ASPI
Appalachia-Science in the Public Interest
50 Lair St., Mt. Vernon, KY 40445

ASPI TECHNICAL SERIES TP 31

POLLINATION:
A NECESSARY & DELICATE BALANCE

> "... flowers are not there for us; their beauty is not for our pleasure. What we see has a much more serious biological function. The kaleidoscope of flower shapes, the rainbow of brilliant colors, the bouquet of scents - all these evolved because it was advantageous to give some guidelines to insects searching for nectar and pollen." (Barth, 1991)

Nectar existed before the evolution of flowering plants, and the secretion of nectar in the broadest sense is by no means always associated with flowers and the process of pollination. Nectar is a food source for many animals and consists of sugars (sucrose, glucose, fructose), which can range in concentrations from about 8% (crown imperial (*Fritillaria imperialis*)), to 76% (marjoram (*Oreganum vulgare*)). Nectar also contains amino acids, proteins, organic acids, phosphates, vitamins, and enzymes. Pollen, which is a science in itself, is also a food source which contains 16 - 30% protein, 1 - 10% fat, 1 - 7% starch, many vitamins, but little sugar.

While nectar and pollen provide benefits to the animal world associated with flowering plants, the significance of pollen to plants is that it provides for the transfer of genetic information upon which species survival and adaptive evolution depends. The epoch of the angiosperms (Greek: *angeion* (container) + *sperma* (seed)), which has been going on now for about 135 million years shows quite clearly that balances of mutual advantage and mutual dependence do occur and that it is most apparent in cases of coevolution. "The typical adaptations of angiosperms, are adaptations of the reproductive organs to the pollination by insects. And, (the)...highest degree of specialization for flower visiting is found in the insects that have evolved entirely or mainly in the epoch of the angiosperms." (Barth, 1991)

The angiosperms, or flowering plants, contain approximately 250,000 known living species. All parts of a flower are modifications of the leaf, and they are often linked to one another by transitional forms. "Plant species... are either self-fertile and set fruit or seed with their own pollen (self-pollination), or are self-infertile and need to receive pollen from other plants of the same species (cross-pollination). Some self-fertile species are automatically pollinated with pollen from their own flowers, but often the flowers are so constructed that either wind or insects are needed to transfer pollen from their anthers to their stigmas. Wind is the principal pollinating agent of grasses and a few other species, whereas most (*berries, fruit, herb, legume, nut, vegetable, native and "naturalized" plants,* ed.) that have conspicuous, colored and scented flowers, are adapted for insect pollination." (Free, 1970)

The purpose of the flower is for reproduction of the species. Some flowers are called hermaphrodite or 'perfect type', since they contain both stamens and pistil, while the flowers of other species have only stamens or pistils. There also exist the dioecious species in which some plants are male, while other plants are female. Pollination is usually most successful when the pollen comes from the flowers of another individual of the same species, and not from the flower that contains the same stigma or even from another flower on the same plant.

The advantages of cross-pollination are genetic in nature. The stigma both receives the pollen and stimulates the male gametes the pollen contains. It also sorts out and rejects undesirable pollen and promotes cross-pollination, to the genetic advan-

tage of the plants. Cross-pollination introduces variability among individuals which increases the range of variation in the population. Thus cross-pollination increases the probability that unfavorable traits will be recessive.

Flowers exhibit a kaleidoscope of forms, colors and scents. This imaginative diversity in the shape, color and scent of flowers is the method by which the individual species keep themselves distinct from one another. Each combination is unique and causes the food-seeking insects (or other pollinators such as some birds and bats) to remain true to that particular species as long as possible, carrying the right pollen to the right stigma in an energy-conserving and reliable way. Herein lies the great difference from the random nature of wind pollination.

Plant species that share a habitat also compete for pollinators. Another co-evolutionary adaptive trait of different plant species that share a given habitat has been the development of characteristic sequences of blooming times - with differences not only in the time of day at which the flowers open and offer food, but also in the time of the year when the plant is in bloom. As a guide to the pollinators, many flowers bear visual guide marks that show the way to the food after the pollinator has landed. Occasionally the nectar and pollen guides for this short-range orientation are very conspicuous to our eyes. In other cases, we cannot see them, although bees can, but we can make the ultraviolet patterns of the flower visible by using special techniques.

The primary means of pollination are by moving air (wind), flowing water (rain) and motile animals. In temperate latitudes, insects are by far the most important vehicle for pollination. While the plant's purpose in this coevolved adaptation is pollination, the insects are all looking for food, and not working to pollinate the flowers on purely altruistic grounds. Insects have existed for approximately 350 million years, and there are approximately 800,000 known species. The main groups that visit flowers include:

Beetles which have existed for about 280 million years and contain approximately 345,000 species (fossil and living);

Hymenoptera (ants, bees and wasps) which have existed for about 200 million years, and contain approximately 105,000 species;

Lepidoptera (butterflies and moths), which have existed for about 65 to 70 million years, and contain approximately 165,000 species; and,

Diptera (flies and mosquitoes) which contain approximately 90,000 species.

The most important pollinating insects are the solitary bees, bumblebees and honeybees which are approximately 100 to 120 million years old. Zoologists have identified about 20,000 species of bees in the present day world, and they are all members of the superfamily Apoidea which have departed from the original wasp habit of feeding on other insects and spiders, and have changed over to nectar and pollen. Most of these species are solitary, which means that there is no queen bee as such. With solitary bees, the female of the species does all the nest building, gathering of nectar and pollen, and egg laying, and many nests may cluster together in an area.

Unlike bees which forage throughout the pollen and nectar seasons to obtain sufficient food for their young, most other insects forage to satisfy their own immediate needs only, and feed on a variety of food other than flowers. Many of the most important supplementary pollinators are various Diptera (flies), including those belonging to the genera: *Bibio, Bombylius, Calliphora, Dilophus, Eristalis, Lucilia, Platycheirus, Rhingia, Sarcophaga, and Syrphus*. The adults of Bee flies (Bombyliidae), and Hover flies (Syrphidae), live entirely on nectar and pollen. Butterflies and moths feed mostly on nectar, and are not significant pollinators except by accident. The beetles feed mostly on aphids, grubs and larvae, although some, such as the checkered beetle, the longhorn beetle and the solder beetle are credited with being minor pollinators.

The bumblebees, honeybees and solitary bees account for about fifty percent of the pollination performed by insects in the temperate latitudes, and are the most studied, both as species and for their role in pollination. Some solitary bees (often referred to as pollen bees), are only active during a short season, and are known for their specialization. These include the alfalfa leafcutter bee (*Megachile rotundata*); the alkali bees (*Nomia melanderi*); the different species of Osmia bees

including: the orchard mason bee (*Osmia lignaria propinqua* Cresson), the hornfaced bee from Japan (*Osmia cornifrons*), and the blueberry bee (*Osmia ribifloris*); the Oxaeid bee (*Ptilogossa arizonensis*); the Polyester bees (*Colletes* species); the shaggy fuzzyfoot bee from Japan (*Anthophora pilipes villosula*); and, the Giant carpenter bee (family Xylocopidae).

There are about 3500 species of pollen bees in North America. These valuable pollinators are called "*pollen bees*" because they are most useful for their pollination of plants. Unlike the seven species of honeybees (*Apis*), and their close relatives the tropical stingless bees (*Melipona*), pollen bees do not make excess honey and wax that people can harvest. Some kinds of pollen bees even live as cuckoos, laying their eggs in the nests of other species of pollen bees. Social pollen bees, such as bumblebees (*Bombus*) and some sweat bees (family Halictidae), have small colonies with a queen and a few workers, and are not limited to one brood generation or a brief foraging period.

The bumblebee is regarded as one of the most efficient pollinators, and it is especially valuable in pollinating those flowers in which its large size facilitates pollen transfer while it is visiting the nectaries. It is also good at pollinating flowers with deep narrow corolla tubes from which only insects with long tongues can obtain nectar. The bumblebees (*Bombus* spp.) are social insects whose colonies are at a stage of organization which is in many ways more primitive than that of honeybees, but more advanced than that of solitary bees.

The size of a bumblebee colony at the climax of its development varies with the different species and there may be considerable variation within species. A large colony whose comb is about 15 to 23cm in diameter may have 150 to 200 bees at the height of the season, while a small colony may be only 8cm in diameter and have only 30 to 40 bees. The colonies are annual, with males and queens being produced at the climax of colony development, and only fertilized queens produced that season survive the winter in hibernation. Bumblebees have a unique temperature-control mechanism which allows them to inhabit a very wide range, and they have been found as far north as 880km south of the north pole.

Coevolution is co-adaptation, that is, it is a process that is mutually beneficial to all the partners in the process. All nectar flowers are decorated with a corolla, and many emit a scent that is always pleasant to the insect for which the nectar is intended. From the plant's point of view, the reason to attract pollinators is for pollination, and from the insect's point of view, the scent of flowers basically falls into the category of food acquisition - both needs are satisfied quite conveniently. There also exist pollen flowers, such as the corn poppy which has 2.6 million pollen grains per flower - more than enough for both pollination and to provide as food.

If the pollinator moved unselectively back and forth among flowers of different species it would be of little value to the plants. It is an important prerequisite for cross-pollination that the insects carry pollen from one flower to the stigma of another flower of the same species. Bees in general, and the honeybee in particular, clearly excel in flower consistency. In addition, the ability of a successful honeybee forager that has found a good source of forage to communicate its location to other members of its colony, undoubtably contributes towards the efficiency of honeybees in exploiting the surrounding flora.

The honeybees are unique in the complexity of their language in the insect world, and the value of the honeybee as a pollinator is several times greater than it is as a producer of honey and wax. Honeybees not only communicate the location of a strong nectar or pollen source to their fellow colony mates, they also bring back to the hive the odor and taste of what they have found, so that it can be more easily recognized by recruited foragers.

Honeybees use both sight and smell to locate a nectar or pollen source when foraging. While humans see colors in the range of violet to red, bees see colors in the range of ultraviolet to orange. The bees see the variegated world of flowers in color, but not in the colors we see. The major color groups for bees are in the blue range (blue, indigo, violet and purple), and in the yellow range (yellow, red-yellow, green-yellow and yellow green). The bees suffer from "hue-confusion" as a general inability to distinguish red from black, and are generally most sensitive to hue-discrimination in the blue-green (and violet) to green spectral region.

It not a real problem for the bees though, because, while the bees long-range action is mostly

visual, their short-range orientation is chemical (odor), and once they get close to the forage, the flowers provide UV-guide marks for visual short-range orientation. Ultraviolet, which for the bee is primarily the color of the sky, is important for navigation by sky light, and so the way to the nectar is commonly indicated by UV-free guide marks on the flowers. Some flowers also have furrows and bumps on their petals to guide insects by use of the insects tactile sense.

Scent marks are even more common than visual marks on plants. It is not only the nectar marks visual to us that are specially scented; the UV-patterns also have an odor distinct from that of their surroundings. And even flowers with no visual nectar guides usually have the approach to the food source marked by odor. The bee, having coevolved with the angiosperms, has about forty thousand sensors (pores) on its antenna. Locating the source of a scent is something bees are very good at.

Bees take both nectar and pollen back to their colony or nests as food to raise brood with, and in the case of the honeybees, as winter stores. Evolution has provided the bees with both the means to chew and digest pollen, as-well-as the ability to sip nectar. The honeybees are not the most adapted nectar sippers though. The cuticle (the mouth parts), are constructed of an admirably adaptable and variable material that has made a great contribution to the remarkable success of insects. Their manifold modifications range from hard toothed pincers to the elegant proboscis with which the butterflies draw nectar from the deepest flowers. Such modifications have enabled the insects to exploit almost all conceivable food sources.

"The length of a sucking proboscis plays a large role in view of the diversity of flower structures and the often hidden position of the nectar. It is a critical determinant of the kinds of flowers an insect can profitably visit - apart from flowers that offer their nectar openly." (Barth, 1991) Charles Darwin was the first naturalist to postulate that insects could be found that were capable of exploiting any nectar source, thereby showing that proboscis length was in fact a product of coevolution. An indication of some of the rank ordering of sucking proboscises given by Barth, who referenced the work of W.O. James and A.R. Chapman (**The Biology of Flowers**, Clarendon Press, Oxford, 1935) are as follows:

Hymenoptera

Honeybees (*Apis mellifera*) 6.5mm

Bumblebees (*Bombus terrestris*) 8-9mm; (*Bombus hortorum*) 14-16mm

Other bees: *Anthophora pilpes* 19-21mm; Orchid bees (*Euglossinae*) 25-30mm

Lepidoptera

Cabbage White (*Pieris brassicae*) 16mm

Hummingbird hawkmoth (*Macroglossum stellatarum*) 25-28mm

other hawkmoths (*Lanhopan morgani* (Madagascar)) 30cm

Diptera

Hoverfly (*Syrphus*) 2-4mm

Bee fly (*Bombylius discolor*) 10-12mm

Nature is also a playful deceiver. The orchids (Orchidaceae) produce no nectar or food pollen for the insects. Instead, the orchid produces attractant substances that either correspond exactly to the female sexual attractant, or have the same effect. The Orchid bees (*Euglossine*: 200+ spp.) are primarily solitary, although a few species are semi-social, with the characteristic behavior of the males to gather this odor substance (terpenes).

However, it is not only by the scent that the flower impersonates a female insect. It is the size of flower, the fact that elongated flowers are more effective female impersonators, the color and color-patterns including the UV components that increase the effectiveness of the mechanically stable, convex labellum into fooling the immature male bees into thinking that this is in fact a female bee. Are they fooled? While the tactile sensation on the labellum are important in eliciting pre-copulating movements, the bee does not fertilize the flower. The male bees do pollinate the orchids though, and for their efforts collect the odor substances which is what they were after in the first place - and nature has coevolved a solution that satisfied both the needs of the orchid and the bees.

Much of what has evolved over the past 130 million years is being destroyed by mankind in the span of less than a century. The intensive clear

cutting and cultivation of the land has destroyed many natural food sources and nesting sites of the wild pollinating insects. Chemical agriculture has poisoned the plants and soils, and the planting of large areas of a single crop tends to only provide forage for a limited period of the season, and there may be little or no forage available to pollinating insects at other times. Plant species are now grown for food, or other uses, in parts of the world far from where they originated, and sometimes in the absence of their natural pollinators, and little, if any, of the plant breeding being done today is done with any thought about pollinating insects.

Agriculture and culture need to coexist in a manner that respects the need for all participants - man, plants and all the other animals that make life possible. The feral bees and even the managed bees are dying at an alarming rate due to unnecessary pesticide use, non-sustainable land use, and the importation of mites and disease from other areas. Since approximately sixty-percent of the food mankind ultimately consumes requires pollination by insects, it would seem prudent to revise our practices to ensure that in fact there will be pollinators available to do the work required.

In order to insure that there are plenty of natural, wild unmanaged (as-well-as managed) pollinators, it is necessary to protect them from pesticides. Biologically based, integrated pest management and practices that are good for wildlife will also encourage pollinators. Since most pollinators have a flight range of less than 100 yards, it is essential to disperse fallow areas among cultivated crop land. The pollinators need nesting habitats such as permanently fallow areas with dry, bare sunny soil and bushy, weedy areas, and bee trees. And like mankind, the pollinators do best in a chemically clean environment.

Notable American Rural and Urban Nectar and Pollen Plants

Alder (*Alnus spp.*)
Alfalfa (*Medicago sativa*)
Allium spp.
Almond (*Prunus amygdalus*)
Alsike Clover (*Trifolium hybridum*)
Angelica Tree (*Aralia spinosa*)
Antelope Brush (*Purshia tridentata*)
Apple (*Malus spp.*)
Apricot (*Prunus armeniaca*)
Arbutus (*Epigaea repens*)
Arrowhead (*Sagittaria*)
Arrow-Wood (*Berthelotia sericea*)
Ash (*Fraxinus*)
Asperula Bedstraw (*Asperula galioides*)
Aspen (*Populus*)
Aster
Avocado (*Persea*)

Barberry (*Berberis spp.*)
Basil or Mountain Mint (*Pycnanthemum virginianum*)
Basswood (*Tilia americana*)
Bean (*Phaseolus* spp.)
Bee Balm (*Melissa officinalis*)
Beech (*Fagus grandifolia*)
Bee Sage (*Hyptis emoryi*)
Bellflower (*Campanula spp.*)
Birdsfoot Trefoil (*Lotus corniculatus*)
Bittersweet (*Celastrus scandens*)
Bitterweed (*Helenium tenuifolium*)
Blackberry (*Rubus fruticosus*)
Black Haw (*VIburnum prunifolium*)
Black Mangrove (*Avicennia nitida*)
Black Medic (*Medicago lupulina*)
Blazing Star (*Chamaelirium Luteum, Liatris, Mentzelia laevicaulis*)
Bloodroot (*Sanguinaria canadensis*)
Blueberry (*Vaccinium spp.*)
Blue Curls (*Trichostema lanceolatum*)
Blue Thistle (*Eeyngium articulatum*)
Bluevine (*Gonolobus laevis*)
Boneset (*Eupatorium, E. coelestenum, E. perfoliatum, Symphytum officinale*)
Borage (*Borago officinalis*)
Boston Ivy (*Ampelopsis tricuspidata*)
Box Elder (*Acer negundo*)
Bramble (*Rubus spp.*)
Broccoli (*Brassica oleracea* Italica)
Broom (*Cytisus, Genista*)
Broomweed (*Gutierrezia texana*)

Buckeye (*Aesculus spp.*)
Buckthorn (*Rhamnus spp.*)
Buckwheat (*Fagopyrum esculentum*)
Buffalo-Berry (*Shepherdia argentea*)
Bur CLover (*Medicago hispida*)
Burdock (*Arctium lappa*)
Burnet (*Sanguisorbia minor*)
Bush Honeysuckle (*Diervilla Lonicera*)
Buttercup (*Ranunculus spp.*)
Butter Weed or Groundsel (*Senecio*)
Button-Bush (*Cephalanthus occidentalis*)

Cabbage (*Brassica oleracea*)
California Holly (*Heteromeles arbutifolia*)
California Laurel (*Umbellularia californica*)
Canada Thistle (*Cirsium arvense*)
Carpet Grass (*Lippia spp.*)
Carrot (*Daucus carota* var. *Carota*)
Castor Bean (*Ricinus communis*)
Catalpa (*Catalpa speciosa*)
Catnip (*Nepeta Cataria*)
Catsclaw (*Acacia spp.*)
Cat's Ear (*Hypochoeris radicata*)
Celery (*Apium graveolens*)
Century Plant (*Agave americana*)
Chamise (*Adenostoma fasciculatum*)
Cherry (*Prunus cerasus, P. ilicifolia, P. serotina*)
Chestnut (*Castanea dentata*)
Chickweed (*Stellaria Media*)
Chicory (*Cichorium intybus*)
Chinquapin (*Castanea pumila*)
Clematis spp.
Cleome spp.
Cleomella (*Cleomella angustifolia*)
Cliff Rose (*Cowania mexicana, C. stansburiana*)
Climbing Boneset or Duckblind (*Mikania scandens*)
Clover (*Trifolium spp.*)
Cocklebur (*Xanthium canadense*)
Cogswellia (*Peucedanum spp.*)
Columbine (*Aquilegia*)
Coma (*Bumelia lycioides*)
Coneflower (*Dracopsis amplexicalilis, Rudbeckia , Ratibeda, Echinacea*)
Coral Vine (*Antigonon leptopus*)
Coreopsis
Coriander (*Coriandrum sativum*)
Corn (*Zea Mays*)
Cotoneaster
Cotton (*Gossypium*)
Cow-Itch (*Cissus incisa*)
Cowpea (*Vigna sinensis*)
Coyote Mint (*Monardella villosa*)
Crab Apple (*Malus*)
Cranberry (*Vaccinium macrocarpon*)
Cranberrybush (*Viburnum americanum*)
Creosote Bush (*Covillea glutinosa*)
Crimson Clover (*Trifolium incarnatum*)
Crocus
Crownbeard (*Verbesina*)
Cucumber (*Cucumis sativus*)
Culver's Root (*Veronica virginica*)
Cup Plant (*Silphium perfoliatum*)
Current (*Ribes spp.*)

Dahlia spp.
Daisy (*Bellis, Chrysanthemum frutescens, C. Leucanthemum*)
Dalea (*Parosela*)
Dandelion (*Taraxacum officinale*)
Dead Nettle (*Lamium*)
Dogbane (*Apocynum spp.*)
Dogwood (*Cornus spp.*)

Elderberry (*Sambucus canadensis*)
Elm (*Ulmus spp.*)
Eucalyptus
Everlasting (*Anaphalis margaritacea*)

False Indigo (*Amorpha, A. fruticosa, Baptisia*)
Farkle-Berry (*Vaccinium arboreum*)
Figwort (*Scrophularia marilandica*)
Filbert (*Corylus americana, C. avellana*)
Fireweed (*Epilobium angustifolium, E. hieracifolia*)
Flax (*Linum usitatissimum*)
Foxglove (*Digitalis purpurea*)

Gallberry (*Ilex glabra*)
Geranium
Germander (*Teucrium canadense*)
Giant Cactus (*Cereus giganteus*)
Gilia spp.
Gladiolus
Globe Thistle (*Echinops sphaerocephalus*)
Golden Aster (*Chrysopsis*)
Golden Honey Plant (*Actinomeris alternifolia*)
Goldenrod (*Solidago spp.*)
Gooseberry (*Ribes spp.*)
Grape (*Vitis* spp.)
Grape Friut (*Citrus decumana*)
Grasses
Ground Ivy (*Nepeta glechoma*)
Gumweed (*Grindelia squarrosa*)

Hackberry (*Celtis spp.*)
Hawkweed (*Hieracium spp.*)
Hawthorn (*Crataegus spp.*)
Hazelnut (*Corylus americana*)
Heartsease (Polygonum)
Heather (*Calluna vulgaris*)
Hedge Mustard (*Sisymbrium altissimum*)
Hedge Nettle (*Stachys*)
Heliotrope (*Heliotropium* curassavicum)
Hellebore (*Helleborus viride*)
Hickory (*Carya spp.*)
Holly (*Ilex spp.*)
Hollyhock (*Alcea rosea*)
Honey Locust (*Gleditsia triacanthos*)
Honeysuckle (*Aquilegia canadensis, Justicia californica, Lonicera, Rhododendron prinophyllum*)
Hop Clover (*Trifolium procumbens*)
Hops (*Humulus Lupulus*)
Hop-Tree (*Ptelea trifoliata*)
Horehound (*Marrubium vulgare*)
Horsemint (*Monarda*)
Hound's-Tongue (*Cynoglossum officinale*)
Huajillo (*Acacia Berlandieri*)
Huckleberry (*Gaylussacia, Vaccinium*)
Hydrangea
Hyssop (*Agastache nepetoides, A. spp. Hyssopus, H. Officinallis*)

Ice Plant (*Mesembryanthemum aequilaterale*)
Indian Corn or Maize (*Zea mays*)
Indian Currant (*Symphoricarpos orbiculatus*)
Indigo Bush (*Amerpha fruticosa, Dalea spinosa*)
Indigo-Weed (*Baptisia tinctoria* and *B. australis*)
Ironweed (*Vernonia, Baldwinii*)
Ironwood (*Olneya Tesota*)
Ivy (*Hedera Helix*)

Jackass Clover or Stinkweed (*Wislizenia refracta*)
Jerusalem artichoke (*Helianthus tuberosus*)
Jerusalem Thorn (*Parkinsonia*)
Jewelweed or Touch-Me-Not (*Impatiens spp.*)

Kinnikinnik (*Archtostaphylos Uva-urse, Rhus virens, R. microphylla*)

Ladino Clover (*Trifolium repens latum*)
Larkspur (*Consolida abbigua, Delphinium spp.*)
Laurel (*Kalmia, K. latifolia, K. hirsuta, K. angustifolia*)
Lavender (*Lavandula officinalis, L. stoechas*)
Leatherleaf (*Chamaedaphne calyculata*) Cassandra
Lemon (*Citrus limon*)
Lespedeza (*Lespedeza bicolor, L. cyrtobatra, L. thungbergii*)
Lettuce (*Lactuca floridana*)
Lime (*Citrus acida*)
Liquorice (*Glycyrrhiza lepidota*)
Lizard's Tail (*Eriophyllum staechadifolium, Saururus cernuus*) Swamp-lily
Lobelia (*Lobelia leptostachys, L. syphilitica*)
Locoweed (*Astragalus, Oxytropis*)
Locust (*Gleditsia triaancanthos Robinia pseudo-acacia*)
Lotibush or Texas Buckthorn (*Zizyphus obtusifolia*)
Ludwigia (*Ludwigia natans, L. palustris or L.*

pilosa)

Lupine (*Lupinus affinis* and *L. subcarnosus*)

Lycium (*Lycium Carolinianum* and *L. halimifolium*)

Madrona (*Arbutus menziesii*)

Magnolia (*Magnolia grandiflora, M. virginiana, M. acuminata*)

Mahala Mats (*Ceanothus prostatus*)

Mallow (*Malva rotundifolia*)

Manzanita or Bearberry (*Arctostaphylos spp.*)

Maple (*Acer spp.*)

Marigold (*Gaillardia pulchella*, also *Tagetes spp.*)

Marjoram (*Origanum vulgare*)

Marsh Fleabane (*Pluchea petiolata*)

Mayweed (*Anthemis Cotula*)

Meadow Foam (*Limnanthes Douglassii*)

Melons (*Cucumis melo*)

Mesquite (*Prosopis glandulosa* or *P. odorata*)

Mexican Clover (*Richardia scabra*)

Mignonette (*Reseda odorata*)

Milk Vetch (*Astragalus haydenianus, A. ob-cordata* or *A. sisicus*)

Milkweed (*Asclepias spp.*)

Mint (*Mentha spp.*)

Mistletoe (*Phoradendron flavescens*)

Monument Plant (*Frasera speciosa*)

Morning Glory (*Ipomoea spp.*)

Motherwort (*Leonurus Cardiaca*)

Mountain Lilac (*Ceanothus*)

Mountain Mahogany (*Cercocarpus*)

Mung Bean (*Phaseolus aureus*)

Mustard (*Brassica campestris, B. ngra, B. alba*)

Nama (*Hydrolea ovata*)

Napa Thistle (*Centaurea melitensis*)

New Jersey Tea or Red-Root (*Ceanothus americanus*)

New Zealand Flax (*Phormium tenax*)

Oak (*Quercus spp.*)

Okra or Gumbo (*Abelmoschus esculentis, Viola palmata*)

Oleaster, Wild Olive, Russian Olive (*Elaeagnus angustifolia*)

Onion (*Allium spp.*)

Orange (*Citrus sinensis*)

Oregon Grape (*Berberis nervosa*)

Ox-Eye Daisy (*Chrysanthemum leucanthemum*)

Pagoda-Tree (*Plumeria rubra* forma *aculifolia, Sophora japonica*)

Palmetto (*Sabal spp.*)

Palo Verde (*Cercidium torreyana*)

Parsnip (*Pastinaca sativa*)

Partridge Pea (*Cassia Chamaechrista*)

Passion Flower (*Passiflora spp.*)

Paulownia (*Paulownia tomentosa*)

Peach (*Prunus persica*)

Pea, Garden (*Pisum sativum*)

Pear (*Pyrus spp.*)

Pennyroyal (*Mentha Pulegium*)

Pentstemon or Beard Toung (*Pentstemon laevigatus, P. barbatus coccineus* and *P. grandiflorus*)

Peony (single varieties) *Paeonia*

Pepperbush (*Clethra alnifolia*)

Pepper-Tree (*Schinus molle*)

Perilla (*Perilla frutescens*)

Persimmon (*Diospyros virginiana*)

Phacelia (*Phacelia spp.*)

Physostegia or False Dragon Head (*Physostegia virgininia*)

Phyllodoce (*Phyllodoce empetriformis, P. glanduliflora*)

Pickerel-Weed or Wampee (*Pondeteria cordata*)

Pin Clover or Filaree (*Erodium cicutarium*)

Pinkmint (*Stachys drummondii*)

Plum (*Prunus spp.*)

Pond Lily (*Nymphaea advena*)

Poplar (*Populus spp., Liriodendron Tulipifera*)

Poppy (*Papaver, P. somniferum, Eschscholtzia californica, Argemone* and *Kallstroemia grandifolia*)

Portulaca

Prairie Clover (*Petalostemon*)

Prairie Crocus (*Anemone patens*) Pasque Flower

Prairie Parsley (*Polytaenia Nuttallii*)

Prickly Ash (*Xanthoxylum Clava-Herculis*) Toothache-Tree

Prickly Pear or Indian Fig (*Opuntia spp.*)

Prince's Plume (*Stanleya*)

Psoralea (*Psoralea Onobrychis, P. lanceolata, P. argophylla, P. esculenta*)

Pumpkin (*Cucurbita spp.*)

Purple-Flowered Mint (*Mesosphaerum spicatum, M. rugosum* (swamp basil))

Purple Loosestrife (*Lythrum Salicaria, L alatum, L. ovalifolium*)

Queen Anne's Lace (*Daucus Carota* var. *Carota*)

Quince (*Cydonia oblonga, C. japonica*)

Rabbit Brush (*Chrysothamnus nauseosus* and *C. lanceolatus*)

Radish or Jointed Charlock (*Raphanus Raphanistrum, R. sativus*)

Ragweed (*Ambrosia trifida*)

Rape (*Brassica Napus*)

Raspberry (*Rubus idaeus, R. occidentalis*)

Rattan Vine (*Berchemia scandens*)

Rattlesnake-Root (*Nabalus altissimus*)

Red Bay (*Persea Borbonia*)

Red-Bud (*Cercis canadensis, C. reniformis* and *C. occidentalis*)

Red Clover (*Trifolium pratense*)

Red Maids (*Calandrinia caulescens*)

Redroot (*Gyrotheca tinctoria*)

Rocky Mountain Bee Plant (*Cleome integrifolia, C. serrulata*)

Rose (*Rosa spp.*)

Rosemary (*Rosmarinus officinalis*) Old Man

Russian Thistle (*Salsola pertifera*)

Safflower (*Carthamnus tinctorius*)

Saffron (*Crocus sativus*)

Sage (*Salvia spp.*)

Sainfoin or Esparcet (*Onobrychis sativa*)

Salal (*Gaultheria shallon*)

Salmonberry (*Rubus spectabilis*)

Sand Cherry (*Prunus pumila*)

Sassafras (*Sassafras officinale*)

Savory (*Satureia hortensis* and *S. montana*)

Scilla (*Scilla siberica*)

Screwbean (*Prosopis pubescens*)

Sea Grape (*Coccolobis uvifera*)

Sea Lavender (*Limonium brasiliense, L. carolinanum*)

Self-Heal (*Prunella vulgaris*)

Senisa (*Leucorphyllum texanum*)

Senna (*Cassia spp.*)

Serviceberry or Juneberry (*Amelanchier*)

Skunk Cabbage (*Lysichiton americanum, Symplocarpus foetidus, Veratrum californicum*)

Snowberry (*Symphoricarpos racemosus*) Waxberry

Snow Brush (*Ceanothus velutinus*)

Snow-On-The-Mountain (*Euphorbia marginata*) Spurge

Soapbush (*Guaiacum angustifolium*)

Soap Plant or Soap Root (*Chlorogalum pomeridianum*)

Sorghum

Sorrel (*Rumex acetosella*)

Sour Clover (*Melilotus indica*)

Sourwood (*Oxydendrum arboreum*)

Sow Thistle (*Sonchus*)

Soybean (*Glycine soja*)

Spanish Needle (*Bidens aristosa, B. frondosa, B. involucrata, B. laevis, B. leucantha, B. pilosa, B. trichosperma*)

Speedwell (*Veronica spp.*)

Spider Plant (*Cleome spinosa* and *C. lutea*)

Spiderwort (*Tradescantia virginiana*)

Spikeweed (*Centromadia pungens*)

Spring Beauty (*Claytonia Virginica*)

Squash (*Cucurbita maxim* and *C. moschata*)

Star Thistle (*Centaurea*) Barnaby's Thistle

Stonecrop (*Sedum pulchellum*)

Stone Mint (*Cunila origanoides*) Maryland Dittany

Strawberry (*Fragaria spp.*)

Sumac (*Rhus spp.*)

Summer Farewell (*Kuhnistera pinnati*)

Sunflower (*Helianthus spp.*)
Swamp Loosestrife (*Decondon verticillatus*)
Sweet Clover (*Melilotus alba, M. officinalis*)
Sweet Fennel (*Foeniculum vulgare*)
Sycamore (*Platanus occidentalis, P. racemosa*)

Tallow Tree (*Sapium sebiferum*)
Tarweed (*Hemizonia*)
Teasel (*Dipsacus fullonum*) Fuller's Teasel (*D. sativus*)
Thimble Berry (*Rubus parviflorus*)
Thyme (*Thymus spp.*)
Ti-Ti (*Cyrilla racemiflora* or *Cliftonia momophylla*)
Trillium spp.
Tulip-Poplar or Tulip Tree (*Liriodendron tulipifera*)
Tupelo (*Nyssa ogeche, N. biflora, N. aquatica, N. sylvantica*)
Turnip (*Brassica rapa*)

Vanilla-Plant or Deer-Tongue (*Trilisa odoratissima*)
Velvet Bean (*Mucuna utilis*)
Vervain (*Verbena spp.*)
Vetch (*Vicia spp.*)
Vine Maple (*Acer circinatum*)
Virginia Creeper (*Parthenocissus quinquefolia*)
Virginia Waterleaf (*Hydrophyllum virginicum*)

Walnut (*Juglans spp.*)
Water Chinquapin (*nelumbo lutea*) Duck Acorn
Water Elm (*Planera aquatica*) Planer Tree
Water Horehound (*Lycopus*) Bugle-Weed
Watermelon (*Citrullus lanatus*)
Water Plantain (*Alisma*)
Watershield (*Cabomba caroliniana*)
Water-Willow (*Dianthera americana*)
Wax Myrtle (*Myrica cerifera*) Waxberry
White Clover (*Trifolium repens*)
Wild Alfalfa or Deer Clover (*Lotus glaber*)
Wild Buckwheat (*Eriogonum spp.*)
Wild Cabbage (*Caulanthus crassicaulis*)
Wild Cherry (*Prunus serotina*)
Wild Cucumber (*Echinocystis lobata*)
Wild Hyacinth (*Camassia esculenta*)
Wild Peach (*Prunus Caroliniana*)
Wild Pennyroyal (*Satureia rigidi*)
Willow (*Salix spp.*)
Winter Cress (*Barbarea vulgaris*) Yellow Rocket
Wolfberry (*Symphoricarpos occidentalis*)
Wood Mint (*Blephilia ciliata*)

Yellow-Top (*Verbesina encelioides*)
Yellow Wood (*Cladrastis lutea*)
Yucca spp.

Suggested Reading and References

Friedrich G. Barth, **Insects and Flowers: The Biology of a Partnership**. 1991, Princeton University Press, 408pp.

John B. Free. **Insect Pollination of Crops**, 1970, London, Academic Press Inc., Ltd., 544p.

Sue Hubbell, **Broadsides from the Other Orders: A Book of Bugs**. 1993, Random House, New York.

Anthony J. Huxley, **Green Inheritance: the World Wildlife Fund Book of Plants**. 1992, Gaia Books Ltd., London.

Frank C. Pellett, **American Honey Plants.** 1976. Dadant and Sons, Hamilton, Illinois.

Edward O. Wilson, **The Diversity of Life.** 1992, The Belknap Press of Harvard University Press, Cambridge, Massachusetts.

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