WILD POLLINATORS of EASTERN APPLE ORCHARDS

and how to conserve them

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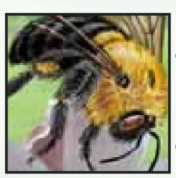
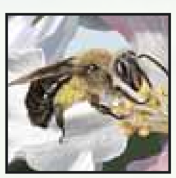
Mission of the Center: *The Northeastern Integrated Pest Management Center fosters the development and adoption of IPM, a science-based approach to managing pests in ways that generate economic, environmental, and human health benefits. The Center works in partnership with stakeholders from agricultural, urban, and rural settings to identify and address regional priorities for research, education, and outreach.*

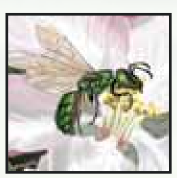
FRONT COVER: Featured Bees



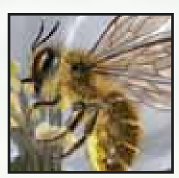
Common Eastern Bumble Bee, *Bombus impatiens*



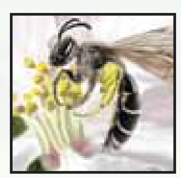
Large Mining Bee, *Andrena regularis*



Blue-Green Sweat Bee, *Augochlora pura*



Hornfaced Bee, *Osmia cornifrons*



Small Mining Bee, *Andrena nasonii*

INTRODUCTION

There is no doubt that insect pollination is a vital service for agricultural systems. Without insect pollinators, roughly a third of the world's crops would flower, only to fade and then lie barren. Pollinators ensure abundant fruits and vegetables. Of all insect pollinators, bees are the most important. In the US alone, the value of pollination services by bees is estimated to be $18 billion[1,2], but these services are threatened and finding alternatives is crucial for long-term pollination success.

WHY CONSIDER WILD BEES AS POLLINATORS NOW?

Honey bees are the most widely used insect pollinator in agricultural systems, as they are easily managed. However, due to disease and competing demands, the cost of hive rentals continues to increase as supplies decrease. Farmers are aware of these challenges as evidenced by a 2009 mail survey where 65% of New York apple growers indicated that Colony Collapse Disorder of honey bees would negatively affect apple production[3]. For the same reason that diversified investing is safer than dependence on a single stock, relying on a single pollinator for this vital service may pose increasing risk. Honey bees will no doubt remain a key pollinator for agricultural systems, but research suggests more and more that wild bees are contributing to apple pollination.

WHAT ARE WILD BEES AND HOW DO THEY BENEFIT ME?

Besides honey bees, about 450 other bee species live in the eastern United States. Over <u>**100**</u> of these wild bees visit apple orchards. Most of these bees are native to the region, while at least one (the Hornfaced Bee, *Osmia cornifrons*) was introduced for fruit pollination. Mail surveys of New York and Pennsylvania apple growers reveal that, when abundant, wild bees provide all the pollination an orchard needs…and they do so for FREE[3,4]! Further, careful pollination studies have shown that wild bees can be more effective pollinators than honey bees on a per-visit basis[5,6,7], meaning they do not need to be as abundant as honey bees to provide the same level of pollination. Wild bees are a valuable orchard asset whose contributions are only now beginning to be fully appreciated.

WHY SHOULD I CARE ABOUT DIVERSITY?

Bee diversity stabilizes pollination services through time[8]. The more species in an area, the more likely there will be a species that can tolerate variable climatic conditions, like a cold and wet spring. Similarly when bee diversity is high, even if there is one species that is extirpated by disease, parasites, pesticides or habitat loss, other species continue to thrive and pollinate.

INTRODUCTION

WIN-WIN FOR WILD BEES AND GROWERS?

Pollinators are declining worldwide, as are their pollination services[9]. Eastern orchards have a unique opportunity to simultaneously conserve wild bee populations and to benefit from their contribution to fruit pollination. The mixed eastern landscape, comprised of orchard blocks interspersed with woodlots, fallow fields and hedgerows, provides bees with needed natural habitat in close proximity to orchards. Simply protecting bee resources that already exist on grower lands is an important first step in ensuring wild bee pollination. By encouraging wild bee abundance and diversity, agricultural growers may be able to buffer rising honey bee rental costs (a win for farmers), while creating an environment that better supports both wild and commercial bees (a win for all bees).

IN THIS BOOKLET YOU WILL FIND...

1. **a photo guide to bees most important for apple production in the East;**
2. **steps to conserving, even optimizing, wild bee pollination in and around your orchard;**
3. **recommendations for plantings to enhance food for pollinators;**
4. **summary of bee toxicities for commonly used orchard pesticides;**
5. **links to other key resources for more information.**

BEE FACTS

WHY IS BEE POLLINATION SO IMPORTANT?

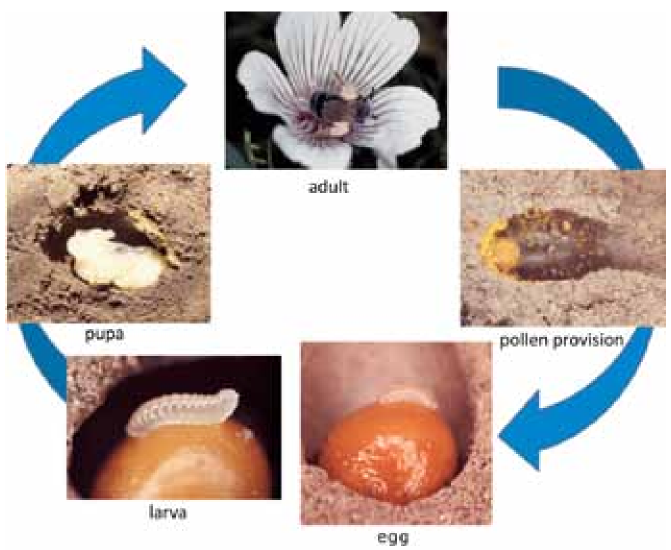
Apple is self-incompatible, meaning a tree's own pollen will not produce fertilized seeds or fruit. Because all trees within a variety are clones (i.e. genetically identical), pollen must move across varieties. Great flyers, adapted to collect pollen with their hairy bodies, bees cross-pollinate flowers as they move throughout the orchard feeding on nectar and pollen.

WHAT DOES IT MEAN TO BE SOCIAL OR SOLITARY?

Honey bees and bumble bees live in social colonies with a queen - charged only with reproducing - and a force of workers, who take care of the colony. Only the workers forage outside the nest. In contrast, 90% of wild bee species live a solitary life. Each solitary female makes her own nest and forages for food for her young.

LIFE CYCLE OF A SOLITARY GROUND-NESTING BEE

Almost 90% of the world's 20,000 bee species are solitary, and 70% of them live underground. Adult solitary bees are active for a relatively short time (weeks to months). During the active period, females construct a nest, consisting of a tunnel and a series of chambers (cells). They provision these chambers with a mix of pollen and nectar, and then lay a single egg in each. The egg is then sealed in the chamber and develops into a larva and then a pupa without parental care. After months underground, when its flight period returns, the adult solitary bee will dig its way out of the nest and restart the cycle.



GROUND-NESTERS

The most important wild pollinators of apple are ground-nesting bees. Ground-nesters excavate underground nests, comprised of tunnels and egg chambers where the young develop – a nesting strategy shared by 70% of bees worldwide. To avoid moisture-loving microbes that attack food and young, nests are built in well-drained soils. These nests are difficult to find because the entrance is normally a simple hole in the ground, just big enough for the bee to move in and out.

Nest requirements: *Well-drained soil with access to bare ground.*
Threats: *Tilling, mulching, toxic herbicides like Paraquat (trade name Gramoxone), and compaction.*
Conservation: *Protect nesting sites from above threats and improve access to bare soil; provide floral resources through the growing season.*

KEY

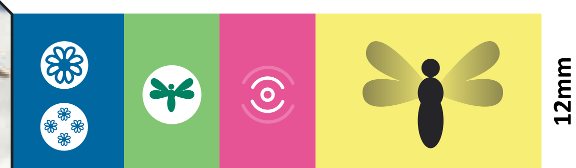
FORAGING: Generalist, Specialist

SOCIALITY: Solitary, Social

FLIGHT RANGE: <500 yds, 500 yds - 1 mile, 1 mile+

actual size

LARGE MINING BEES *(Andrena spp.)*



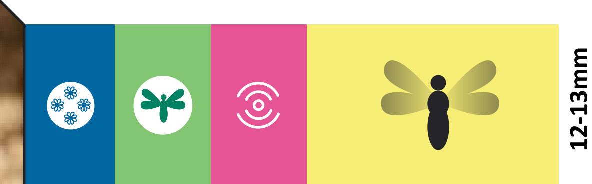
At most sites, large mining bees are the most abundant and widespread native pollinators of apple. They deposit 2-3 times more pollen than honey bees per visit.

SMALL MINING BEES *(Andrena spp.)*

Flight ranges are often estimated from body size. The smaller the bee, the shorter the distance it can fly.

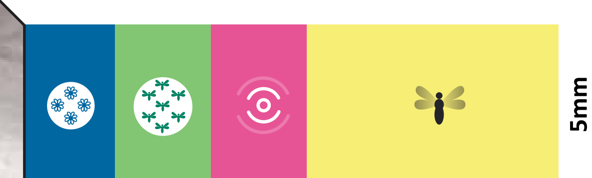
GENERALIST OR SPECIALIST? These terms refer to the diet breadth of the bee. Generalists use many types of plants as a food source, while specialists only use a single species, genus or family of plants. Crop pollinators are typically generalists.

CELLOPHANE BEES
(Colletes inaequalis)

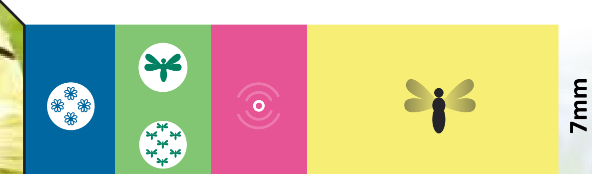


Named for the iridescent coating that lines their nest walls, cellophane bees are solitary but nest in large aggregations in grass-covered, sandy soil.

DARK SWEAT BEES
(Lasioglossum spp., Halictus spp.)



BLUE-GREEN SWEAT BEES
(Augochlora pura, Agapostemon spp., Augochlorella aurata)



Unlike the other bees in this group, *Augochlora pura*, pictured here, nests in rotting wood.

THE MOST COMMON BEES IN YOUR ORCHARD

CAVITY-NESTERS

This bee group is most familiar to us and includes honey bees and bumble bees. Such bees do not excavate their own nest, but find existing cavities to house their social colonies and honey supplies. Because these bees are active all summer long, they require constant (or at least long term) floral resources in the vicinity of the hive.

Nest requirements: *Cavities in trees, in wooden structures or below-ground.*
Threats: *Habitat loss (i.e., inadequate nesting and food sites), pesticide drift.*
Conservation: *Protect or enhance adjacent, woody natural areas; provide floral resources through the growing season; establish 20-ft buffer for drift.*

KEY

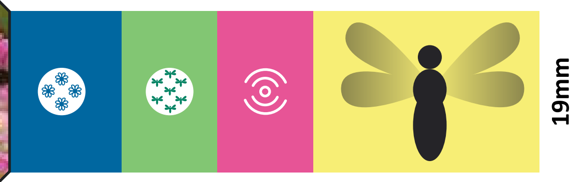
FORAGING: Generalist · Specialist

SOCIALITY: Solitary · Social

FLIGHT RANGE: <500 yds · 500 yds - 1 mile · 1 mile+

actual size

BUMBLE BEES *(Bombus spp.)*



Queen bumble bees are, generally, the only individuals active during apple bloom. In the wild, workers are produced later once the colony is established. In contrast, commercial colonies are raised indoors and contain both queen and mature workers.

HONEY BEES *(Apis mellifera)*

Honey bee color ranges from the familiar orange-brown to black like the bee pictured here.

TUNNEL-NESTERS

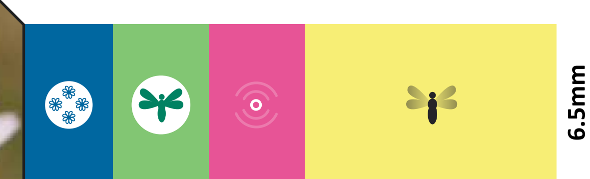
As their name implies, these bees either excavate tunnels in wood (e.g., carpenter bees) or use abandoned cavities, such as beetle burrows, or even cracks in masonry (e.g., mason bees). Among the most important native (and sometimes managed) pollinators are mason bees (genus *Osmia*). Mason bees are effective apple pollinators and populations can be increased through the use of artificial nesting materials. For more information on mason bee biology and management, see Bosch & Kemp 2001 (listed below under section entitled "MORE POLLINATOR CONSERVATION RESOURCES").

Nest requirements: *Stems, trees, rotting logs, wooden structures or old masonry.*
Threats: *Habitat loss (i.e., not enough nesting sites) and pesticide drift.*
Conservation: *Protect or enhance adjacent, woody natural areas and old stone walls; provide nesting materials; maintain floral resources through the growing season; establish a 20-ft buffer for drift.*

LARGE CARPENTER BEES *(Xylocopa virginica)*

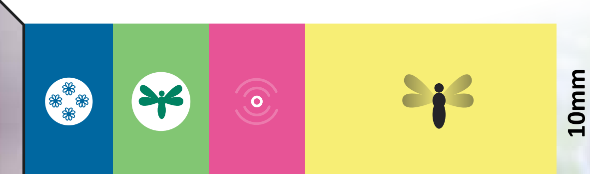
Often considered pests because they tunnel in structural wood, carpenter bees are effective pollinators of apple.

SMALL CARPENTER BEES *(Ceratina spp.)*



Small carpenter bees excavate nests in pithy stems, such as bramble.

MASON BEES *(Osmia spp.)*



Mason bees use mud to partition cells within their nest. Out West, the blue orchard bee, *Osmia lignaria*, is managed for orchard pollination. In the East, the introduced hornedfaced bee, *O. cornifrons*, is a more common pollinator of apple.

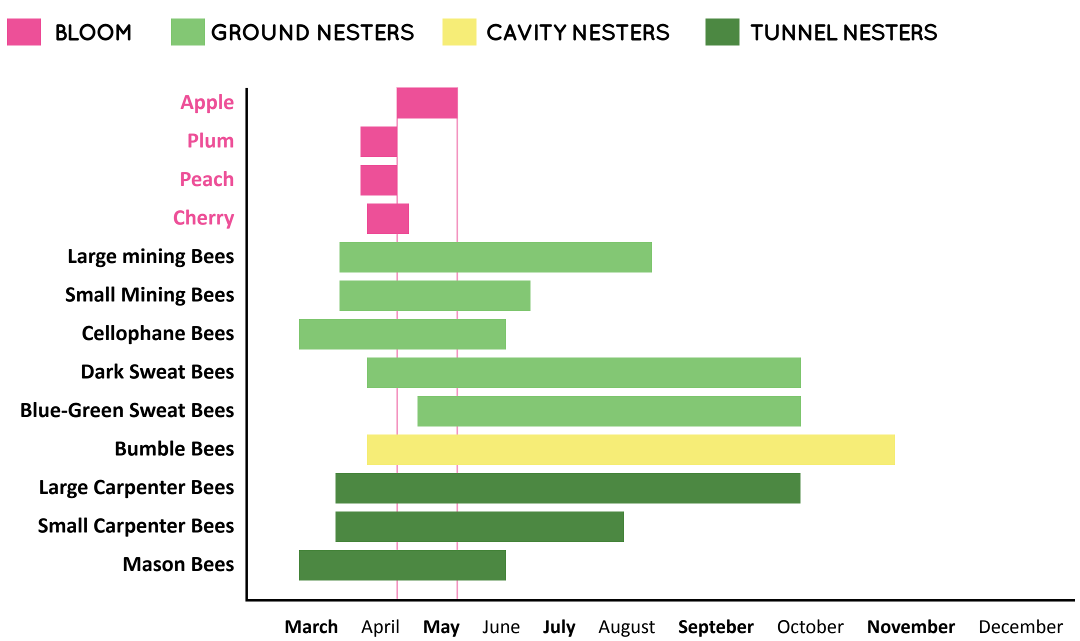
CONSERVATION

IN ORDER FOR WILD BEES TO THRIVE, THREE BASIC NEEDS MUST BE MET:

1. **adequate food,**
2. **safe nesting sites, and**
3. **protection from pesticides.**

You may already take great care to provide these needs for honey bees, but wild bees are unique in that they cannot be taken in and out of the orchard at will, so they must be considered beyond the short bloom period. Moreover, wild bees are more vulnerable because, unlike honey bees that send workers to forage, wild bee foragers are the reproducing individuals for that population.

BEE & BLOOM PHENOLOGY*



** Timing is generalized for the eastern U.S. and will vary according to your latitude and microclimate.*

PROTECT AND ENHANCE POLLINATOR FOOD SOURCES

Wild bees require a continuous and diverse source of pollen and nectar to sustain themselves and their young. Because they live longer than the short apple bloom, it is critical that other floral resources are available within flight distance from your orchard. **Here's what you can do...**

First step, protect floral resources already available on your land:

- **wild blooming trees and shrubs, like willow, red maple, and basswood**
- **flowering weeds along roadsides and on lawns**
- **other early blooming fruit, such as cherry, plum and raspberry**
- **hedgerows**
- **your home garden**

Next step, increase floral resources on your property to build pollinator populations. Floral plantings come in various forms:

- **strips or scattered blocks at orchard margins**
- **cover crops**
- **expanded home gardens**

USDA Plant Materials Centers, Xerces Society and university researchers are developing region-specific plant mixes for pollinators; funding is available for such plantings on farms (discussed below). Flip to pages 14 and 15 for a guide to plants that benefit orchard pollinators.

Pollinator planting jointly established by the Xerces Society, USDA NRCS, and the University of New Hampshire Extension.

GOVERNMENT COST-SHARE PROGRAMS

USDA's Farm Service Agency (FSA) and Natural Resources Conservation Service (NRCS) provide funding opportunities for individual farmers to defray the costs of improving lands for pollinators:

1. Conservation Reserve Program (CRP) is a land retirement program that aims to enhance wildlife habitat.
   Website: **www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp.** Contact your local USDA FSA service center to apply.

2. Environmental Quality Initiatives Program (EQIP) supports conservation practices that improve environmental quality of land.
   Website: **www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip.** See website for state-specific application instructions.

3. Wildlife Habitat Incentives Program (WHIP) funds establishment and improvement of wildlife habitat.
   Website: **www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/whip.** Contact your local USDA NRCS service center to apply.

PROVIDE SAFE NESTING SITES

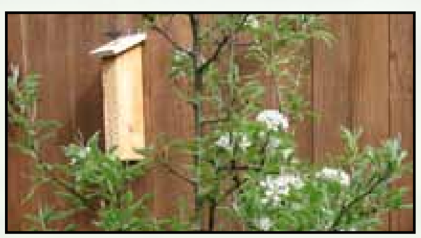
The best way to provide safe nesting is to maximize undisturbed areas around your farm. Ground nesters benefit most if areas with semi-barrren, sandy soils are protected from compaction or tilling. Both tunnel- and cavity-nesters nest in or at the edge of woody semi-natural or natural areas, as well as in old stone walls and sheds.

HOW TO CREATE NEW NESTING SITES

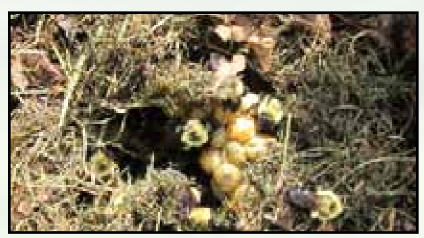
BEE GROUP

GROUND-NESTERS	Shallow till well-drained areas once and maintain bare ground with glyphosate.
TUNNEL-NESTERS	Pile old trees that are pulled near orchard. Place self-made or purchased stem nests made from tubes or drilled wood close to orchard but safe from pesticide drift. Start small to see if tunnel-nesters are in your area. See Mader *et al.* 2010[10] for further information.
SOCIAL CAVITY-NESTERS	Pile old trees that are pulled near orchard. Do not destroy rodent holes

Cellophane bee at the entrance of her ground nest.



Block nest for mason bees by a pear tree.



Bumble bee nest in a pile of old leaves and grass.

PROTECT BEES FROM PESTICIDES

Pesticides, including fungicides and even some herbicides, are a general danger to bees, but wild bees are more impacted because they reproduce more slowly than honey bees and each wild bee is not only a worker but also a reproducer. Here are some general guidelines to protect bees from pesticides:

- **If you have a choice, use the least hazardous formulation.**
- **Avoid dusts and microencapsulated sprays; bees easily pick them up on their hairs or mistake them for pollen.**

- **Follow label guidelines.**
- **Minimize drift and direct exposure of chemicals to foraging bees. Apply sprays at night or very early when winds are usually calm and bees are not active. Non-toxic when dry, surfactants can physically drown pollinators if applied while bees are active.**

In general, be mindful that wild bees are present on farms before and after the apple bloom and may even be nesting within tree rows. On pages 16 and 17, you will find a table that ranks bee toxicity of pesticides most commonly used in orchards.

MORE POLLINATOR CONSERVATION RESOURCES...

WEBSITES:

- The Xerces Society, **www.xerces.org**, provides a wealth of information on pollinator conservation, including downloadable factsheets and publications, as well as links to other sources.
- Pollinator Partnership, **www.pollinator.org**, is a non-profit coalition dedicated to the conservation of North American pollinators. Check out their resources for farming.
- Penn State University's Center for Pollinator Research, **ento.psu.edu/pollinators**, conducts research and outreach for wild and managed pollinators. Latest news on CCD and outreach information are found here.
- Cornell University's Wild Pollinator Program, **entomology.cornell.edu/wildpollinators**, serves as a portal to research and outreach about non-honey bee pollinators of New York crops and native plants.

RECOMMENDED PUBLICATIONS:

- Bosch, J. and W. Kemp. 2001. How to Manage the Blue Orchard Bee as an Orchard Pollinator. The National Outreach Arm of USDA-SARE, Handbook Series, Book 5. Sustainable Agriculture Network, National Agricultural Library, Beltsville, MD. **http://www.sare.org/Learning-Center/Books/How-to-Manage-the-Blue-Orchard-Bee**
- Mader, E., M. Shepherd, M. Vaughan, S.H. Black and G. LeBuhn. 2011. Attracting Native Pollinators. Storey Press.
- Mader, E., M. Spivak and E. Evans. 2010. Managing Alternative Pollinators: A Handbook for Beekeepers, Growers, and Conservationists, SARE Handbook 11, copublished by SARE and NRAES. **http://mysare.sare.org/publications/pollinators/pollinators.pdf**
- Reidl, H., E. Johansen, L. Brewer and J. Barbour. 2006. How to Reduce Bee Poisoning from Pesticides. Oregon State University. **http://extension.oregonstate.edu/catalog/pdf/pnw/pnw591.pdf**
- USDA NRCS. 2009. New England Biology Technical Note: Pollinator Biology and Habitat. **ftp://ftp-fc.sc.egov.usda.gov/NH/WWW/Technical/New_England_NRCS_Pollinator_Tech_Note_FINAL.pdf**
- Vaughan, M., M. Shepherd, C. Kremen, and S.H. Black. 2007. Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms. 2nd ed. **http://www.xerces.org/pubs_merch/Farming_for_Bees.htm**

FORAGE PLANTS FOR WILD POLLINATORS

COMMON NAME | SPECIES NAME | FORM

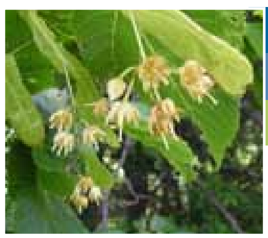
Both wild and commercial bees would benefit from increased floral resources on your land. Choose combinations of plants, so that different flower types are available throughout the entire growing season. The species recommended below are all eastern native perennials.

FLOWERING SEASON: SPRING

Service berry
Amelanchier spp.
tree
Soil: mesic

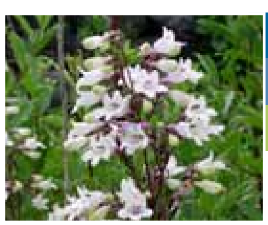
Pussy willow
Salix discolor
tree-shrub
Soil: wet

Lupine
Lupinus perennis
forb
Soil: mesic, dry

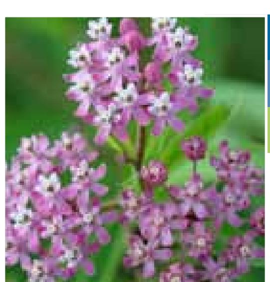


Basswood
Tilia americana
tree
Soil: mesic

Lance-leaf coreopsis
Coreopsis lanceolata
forb
Soil: wet to dry



Smooth penstemon
Penstemon digitalis
forb
Soil: mesic, dry



Milkweed
Asclepias spp.
forb
Soil: wet to dry

SUMMER

SUMMER

Purple coneflower
Echinacea spp.
forb
Soil: mesic

Wild bergamot
Monarda fistulosa
forb
Soil: mesic, dry

Joe Pye weed
Eupatorium purpureum
forb
Soil: mesic, wet

Blue giant hyssop
Agastache foeniculum
forb
Soil: mesic

Giant sunflower
Helianthus giganteus
forb
Soil: mesic, dry

White meadowsweet
Spiraea alba
shrub
Soil: mesic

New England aster
Symphyotrichum novae-angliae
forb
Soil: mesic

FALL

TOXICITY OF PESTICIDES TO BEES

(NOTE: TOXICITY RATINGS BASED ON HONEY BEE TESTS)

Disclaimer: These data mostly incorporate studies looking at acute, short-term adult toxicity. The effects on other life stages from feeding on contaminated pollen might be different in chronic exposure. For example, larvae exposed to some IGRs could have developmental and reproductive effects including reductions in fecundity and fertility. Also, effects on non-honey bee, pollinating insects are not well known.

CHEMICAL CLASS/GROUP	EXAMPLES OF COMMON NAMES	EXAMPLES OF TRADE NAMES	TOXICITY LEVEL: NON	LOW	MODERATE	HIGH
CARBAMATES	oxamyl	Vydate			■	
	carbaryl, methomyl	Sevin, Lannate				■
NICOTINOIDS	clothianidin, imidacloprid, thiamethoxam	Clutch, Provado, Actara				■
	acetamiprid, thiacloprid	Assail, Calypso		■		
ORGANOPHOSPHATES	azinphos-methyl, chlorpyrifos, diazinon, dimethoate, malathion, methidathion, phosmet	Guthion, Lorsban, Diazinon, Dimethoate /Dimate, Malathion, Supracide, Imidan				■
CHLORINATED HYDROCARBON	endosulfan	Thiodan/Thionex			■	
PYRETHROIDS	bifenthrin, cyfluthrin, deltamethrin, esfenvalerate, fenpropathrin, lambda-cyhalothrin, permethrin	Brigade, Baythroid, Decis, Asana, Danitol, Warrior, Ambush/Pounce				■
	pyrethrum/pyrethrin	PyGanic			■	
INSECT GROWTH REGULATORS (IGRS)	methoxyfenozide, tebufenozide	Intrepid, Confirm	■			
	buprofezin, pyriproxyfen	Applaud/Centaur, Esteem		■		
	novaluron	Rimon				■
DIAMIDES	chlorantraniliprole, flubendiamide	Altacor, Belt	■			
MACROCYCLIC LACTONES	abamectin/avermectin, emamectin benzoate, spinetoram, spinosad	Agri-Mek, Proclaim, Delegate, Entrust/Success				■
MITICIDES	acequinocyl, clofentezine, extoxazole, fenpyroximate, fenbutatin-oxide, hexythiazox	Kanemite, Apollo, Zeal/Secure, Fujimite/Portal, Vendex, Onager/Savey	■			
	spirodiclofen	Envidor		■		
	bifenazate	Acramite			■	
	pyridaben	Nexter/Pyramite				■
OTHER INSECTICIDES	formetanateHCI	Carzol				■
	azadirachtin, horticultural mineral oils, indoxacarb, spirotetramat	Aza-Direct/Neemix, Stylet Oil, Avaunt, Movento			■	
	flonicamid, kaolin clay, potassium salts of fatty acids/soap	Beleaf, Surround, M-Pede		■		
	Bacillus thuringiensis, Cydia pomonella granulosis virus	Bt/Dipel, Carpovirusine/Cyd-X	■			
FUNGICIDES	captan, mancozeb	Captan, Dithane/Manzate/Penncozeb		■		
	sterol inhibitors, strobilurins	Indar/Nova/Rally/Rubigan, Flint/Sovran	■			
	lime sulfur, sulfur					■
PLANT GROWTH REGULATORS	ethephon, NAA/1-Naphthaleneacetic acid	Ethrel	■			

Note: On-going research has recently shown that even the inert ingredients that are part of the pesticide formulation can be toxic to honey bees by impairing their ability to learn. Of the inert ingredients tested, organosilicone surfactants/adjuvants were most toxic. Other non-ionic surfactants showed some toxicity and crop oils were least toxic.

NOTES

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Page:

4: Milkweed, *Asclepias syriaca*, Albert F. W. Vick, Lady Bird Johnson Wildflower Center.

5: Bee life cycle, Dennis Briggs and Robbin Thorp (pupa), UC Davis; bottom left, *Colletes inaequalis*, John Ascher, www.discoverlife.org; bottom right, *Andrena* spp., Kent Loeffler, Cornell University.

6: Large and small mining bees, *Andrena* spp., Kent Loeffler, Cornell University.

7: Cellophane bee, *Colletes inaequalis*, Alberto Lopez; dark sweat bee, *Lasioglossum* spp. and *Halictus* spp., Kent Loeffler, Cornell University; blue-green sweat bee, *Augochlora pura*, Tom Murray, www.pBase.org.

8: Bumble bee, *Bombus impatiens*, Tom Murray, www.pBase.org; honey bee, *Apis mellifera*, Kent Loeffler, Cornell University.

9: Large carpenter bee, *Xylocopa virginica*, Kent Loeffler, Cornell University; small carpenter bee, *Ceratina dupla*, JelleDevalez, www.discoverlife.org; mason bee, *Osmia cornifrons*, USDA ARS.

10: Bumble bee on *Monarda fistulosa*, Eric Mader, The Xerces Society.

11: Pollinator planting, Don Keirstead (USDA-NRCS).

12: Left, cellophane bee nest, Margarita Lopez-Uribe; center, block nest, Matthew Shepherd, The Xerces Society; right, bumble bee nest, Al Eggenberger.

14: Service berry, *Amelanchier* spp., David G. Smith, www.delawarewildflowers.org; Pussy willow, Salix discolor, Albert F. W. Vick, Lady Bird Johnson Wildflower Center; Lupine, *Lupinus perennis*, W. D. Bransford, Lady Bird Johnson Wildflower Center; Basswood, *Tilia Americana*, Toby Alexander/USDA-NRCS; Lance-leaf coreopsis, *Coreopsis lanceolata*, David Cappaert, Michigan State University, Bugwood.org; Smooth penstemon, *Penstemon digitalis*, David G. Smith, www.delawarewildflowers.org; Milkweed, *Asclepias syriaca*, Albert F. W. Vick, Lady Bird Johnson Wildflower Center.

15: Purple coneflower, *Echinacea purpurea*, Joseph A. Marcus, Lady Bird Johnson Wildflower Center; Wild bergamot, *Monarda fistulosa*, Catherine Herms, The Ohio State University, Bugwood.org; Joe Pye weed, *Eupatorium purpureum*, Matthew Shepherd, The Xerces Society; Blue giant hyssop, *Agastache foeniculum*, Andy and Sally Wasowski, Lady Bird Johnson Wildflower Center; White meadowsweet, *Spiraea alba* sub. *latifolia*, J.S. Peterson, USDA-NRCS PLANTS Database; New England aster, *Symphyotrichum novae-angliae*, Pennsylvania Department of Conservation and Natural Resources, Forestry Archive, Bugwood.org.

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