Pollination and Bee Plants

Pollination

This section is about how flowers, from apples to rutabagas, are pollinated, set seed and bear fruit. It also outlines the importance of adequate pollination from bees and other pollinators. Growers and beekeepers may have to have wild or native bee pollinators help honey bees with the pollination tasks. Many beekeepers are supplementing the pollination workforce by rearing native bees such as sweat bees, bumble bees and leafcutter bees, to name a few.

Some Definitions

Flowers are the reproductive parts of a plant, where seeds are formed and from which the fruits and vegetables develop. For the cycle to begin, a pollen grain, which is often carried on an insect or by the wind, comes in contact with the stigma (or female part) of the same flower species.

Fertilization takes place when pollen from the anther (male organ) unites with a female ovule, which forms the seed and fruit. Each species of plant has its unique shape and form of pollen grains, which enables paleobotanists, studying ancient plants, to identify pollen from the mud at the bottom of 10,000 year old bogs. The transfer of pollen from male to female sex organs is called pollination. All plants must be pollinated before seed (or fruit) will set. Pollen is transferred from the anthers to the stigma by wind, water, gravity, mammals, birds, humans and insects.

If the transfer takes place on the same blossom or on another blossom on the same plant, it is called self-pollination. Beans, for example, are self-pollinating. Though many kinds of beans and other plants do not need insect visitors, they do benefit from the extra pollen carried by them and may even set better or more fruit. This is true for soybeans and lima beans.

But if the pollen goes from a Red Delicious apple tree to a Granny Smith apple tree, this is called cross-pollination. Apples and many fruits have a further complication. Many varieties are self -sterile. That means the pollen from the Red Delicious will NOT pollinate itself or flowers from other Red Delicious trees. It must have another variety of apple pollen to set fruit.

The placement of apple varieties, size of the blocks of *pollenizers* (trees used just as a source of pollen) and length of rows may be important in fruit set in the orchard. Pollinizers in apple orchards are sometimes crabapple trees. It is important not to have too big a block of any one variety in any single area of the orchard.

Many plants are wind pollinated, including all the grasses (and their cultivated cousins corn, oats, wheat, rice), tomatoes, ragweed and evergreen trees. Such pollen is light and is produced in enormous quantities and is the cause of allergic reactions or hayfever to many people.

Structure of a flower

The sexual organs of flowers are protected by delicate petals that form the *corolla* or the colored part of a flower. The male parts include the *stamen*, which are hairlike filaments bearing *anthers* at the end; see illustraion on page 3. The anthers *dhisce*, that is, break open and disgorge the microscopic (20-25 micron) *pollen grains*, anywhere from tens of individual pollen grains to billions of them. The female parts are contained in the *pistil*, and include an *ovary* with one to many *ovules*, a *style*, which extends from the ovary and bears the *stigma* at the tip.

The Ovary produces the fruit and the ovules the seeds. The flower may open for only an hour or so, or may stay open for over 100 days or more (orchids). NECTARIES of flowers are usually at the base of the sexual column

The Mechanics of Fertilization

When a bee visits an apple flower, she picks up *pollen* grains from the male sex organ called the *anther*. Pollen carries the sperm cells needed to fertilize the female ovule. The bee picks up the pollen grains and then moves on to another apple flower, where her body may brush up against the *stigma* or female organ. Grains of pollen stick to the moist tip of the stigma, after which incredible things begin to happen. The pollen grains start to grow a root, called a *pollen tube*, down the pistil, to deliver two sperm cells to the female ovule (embryo seed). This tube has to grow down the entire length of the stigmatic tissue to reach the ovary. Once it has found an unfertilized ovule, the two sperm cells are released. When one sperm cell fuses with an egg nucleus, it becomes the *seed*. This fertilized egg becomes the embryo of a new plant, which includes the body of the plant. The other sperm cell goes to the center of the ovule to unite with the polar nuclei; this develops into tissue called the endosperm, which

nourishes the developing embryo. The endosperm becomes the seed leaves or cotyledons of the new plant.

After fertilization, the ovules secrete hormones that stimulate the wall of the ovary to thicken into the surrounding fruit tissue. From this complex, double fertilization, almost all flowering plants on earth are pollinated. Even 'seedless' varieties of some crops need to be pollinated, as they usually start to form a seed, but it is aborted early in its development.

Plant breeding systems

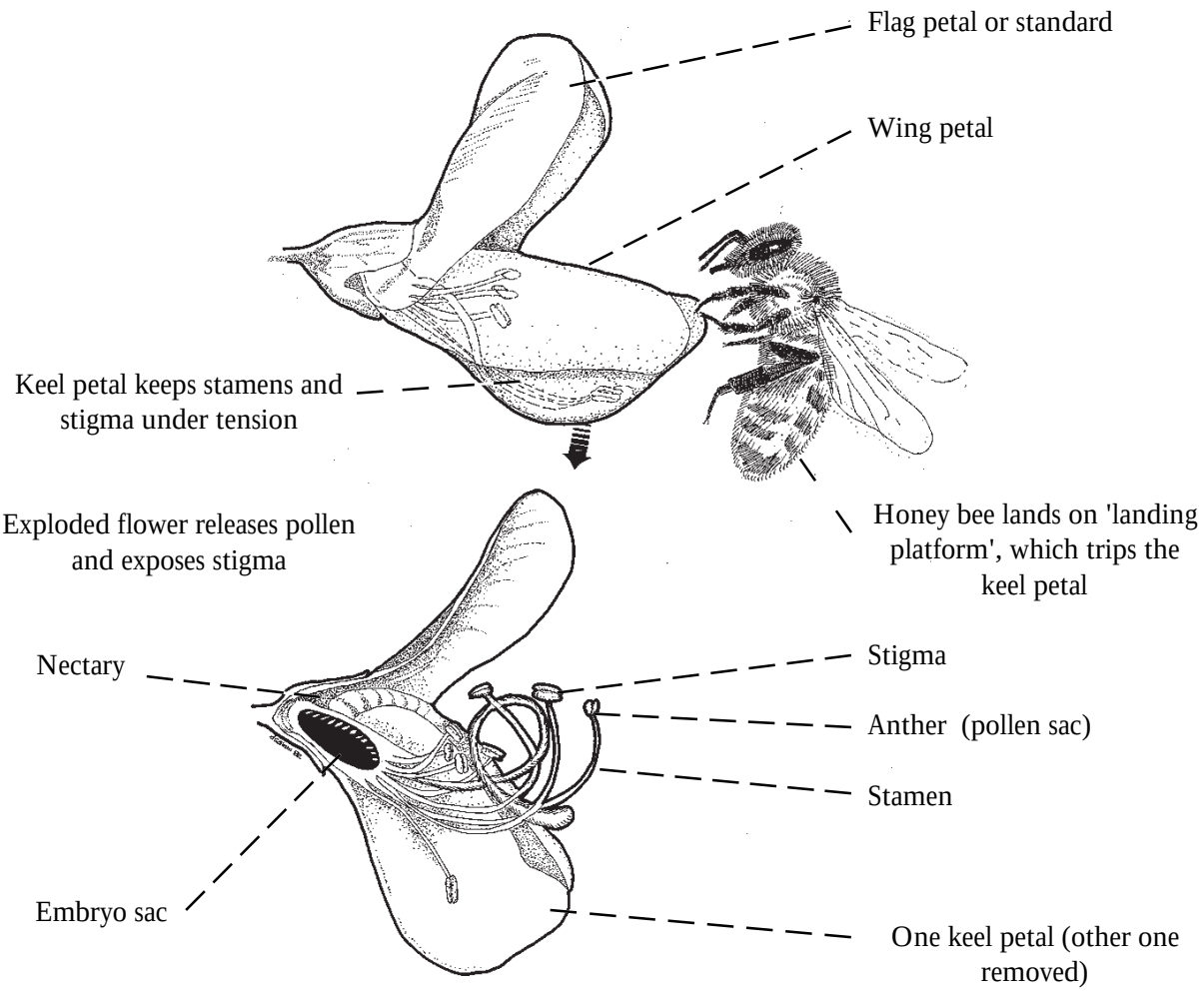
Abiotic pollination does not require or rely upon a pollinator. The plants are usually wind pollinated, with small, inconspicuous flowers that release lots of small, dry pollen. Examples include grasses (such as corn, wheat) and many trees (pine, aspen).

Biotic pollination systems need animal or insect intervention. The flowers are enlarged and "gaudy" and sometimes scented. The advantage of this system is that the efficiency of pollen dispersal gets it directly to conspecific flower type (little waste of pollen). The cost to the flower is that it needs to manufactor a reward to give to the pollinator that is present in the environment

Fossil record of floral (nectary) morphology and pollen types show that fossilized insects carried pollen. Insect pollination may have evolved in seed ferns when the first insect appeared, during the Carboniferous Period (300 MYA). The first pollinators were probably small beetles that landed on reproductive plant parts and encountered a protein source. They would accidentally move pollen around in sloppy manner (the way they do even today) while eating the pollen. *Angiosperms* or flowering plants, appear during Cretaceous Period (130 MYA) and nectaries by late Cretaceous, which was followed by a period of great radiation (adaptive success).

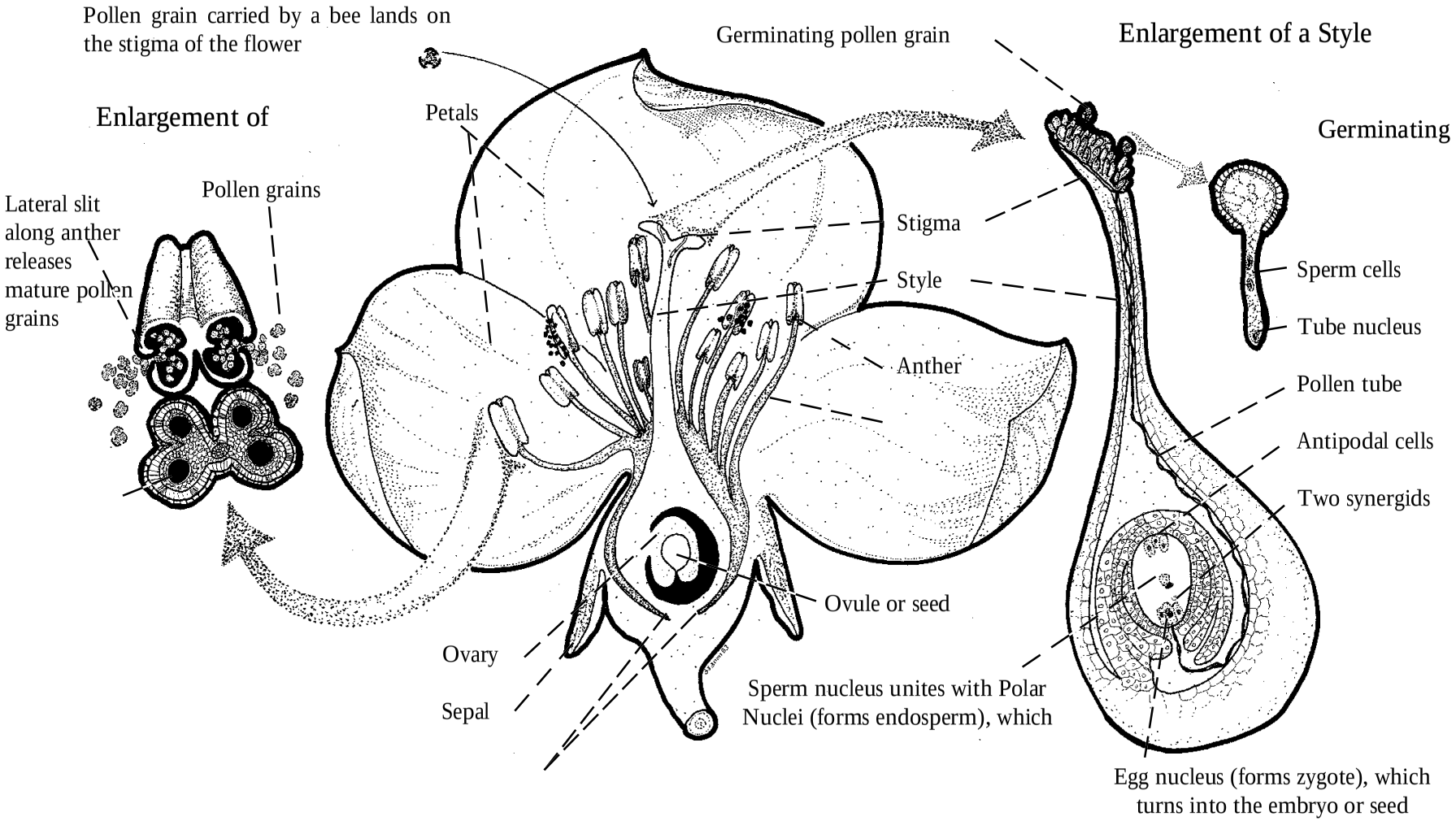
A Honey Bee Tripping an Alfalfa Flower

Drawing by D. Sammataro ©1997



FERTILIZATION OF A FLOWER

Drawing by D. Sammataro ©1997



Different types of pollination systems in angiosperms developed, depending on plant species. One system is the *autogamous,* where plants can self pollinate with their own pollen, such as the Legumes, or pea family. Some of these plant species are self-compatible, but can outcross with another plant. Occasionally, these plants still need insects or wind to transfer pollen from anthers to stigma to increase outcrossing.

The other system of pollination includes plants that are *self-sterile,* those that are not receptive to thier own pollen. The result is obligate outcrossing to avoid in-breeding depression; i.e., avoid expression of deleterious traits due to homozygosity. The disadvantage of this system is that the plant needs reliable pollinators. Frequently, structure of the flower precludes selfing by placement of anthers and stigma in such a way that pollen will not fall on stigma. In addition, pollen grains from the same plant many times do not germinate or grow a tube as effectively as would those from another plant of the same species (e.g. alfalfa flower). In alfalfa, the sexual column is released when the bee lands on the flower and probes for nectar. This movement places pressure on the keel petal such that the column shoots upward to hit the bee on the underside of the head. The stigma, first to be exposed, picks up pollen on the bee's body, that are from other flowers. Next to be exposed are the anthers, which deposit pollen on the bee; see illustration of the bee tripping an alfalfa flower.

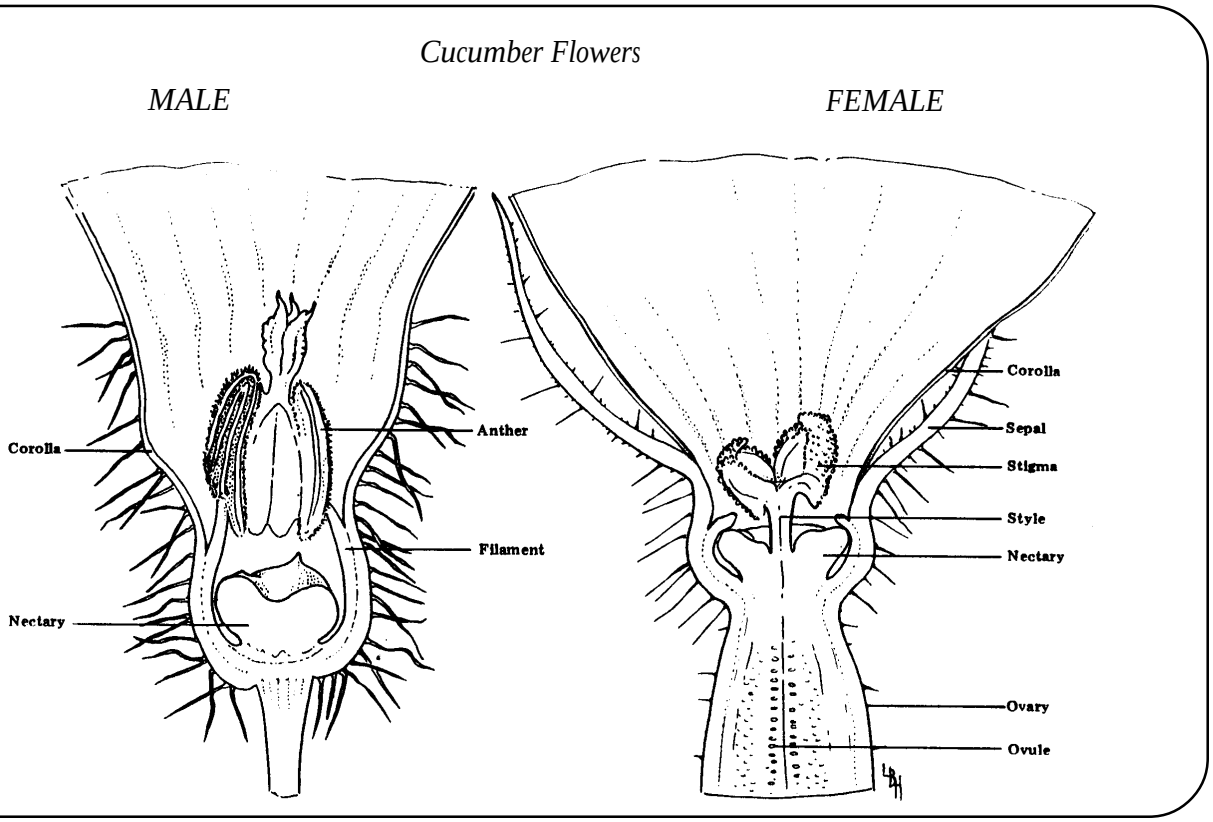
MONOECIOUS vs. DIOECIOUS

In monoecious systems, the stamens and pistils are on the same plant. The flower is said to be *complete, perfect* or *hermaphroditic* if it possess both stamens and pistils. Only female (*pistillate*) or male (*staminate*) parts may be present in a single flower, but both occur on same plant, such as cucumbers; see cucumber flower illustration. However, to get a cucumber fruit, honey bees must visit the staminate and pistillate flowers often to make sure all the seeds set. Since the staminate flower only lasts a few hours, the pistillate flower must have over 20 visits before a perfect cucumber is formed.

In dioecious systems, the male and female parts are on different plants. This includes plants like the holly (*Ilex* spp.) and is very common in tropical plants.

Problems in pollination today include changes in flower morphology by plant breeders. Most plant scientists are looking at the results of breeding and often disregard the flower shape or how it gets pollinated. In some instance, breeders are trying to eliminate the pollinators altogether. Lack of bees and other pollinators is becoming a serious problem in the 21st century. The number of bees per flower needed for adequate pollination varies depending on the species; e.g., 1 bee per 100 flowers is a good estimate for effective pollination of fruit orchards.

Cucumber Flowers



–Bees as Pollinators

The most efficient pollinators—since they are highly motile, capable of learning, are small and plentiful—are the insects. Major insect pollinators include beetles, flies, butterflies, moths and bees. Bees are probably the principal pollinating agents of plants whose flowers have colors within a bee's visual range of blue, yellow, green and ultraviolet.

While honey bees are the most efficient pollinating insect for some plants, in others, such as alfalfa, honey bees are not very efficient. They do not like to work the flowers because of the unique tripping mechanism, which hits the bee's body while she works. In this case, other solitary bees are used, such as the Alkali bee or the Alfalfa leafcutting bee.

But for the most part, honey bees are the best pollinators. It takes several trips by many bees, for example, to adequately pollinate one apple or one cucumber, because there are many seeds in each fruit and each one needs a pollen grain. For cucumbers this is essential, since the female blossom lasts only ONE DAY. Pollen must be moved from the male flower to the female flower before it closes up for the night; bees are the most cost effective way of doing this.

Honey bees are desirable pollinating agents for these reasons:

- Colonies of bees can be moved to crops needing pollination.
- Each colony contains large populations of foragers to work crops within a narrow pollinating window.
- Bees will usually work only one type of flower on each trip, (flower fidelity) not mixing pollen types. For example, when the honey bee flies out to gather nectar and pollen from an apple blossom, this is the only type of flower she will visit on this flight.
- Crops can be sprayed with certain attraction pheromones assuring the bees will work only the target crop.

Recommendations for Growers

Many growers and orchardists have planted large blocks of crops that require migratory honey bee pollinators. A good rule of thumb is one to two colonies per acre and more is definitely better. In early spring, the more bees in the orchard, the closer they will be to the target crops. If the weather turns bad, more bees in the field will help ensure adequate pollination. Also, colonies in the spring may be weaker than colonies in the summer and to compensate for this, make sure there are four or more frames of brood covered with bees per colony.

If growers are not diligent, bees can be killed by pesticides sprayed on the crops, on nontarget plants and weeds, or as it drifts over hives or in the water supply. Work closely with the grower to time spraying when bees are NOT in the field. Make it a clear part of the lease contract. Remember, about 15 billion dollars worth of crops are pollinated by bees in the United States each year.

In many cases, native pollinators have been killed by destructive farming practices, loss of habitiat or pesticide use. Many non-honey bee pollinators are valuable to growers and need to be cultivated. You, as beekeepers can also raise alternate pollinators as a sideline. These may be more important to future growers as the number of feral bee colonies succumb to mite infestation.

However, these non-apis bees and honey bees both need flowers for an entire season to stay alive and rear offspring. By placing your colonies near uncultivated areas (or by planting certain forage crops), you will have better success in keeping and establishing all kinds of bees. See the list on Common Bee Plants.

Leasing Bees

Many beekeepers lease their hives to fruit and vegetable growers whose crops benefit from or require bees for pollination. The need for bee pollination is increasing, due in part to declining bee populations (especially feral or wild honey bee nests), caused by urbanization of natural foraging land, pesticide use, mites and pollution.

Some factors to consider when leasing or renting bees are:

- Number of hives: If other factors are favorable, count on one colony per acre of fruit crops, more for other crops.
- Weather: Optimum flying conditions for bees include temperatures between 60° and 90°F (15.6 and 32.2°C), winds of less than 15 mph and fair, sunny days.
- Colony strength: Each colony should have at least four frames of brood and bees and a laying queen.
- Timing: Set out bees just as crop comes into bloom; if set out too early, bees may work other blooming plants and may not switch to target crop.
- Leasing fees: Although there is no flat fee for leasing bees, some factors that may affect the price include, time of year, pesticide hazard, loss of queen, bees and/or honey and the difficulty of getting into and out of the field.

Some beekeepers remove frames of pollen from colonies to stimulate bees to collect more pollen. Others use pollen traps for the same reason, or install queenless colonies that have queen cells. All of these techniques require close attention to the condition of the bees and the crop as well as the weather.

Pollination Contracts

In order to be fair, a pollination contract or agreement between the beekeeper and the grower should be employed. This will help prevent misunderstandings while detailing the expectations of all parties.

Key points include:

- Date of placement of bees into the crop and their removal (relative to bloom time and condition).
- Location of crop.
- Number and strength of colonies.
- Pattern of colony placement.
- Rental fee and date on which it is paid.
- Grower agrees not to apply bee-toxic pesticides while bees are in the crop or will give the beekeeper 48 hours notice.
- Grower will warn beekeeper of other spraying in the area.
- Grower will reimburse beekeeper for any additional movement of colonies in, out or around the crop.
- Grower will provide right-of-entry to beekeeper for management of bee colonies.

Sample contracts can be obtained from *Bee Culture* magazine (A.I. Root, Medina, OH 44256); Department of Entomology, Penn State University, 501 ASI Bldg., University Park, PA 16802; or the Department of Entomology & Nematology, Institute of Food and Agriculture, University of Florida, Gainesville, FL 32611 (Sheet ENY-110).

Commercial Crops Benefiting from Honey Bee Pollinators

Many commercial crops benefit directly by insect pollination. Here is the list of plants grown commercially, which benefit from but do not require bee visitation:

Asparagus
Apricots
Broadbeans
Caraway
Cherimoya
Chestnut
Chives
Citrus
- Grapefruit
- Lemon
- Mandarin
- Orange

Clove
Clovers, minor
Coconut
Coffee
Cotton
Cowpeas
Cut flower seeds
Drug plants
Feijoa
Flax
Guava
Herbs (spices)
Kapok
Lespedeza
Lima beans
Loquat
Mangosteen
Nectarines
Oil palm
Okra
Onion and Leek
Opium poppy
Papaya
Pears
Peppers
Pyrethrum
Safflower
Scarlet runner beans
Strawberry
Tephrosia
Tomatoes
Vanilla
Vegetable seeds
- Anise
- Chervil
- Endive

–Commercial Crops *Requiring* Honey Bee Pollinators

Many crops grown commercially today REQUIRE insects to pollinate them and set the fruit. Here is a list of those plants that must have bee pollinators:

- Alfalfa
- Allspice
- Almonds
- Alsike clover
- Apples
- Avocado
- Berseem
- Blackberries
- Blueberries
- Buckwheat
- Cacao
- Carambolo
- Cardamom
- Cashew
- Celeriac
- Chayote
- Cherries
- Chinese gooseberry or kiwi
- Cicer milkvetch
- Cinnamon
- Citron
- Citrus
  - Pummelo
  - Tangelo
  - Tangerine
- Clovers, minor
- Cranberries
- Crimson clover
- Crownvetch
- Cucumbers
- Currants
- Cut flower seeds
- Dewberry
- Drug plants
- Eggplants
- Garlic
- Gooseberries
- Herbs (spices)
- Huckleberry
- Jujube
- Kenaf
- Kohlrabi
- Kola nut
- Lavender
- Litchi
- Longan
- Lotus
- Macadamia
- Mango
- Muskmelons
  - Cantaloupe
  - Casaba
  - Crenshaw
  - Honeyball
  - Honeydew
  - Persian melon
- Mustard
- Niger
- Nutmeg
- Parsley
- Parsnip
- Passion fruit
- Peaches & nectarines
- Pears
- Persimmon
- Pimenta
- Plums & prunes
- Pumpkin & squash
- Quinine
- Radish
- Rape
- Raspberries
- Red clover
- Rutabagas
- Sainfoin
- Sapote
- Sunflower
- Sweetclovers
- Sweetvetch
- Tea
- Trefoils
- Tung
- Turnips
- Vegetable seeds
  - Artichoke
  - Asparagus
  - Caraway
  - Carrots
  - Celery
  - Chicory
  - Chives
- Cole crops
  - Broccoli
  - Brussels sprouts
  - Cabbage
  - Cauliflower
  - Collards
  - Kale
  - Tendergreens
- Coriander
- Dill
- Fennel
- Leek
- Onion
- Vetch (hairy)
- Welsh onion
- Watermelon
- White clover

Common Floral Sources in PA
(Listed by time of year they bloom)

Common (Scientific) Names	Nectar	Pollen
Skunk Cabbage (*Symplocarpus foetidus*)	—	+
Elm (*Ulmus* spp.)	—	+
Willow (*Salix* spp.)	+	++
Maple (*Acer* spp.)	+	++
Cottonwood /aspen (*Populus* spp.)	—	+
Dandelion (*Taraxacum officinale)*	++	++
Fruit: Apple, peach, pear, cherry, plum (*Malus, Prunus, Pyrus* spp.)	+	+
Wild cherry (*Prunus* spp.)	+	+
Yellow rocket (*Sisymbrium irio*)	+	+
Black locust (*Robinia pseudoacacia*)	++	+
Tulip poplar (*Liriodendron tulipifera)*	++	+
Brambles: Blackberry, raspberry (*Rubus* spp.)	++	+
Blueberry, Cranberry (*Vaccinium* spp.)	+	+
Huckleberry (*Gaylussacia* spp.)	+	+
Yellow Sweetclover (*Melilotus officinalis)*	+++	++
White Sweetclover (*M. alba*)	+++	++
Blueweed, Viper's bugloss (*Echinum vulgare)*	++	+
Alfalfa (*Medicago sativa*)	++	+
Corn, sweet (*Zea mays*)	—	+
Basswood or Linden (*Tilia* spp.)	+++	+
Clover: Alsike, Ladino, White Dutch (*Trifolium* spp.)	+	+
Sumac (*Rhus* spp.)	+	+
Vetch (*Vicia* spp.)	+	—
Birdsfoot trefoil (*Lotus corniculatus)*	+	+
Canadia thistle (*Cirsium arvense)*	+	+
Wild carrot, Queen Anne's Lace (*Daucus carota*)	+	+
Milkweed (*Asclepias* spp.)	++	+
Cucurbits: Cucumber, Squash, Pumpkin, Watermelon, Canteloupe) (*Cucumus* spp., *Cucurbita* spp., *Citrullus lanatus*)	+	+
Buttonbush (*Cephalanthus occidentalis*)	+	+
Catnip (*Nepeta cataria*)	+	+
Chicory (*Chichorium intybus*)	+	+
Starthistle, Spotted Knapweed (*Centaurea maculosa*)	++	+
Sunflower (*Helianthus* spp.)	+	+
Purple Loosestrife (*Lythrum salicaria)*	++	+
Thyme (*Thyums* spp.)	++	+
Smartweed (*Polygonum* spp.)	+	+
Red Clover (*Trifolium pratense*)	+	+
Wild bergemont, Horsemint (*Monarda* spp.)	+	+
Wild Marjoram (*Origanum vulgare*)	+	+
Fireweed (*Epilobium angustifolium*)	+	+
Pepperbush (*Clethra alnifolia)*	+	+
Clematis (*Clematis* spp.)	+	+
Lima bean (*Phaseolus limensiss)*	+	—
Soybean (*Glycine max*)	+	+
Japanese bamboo or knotweed (*Polygonum* spp.)	++	+
Spanish needle (*Biden* spp.)	+	+
Staghorn sumac (*Rhus typhina*)	+	+
Buckwheat (*Fagopyrum esculentum*)	++	—
Goldenrod (*Solidago* spp.)	+++	++
Aster (*Aster* spp.)	++	++