Pollination and Honey Production in the Forest and Agroforest[1]

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ABSTRACT: It has been estimated that every third bite of food is dependent, directly or indirectly, on the active pollination of a food plant (Buchmann and Nabhan 1996). The vast majority of active pollination relies on the efforts of various vertebrate and invertebrate animals, especially insects. Although we have the greatest familiarity with the European honeybee (*Apis mellifera*), there are many native bees which also pollinate flowering plants. These native species are often called pollen bees to differentiate their major activity from that of the honeybees. Many forest tree species are dependent on insect pollination in order to fruit and set seed.

In addition to their importance as pollinators, honeybees are valuable as producers of honey and several other marketable hive products. Forested areas provide both forage and protection from excessive sun or wind. Forest management can be adjusted to open space around the crowns of favored bee forage species to maximize foraging area. In agroforestry techniques such as windbreaks, alley cropping and riparian buffer strips, tree and shrub species can be selected to favor bee forage. Raising honeybees in forests, windbreaks, tree alleys and riparian buffer strips enhances the direct economic return from implementing these management techniques.

Introduction

The importance of pollinating plant material has long been understood in a general way, with the exception of specific crops, such as orchard fruits and members of the cucurbit family, which farmers have long known require bee pollination in order to set fruit effectively. Both vertebrate and invertebrate animals are responsible for *active* pollination. Pollination can also occur *passively*, through the effects of wind and water movement. Bats are perhaps the best known of the mammals, and many bird species are known pollinators. At least one reptile, the gecko lizard, is also a pollinator. But by far, the insect world constitutes the greatest volume in the society of pollinators. The most common families of pollinating insects are the moths and butterflies [*Lepidoptera*], the flies and their relatives [*Diptera*], the beetles [*Coleoptera*], and the bees, wasps and ants [*Hymenoptera*]. This paper is concerned solely with the Hymenoptera, specifically the bees.

In North America alone, it is estimated that we have **four** to **five thousand** species of twig- and ground-nesting bees responsible for pollination. There are more than **twenty-five thousand** bee species and over **four thousand** wasp species which pollinate all over the world. Perhaps a more surprising statistic is that 85% of these pollinator species are **solitary**, not **social**, insects (Buchmann and Nabhan 1996, Batra 1997). Although some species, like the European honeybee, are generalists and pollinate a variety of plant species, there are other species which have evolved a very particular **obligate** relationship with a specific plant, which often means the demise of both if one half of the relationship is destroyed. This is of particular importance when the issue of endangered plant species is raised. If we do not fully understand the relationship of that plant to its pollinator(s), it may be futile to protect the plant species without also assuring the appropriate habitat for their insect associates.

Various factors in modern western lifestyle tend to threaten or eliminate habitat for our native bee species. Mite or insect and disease problems also threaten the lives of bees directly, especially our most familiar, though non-native, European honeybee. Although we think of pollination primarily in relation to agronomic crops, the role of bees and other pollinators in pollinating forest trees is poorly understood, but nonetheless important. Forest trees, whether in natural stands or as components in the design of various agroforestry techniques, can provide both forage for pollinating bees, as well as protection from excessive sun or wind (Webster and Hill 1994, Hill and Webster 1995). Products from the hives of honeybees can provide supplementary income that can partially offset the costs of appropriate forest tree management.

Bee Types

In general, bees can be separated into two groups, the bees which are naturally social insects, and the ones which are solitary. All bees collect nectar and pollen and make honey, but the solitary bees make only enough honey for themselves and their progeny. Each

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mated solitary bee makes a nest with approximately ten brood cells (Hubbell 1997). The social bees, such as the European honeybee, make large stocks of honey, most of which can be removed without damaging the viability of the hive. Solitary bees (Table 1) make their homes in twigs, in the ground, on adobe walls, in mud, in locations where other animals have already made holes, in wood, cardboard, and other materials.

TABLE 1. Solitary Pollinating Bees of North America

Common name	Genus	Number Species	Habitat
Carpenter bees	*Xylocopa*	8	chew holes in wood
Mason bees	Osmia	140	nest in pre-existing holes, close up with mud
Mining mud bees	*Anthopora*	60	nest in dry cliffs, adobe buildings
Polyester bees	*Colletes*	100	nest in ground, may occur in groupings
Digger bees	*Andrena*	500	nest underground
Leaf-cutter bees	*Megachile*	120	nest in pre-existing holes, line nest with leaf sections
Sweat bees	several	500	nest underground

(Information from Batra 1997, Lee 1998)

Most solitary bees overwinter in their nests and re-emerge in the spring when temperatures and other climatic conditions are appropriate for their spring activity. Almost all of the genera of solitary bees are beneficial for fruit crops (mining mud bees, mason bees, digger bees). *Anthophora abrupta*, one of the mining mud bees, is important in cranberry pollination (Lee 1998) and some of the polyester bees are particularly valuable for blueberry pollination (Batra 1997). [For the curious, polyester bees are so-named because they extrude a clear material to form a waterproof cover for their brood cells, and with a flap that closes the cell, the final result looks very much like a Ziploc bag. The clear material **is** a form of polyester.] Carpenter bees pollinate woody species including catalpa [*Catalpa speciosa*] and wisteria [*Wisteria frutescens*], and some species of digger bees pollinate red maples [*Acer rubrum*]. Leafcutter bees and sweat bees pollinate herbaceous species, including alfalfa. The alkali bee [*Nomia melanderi*], one of the sweat bees, is essential for alfalfa production in the western United States (Batra 1997).

Both carpenter bees and polyester bees may nest close to one another, so that even though they do not have the integrated social structure of a species such as the European honeybee, it may be possible to raise them communally, in order to have sufficient numbers of them for pollinating a particular crop. Although this may succeed logistically with the solitary bee species that already tend to nest in groups, a higher density of nest sites may make these pollen bees more susceptible to fungus diseases or other problems resulting from overcrowding (Hubbell 1997).

The smaller number of species, the social bees, include the European honeybee and bumblebees [*Bombus* spp.] as well as some genera of sweat bees, although the majority of sweat bees are solitary. Although apiculture, the raising of European honeybees [*Apis* spp], has been practiced both in the New and the Old World for centuries, **bombiculture**, the raising of bumblebees, is a fairly new development and more challenging than apiculture. Bumblebees are true social insects, with a queen, division of labor among drones and workers, and overlapping generations of individual bees. Bumblebees are excellent pollinators, especially for such crops as hothouse tomatoes. One of the characteristics that makes them so effective is that they "buzz" on the flowers, a process known as *sonication*. This vibration shakes the flowers and causes pollen from the flowers to scatter in all directions. Bumblebees can be raised right in the greenhouses with the tomatoes (Buchmann and Nabhan 1996).

The European honeybee is the best known of our pollinators. A generalist, it is often considered the best

insect pollinator because:

- individual worker bees show species fidelity to single species of flowering plants;
- the necessity of feeding 50,000 to 80,000 bees per hive means that each bee will make multiple trips daily to the same species of flowers; and

- honeybees overwinter as adults in colonies, so they can "jumpstart" with pollination and nectar collection in the springtime with a large resident population of foraging bees (Hill and Webster 1995). In a mild winter (with many days having temperatures over 50 degrees Fahrenheit), honeybees may even be able to do some limited foraging during that time, thereby reducing demand on stored hive reserves.

On the down side, some scientists have expressed concern that honeybees are *too* efficient in their collection of nectar and pollen, leaving none in a given local flower source for the foraging of other pollinators (Buchmann and Nabhan 1996, Hubbell 1997). Native Americans called the European honeybee "the white man's fly" because swarms of the honeybees often preceded the colonization of land by European pioneers (Hubbell 1997). Nonetheless, in the past three centuries of this country's existence, the honeybee has become a mainstay of the American agricultural scene, and the products of the hive much appreciated by the public.

Threats To Pollinators

Since the variety of pollinators use a diversity of habitats, the more diverse the agronomic ecosystem is, the more likely it will support a healthy variety of beneficial insects, including the pollinators. The more agribusiness advances the spread of square miles of monocultural crops, as well as the removal of hedgerows and windbreaks to maximize the area cultivated, the more the diversity of this particular microfauna will be threatened. Large-scale irrigation is another activity that may destroy the nests of ground-nesting bee species. Heavy use of insecticides is an additional problem for pollinators, as many of them are particularly sensitive to chemicals. Improving knowledge of the variety of pollinators available to pollinate agronomic and orchard crops can help farmers make their farms more profitable. Understanding the habitat needs of these pollinators and providing appropriate habitats for these insects can improve integrated pest management programs and reduce the need for chemical pesticides (Roland 1998).

Another problem, specifically for the European honeybee, is a combination of two mites that have attacked the honeybee population over the last several years. The first is a tracheal mite [*Acarapis woodi*] that infests the windpipes of the honeybees. The second is an external mite [*Varroa jacobsoni*], that parasitizes honeybee larvae. Both are lethal to the honeybees. Tracheal mites can be controlled with plantings of members of the mint family [*Mentha* spp] around the hives, and with medicinal applications of camphor or menthol inside the hives. The *Varroa* mite is more difficult to control, but hives can be medicated with some success. Interestingly enough, a related *Apis* species in the Orient has co-evolved with the *Varroa* mite, and has also evolved a grooming behavior to remove the mite from its body. If the mites get into places that the individual honeybee cannot reach by itself, the species has also evolved a grooming "dance" to alert fellow hive mates about the need for assistance. It would be ideal if the two species could somehow be put together so the European honeybees could learn the grooming behaviors from their Oriental cousins! Approximately two years ago, it was estimated that more than 90% of the feral or wild populations of honeybees had succumbed to the double jeopardy of the mite infestations (Hubbell 1997). Even domestic populations dropped by over 50% the winter of 1995-1996. However, in the summer of 1998, I began to hear anecdotal evidence in both southern Ohio and in Kentucky, that beekeepers and others were seeing wild swarms of honeybees, some of which had taken up residence in abandoned domestic hives. If the feral honeybees are indeed making a comeback, they probably have developed some kind of resistance to the mite problems.

Management For Pollinators

Human activity is not all bad for either pollen bees or honeybees. Bees tend to like open, sunny areas, so cultivation of the land and opening up of the original forested lands of the eastern United States helped with the development and spread of bees. Both traditional forestry and agroforestry provide opportunities for improving habitat for all species of bees.

In forestry, a practice known as **crop tree release** involves selecting the best commercially valuable trees in a stand - usually every thirty feet or so in a fully stocked stand - and marking to thin all trees around the

crop trees to allow the selected trees maximum amounts of light, nutrients, and water. Opening the stand in this manner allows more light into the midstory and forest floor than is available under a closed canopy. Another option, useful for managing for a non-timber crop such as maple syrup as well as for bee forage, is thinning the stand to a level where crowns of adjacent trees are not touching, allowing the crowns to grow fuller in circumference and deeper down the stem of the tree. The larger surface area thus provided produces more flowers - and bee forage - than a smaller crown. Although this type of management shifts the growth of the tree to an increased crown rather than greater height or diameter growth, it is possible to manage for maple syrup, nut production (walnuts) and/or bee foreage area on forest trees and still make them a timber crop at a later date. For timber value, it is important that the first 16-20 feet of the tree bole or trunk is free from branches.

Honeybees expend energy to cool themselves and their hives during hot weather. If the hives are shaded, that energy can be diverted to honey production and necessary hive maintenance activities. Forest trees, especially deciduous forest trees, are excellent for shading beehives, especially if the hives are placed on the north or northwest sides of the trees. On those aspects, the hives will receive maximum shading during the summer heat, yet be able to receive insolation in the winter when the leaves have fallen from the trees (Webster and Hill 1994). If a forested area has been thinned for crop tree release or **crown release**, the openings thus available would be excellent locations for siting hives, providing both some light and protection from too much sunlight and too much wind.

In agroforestry, the techniques of alley cropping, riparian buffer strips and windbreaks offer design opportunities to include tree and shrub species particularly good for bee forage, such as basswood [*Tilia americana*], black gum or tupelo [*Nyssa sylvatica*] or yellow-poplar [*Liriodendron tulipifera*]. Windbreaks in particular use three to seven rows of mixed deciduous and coniferous trees to form a wall which will break or divert the force of prevailing winds. Fast-growing species in such a formation could provide both appropriate bee forage as well as physical protection from excessive sun and wind (Hill and Webster 1995). Of these three agroforestry techniques, alley cropping may have the least flexibility, as there is usually only a single row of trees in the tree rows between the alleys of agronomic crops. Alley cropping could, however, use bee forage trees for the long term crop. Riparian buffer strips follow the contours of the stream or other watercourse they are protecting, and their multi-layered format (zone 1 - trees along the water, zone 2 - shrubs behind and upslope from the trees, zone 3 - native grasses behind and upslope from the shrubs) offers many opportunities for siting hives and/or providing bee forage.

Products From The Hive

Honey is by far the most common and best known (and appreciated!) product from the honeybee hive. Honey has been a source of sweetness in the diets of humans and other animals since the beginning of recorded time. Aside from its value as a high-energy food source, honey also has natural antiseptic, antibiotic and antimycotic characteristics (Lee and Lee, 1995). Honey is an easily digested food, primarily because it is already pre-digested by the bees themselves. Recent research at the University of Illinois, Urbana-Champaign, indicates that not only does honey taste good to us, but also it contains antioxidants, on average about the same amount as tomatoes. Although this quantity is not overwhelming on its own, especially if we use honey by the teaspoonful, it can be significant if some of the higher level antioxidant honeys are used in food processing. Some studies in food science at Clemson University indicated that using honey in prepared meats especially reduced the rate of oxidation of those meats once they were cooked (Raloff 1998). On a commercial basis, much of the honey available is clover honey or wildflower honey. However, there is a sizable gourmet market that seeks out honeys made from tupelo, basswood, or sourwood [*Oxydendrum arboreum*] trees. Some enterprising entrepreneurs have even started to add special flavorings to honey, such as ginseng, which creates a product with a considerably higher value than the original honey itself.

Beeswax is probably the second most familiar product of the hive. Beeswax is the waxy coating that bees use to seal off the honey-containing cells as well as the brood cells for new queens. It has been used for candle-making and a wide variety of domestic and industrial applications. Its value in the marketplace has been increasing, along with the value of honey, over the past two decades.

Bee pollen is another product from the hive. The average hive in North America can produce about 50 pounds of honey per year. That same hive may also be

able to produce 50 pounds of pollen per year. Bee pollen has been used in sports medicine as a legal quick-energy supplement. It contains amino acids, enzymes and hormones and can not only provide a jolt of energy, but also can be used to treat disease, increase working capacity, and diminish tiredness. Along with studies to use locally produced honey to combat allergies, the United States Government has been studying bee pollen as a treatment to prevent or reduce allergenic reactions (Lee and Lee 1995)

Royal jelly, a glandular secretion produced by young female bees, is primarily for the exclusive diet of the queen. Every honeybee larva receives a three-day supply of this extraordinary material at the beginning of its development. The queen receives *only* this material during her entire development. This unique diet produces an insect that is 40 percent larger and 60 percent heavier than the other bees and enables the queen to live for up to five years, in contrast to an average bee's lifespan of three months or less. The queen bee is also capable of laying up to 2000 eggs per day to repopulate the hive. Royal jelly has strong antimicrobial and anti-inflammatory properties, aids skin regeneration (hence its value to the cosmetic industry!), and increases resistance to disease (Lee and Lee 1995).

Propolis, the last of the hive products, is a sticky, resinous material that the worker bees collect from small bark wounds in hardwood species such as poplars [*Populus* spp] and from conifers. It is brought into the hive for various repair work, often used to seal the interior of the hive, and to reinforce the walls of brood chambers and passageways. It also protects the bees from viral and bacterial infections. Research indicates that propolis can stimulate the thymus gland in humans and boost the immune system. Propolis has antifungal, antibiotic, and antiseptic properties (Lee and Lee 1995).

In addition to all these hive products which can be marketed in grocery stores, farmers' markets, natural food and health food stores, there is considerable anecdotal evidence that people suffering from rheumatoid or arthritic problems have found relief from the pain of those afflictions through **bee venom.** The problem with this treatment is that it still needs to be administered by the bee, which dies in the process. This treatment has been used more widely in Western and Eastern Europe and in China than in the United States, but has been observed as effective for generations. Beekeepers usually don't have arthritis - or at least experience pain from it! (Mraz 1995, Lee and Lee 1995).

All of these hive product options have substantial economic value. The price of honey has increased from about 17.5 cents a pound in 1970 to over 3 dollars a pound today (Jones 1985, Fox 1997). A pound of bee pollen may be worth twice that. Royal jelly and propolis are produced in smaller volumes per hive per year, and are priced in response to a limited supply and an increasing demand. Marketing beehives for pollination work has changed from a price of $22 per colony in the 1980s to $34 per colony in 1997 (Hubbell 1997). Nurturing our honeybees and protecting them from mite and disease problems yields financial benefits in return.

Summary

We are slowly becoming aware of just how important pollinating insects are to the continuance and health of our food plants. We also realize that many of those same insects are essential for the healthy reproduction of our forests and agroforests. Both pollen bees and honeybees would benefit from more attention paid to the preservation and restoration of appropriate habitat as well as to a diversity of flowering species for bee forage. As agriculture becomes more simplified and conducted on larger scales as agribusiness, it will be increasingly important to monitor practices such as large scale irrigation and use of insecticides so that negative impacts on these pollinators are minimized. In addition to their essential role in pollination, the European honeybee continues to provide us with food and medicinal products from its hives. These activities continue despite attacks by two lethal mites as well as environmental challenges. The value of crop pollination probably can be measured in billions of dollars nationally, while the hive products contribute more millions to local economies on an annual basis. Appropriate management of our native forests, as well as the tree components of agroforestry techniques such as alley cropping, riparian buffer strips and windbreaks, will help ensure the health and survival of these "busy" workers.

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