have significant parasites (mainly the small parasitic wasp *Melittobia acasta* or many *Psithyrus*). Colonies with *M. acasta* have to be destroyed (put in a freezer, and hives treated with pyrethroids to kill residual parasites). Collection of large colonies from such sites with a net, cooler box and ice pads, tubes or canisters during the day takes about an hour before all bees return (foragers make up 30-50 %) of workers in growing and mature colonies. Removal of pupae of the bumblebee brood flies *Brachicoma* and adult moths *Vitula edmandsae* can in badly infected colonies take about 30 minutes. Readily accessible, medium sized colonies can sometimes be transferred to hives at night within a few minutes with only bee gloves for protection. The use of CO₂ as soon as the first of the brood clump of enclosed underground colonies is exposed may speed up collection. In practice, collection of colonies is used with some care to provide queens for bumblebee rearing. Eventually some suburban areas may provide limited amounts of colonies for crop pollination once “underemployed” bee keen youths can take advantage of this opportunity. Before this happens growers need to know the value of these colonies, which should be kept separate from commercial colonies to minimize the risk of spread of colony enemies.