April 22, 2014, MN Landscape Arboretum, Earth Without Bees and Most Flowering Plants, Apply Your Sunscreen

www.entomology.umn.edu/cues

Visit pollinator conservation website: Bulletins, posters, online workshop, research,

Vera Krischik, Associate Professor, Depart of Entomology, UMinnesota and others

Why do plants make flowers?

- 250 million years crustaceans crawled onto land and evolved into insects.
- Todays insects are ancestors of shrimps, crabs, and lobsters
- Devonian, age of fish, 350 million years ago, insect similar to basement silverfish

Why do plants make flowers?

- **Conifers, ginkgos, cycads, seed ferns are earliest plants**
- **Angioseperms, flowering plants evolved 150 million years, flowers and fruits containing seeds**

Why do plants make flowers?

- **beetles evolved ~300 million years ago,**
- **flies evolved ~250 million years ago,**
- **moths evolved ~150 million years ago**

Why do plants make flowers?

- **150 million years, Angioseperms evolved, flowering plants coevoled with insects to pollinate flowers.**
- **Flower color, shape, nectar and pollen rewards are due to insects.**

Why do plants make flowers and are aromatic?

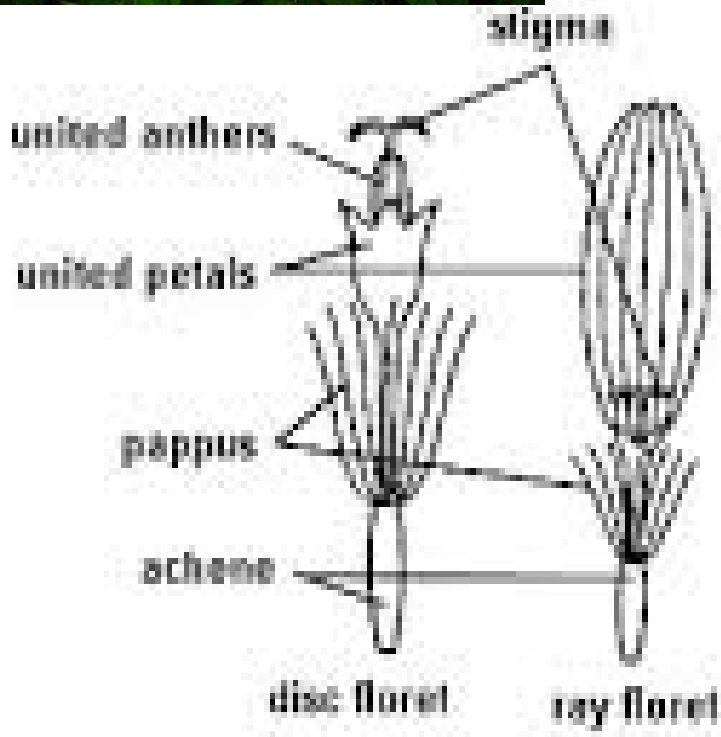


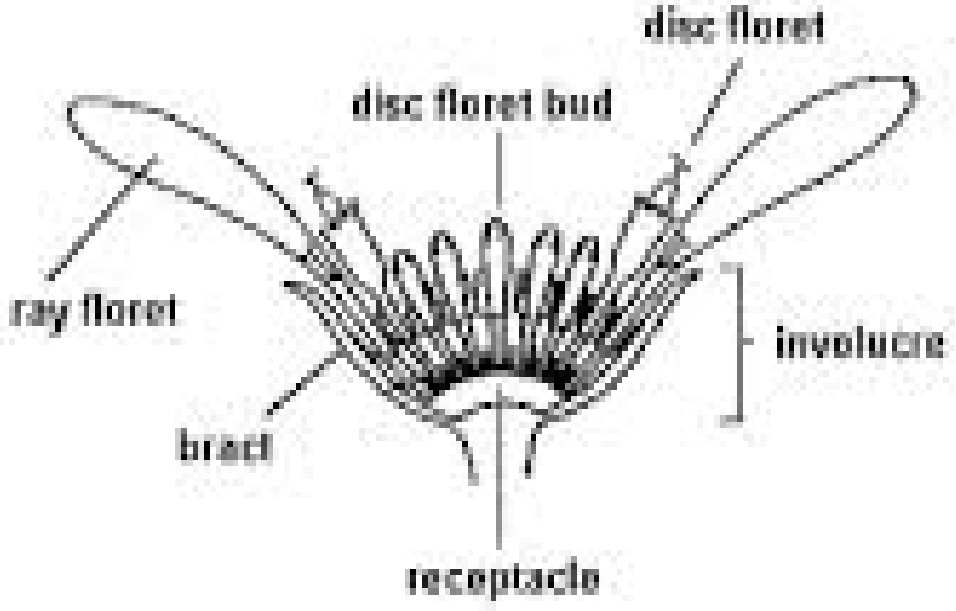

- **Plants evolved chemical defenses against insects, which evolved mechanisms to deal with plant toxins.**
- **Insects used these toxins for protection themselves from predators.**
- **Insects advertise their toxicity using warning colors.**
- **Over time, this led to coevolved species.**

Native flowers advertise pollination by turning colors. Breeding removes this trait.

Double flowers are when stamens become petals, provides no pollen or nectar.

Family Compositae, advanced flower, multiple ray and disc flowers in one head





American ash, rose, apple, etc, family Rosaceae, the rose family, pollinated by bees and fruits dispersed by birds

Chelone glabra (white turtlehead) family Plantaginaceae, the plantain family, pollinated by bumblebees

Catalypa, family Bigoniaceae coevolved with bumblebees

Tecoma stanz, Esperanza, family Bigoniaceae, coevolved with bumblebees

Formerly family Asclepiadaceae, now classified as the subfamily Asclepiadoideae of the dogbane family Apocynaceae.

Formerly family Asclepiadaceae, now classified as the subfamily Asclepiadoideae of the dogbane family Apocynaceae.

Passiflora caerulea, passion flower vines, family Passifloraceae, pollinated by bees and fruits dispersed by animals

***Passiflora caerulea*, passion flower vines, family Passifloraceae coevolved with zebra longwing butterfly, Family Nymphalidae Subfamily Heliconiinae**

Zebra longwing butterfly, Family Nymphalidae Subfamily Heliconiinae

Bee Plants

Early Season Bloomers

Serviceberry
(*Amelanchier* spp.)

Pussy willow
(*Salix discolor*)

Photos: Prairie Moon Nursery, www.prairiemoon.com

Bee Plants

Early Season Bloomers

Carolina lupine
(*Thermopsis villosa*)

Siberian squill
(*Scilla siberica*)

Photos:
Carolina lupine: Prairie Moon Nursery, www.prairiemoon.com
Siberian squill: Heike Löchel (fotografiert von Heike Löchel) [CC-BY-SA-2.0-de (http://creativecommons.org/licenses/by-sa/2.0/de/deed.en)], via Wikimedia Comms

Bee Plants

Early to Mid Season Bloomers

Wild rose
(*Rosa* species)

Basswood, linden
(*Tilia americana*)

Photos:
Wild rose: Prairie Moon Nursery, www.prairiemoon.com
Basswood: Paul Wray, Iowa State University, Bugwood.org

Bee Plants

Early to Mid-Season Bloomers

Garden sage
(*Salvia nemorosa* 'May Night')

Catmint
(*Nepeta x faassenii*)

Photos: North Creek Nurseries, www.northcreeknurseries.com

Bee Plants

Mid Season Bloomers

Purple prairie clover
(*Petalostemum candida*)

Swamp milkweed
(*Asclepias incarnata*)

Photos:
Purple prairie clover: Prairie Moon Nursery, www.prairiemoon.com
Swamp milkweed: North Creek Nurseries, www.northcreeknurseries.com

***Also consider: Common milkweed (*A. syriaca*), butterfly weed (*A. tberosa*)**

Bee Plants

Mid Season Bloomers

Billard's spiraea
(*Spiraea x billardii* 'Triumphans')

Catnip
(*Nepeta cataria*)

Photos:
Billard's Spiraea: Alfred Osterloh, via Hortipedia Commons
Catnip: Theodore Webster, USDA Ag Research Service, Bugwood.org

Bee Plants

Mid to Late Season Bloomers

Anise hyssop
(*Agastache foeniculum*)

Wild bergamot
(*Monarda fistulosa*)

Photos:
Anise hyssop: Prairie Moon Nursery, www.prairiemoon.com
Wild bergamot: North Creek Nurseries, www.northcreeknurseries.com

Bee Plants

Mid to Late Season Bloomers

Sunflower
(*Helianthus* species)

Globethistle
(*Echinops* species)

Photos:
Sunflower: Prairie Moon Nursery, www.prairiemoon.com
Globethistle: Barbara Tokarska-Guzik, University of Silesia, Bugwood.org

Bee Plants

Late Season Bloomers

New England aster
(*Symphyotrichum novae-angliae*)

Goldenrod
(*Solidago species*)

Photos:
New England aster: North Creek Nurseries, www.northcreeknurseries.com
Goldenrod: Prairie Moon Nursery, www.prairiemoon.com

Bee Plants

Late Season Bloomers

Korean angelica
(*Angelia gigas*)

Stonecrop
(*Sedum* species)

Photos:
Korean angelica: Hardyplants at English Wikipedia (Own work) [Public domain], via Wikimedia Commons
Stonecrop: North Creek Nurseries, www.northcreeknurseries.com

Bee Plants

How are plants pollinated?

- **Pollen collects on hairs and scales of insects.**
- **Most bees also have specialized structures called corbiculae or scopae to collect pollen.**

Save the bees plant flowers and trees

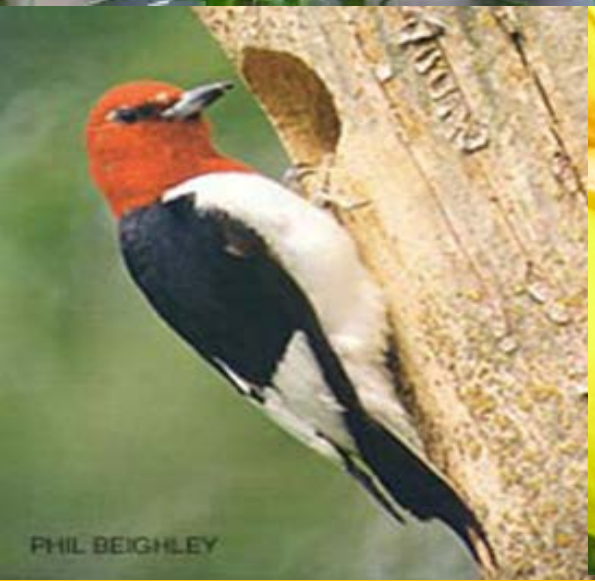
1. Use contact insecticides on flowering plants, such as bifenthrin, cyfluthrin, neem, azadirachtin, and spinosad.
2. Do not use systemic insecticides.
3. Plant a seasonal phenology of native and garden plants for nectar and pollen.
4. Only single-flowered plants, not double flowers, provide pollen and nectar.
5. Provide overwintering habitat for bees.
6. Do not kill queen bees in the spring, they will not sting.
7. Understand the different types of bees and wasps so you can conserve bees.

So why should we care about bees?

Food for thought.

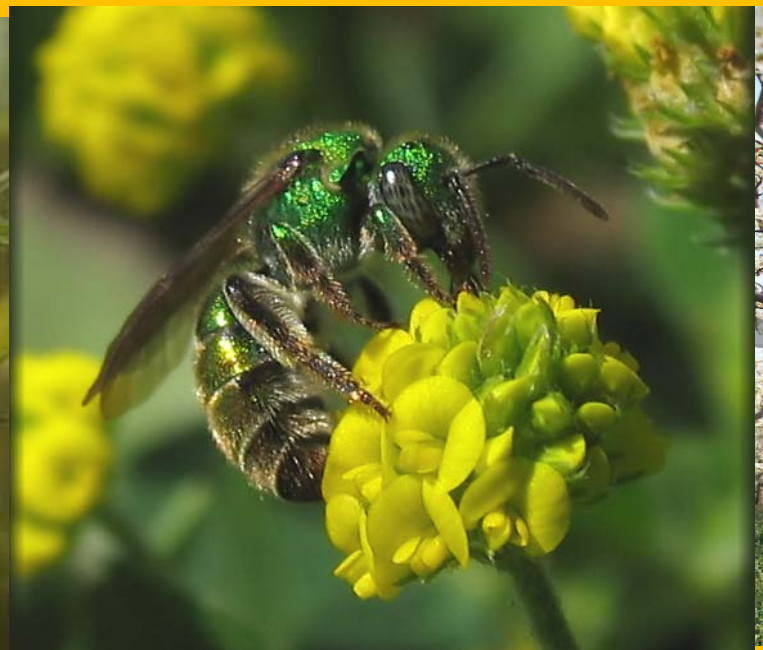
So why should we care about bees?

What will birds and wildlife eat without seeds and fruits?



So why should we care about bees?

- **Bees pollinate native plants that produce seeds and fruits for wildlife, bears to voles.**
- **300 bee pollinated plants are commonly used as a food source (McGregor 1976).**
- **35% of the food we eat is pollinated by bees**



Native Bees in Decline

Leafcutter bee: *Megachile*

Economic value of native pollinators

1. **Hundreds of species of native bee contribute significantly to crop pollination.**
2. **$3 billion/year**

Sweat bee: Halictidae

Mason bee: *Osmia*

Bumble bee: *Bombus*

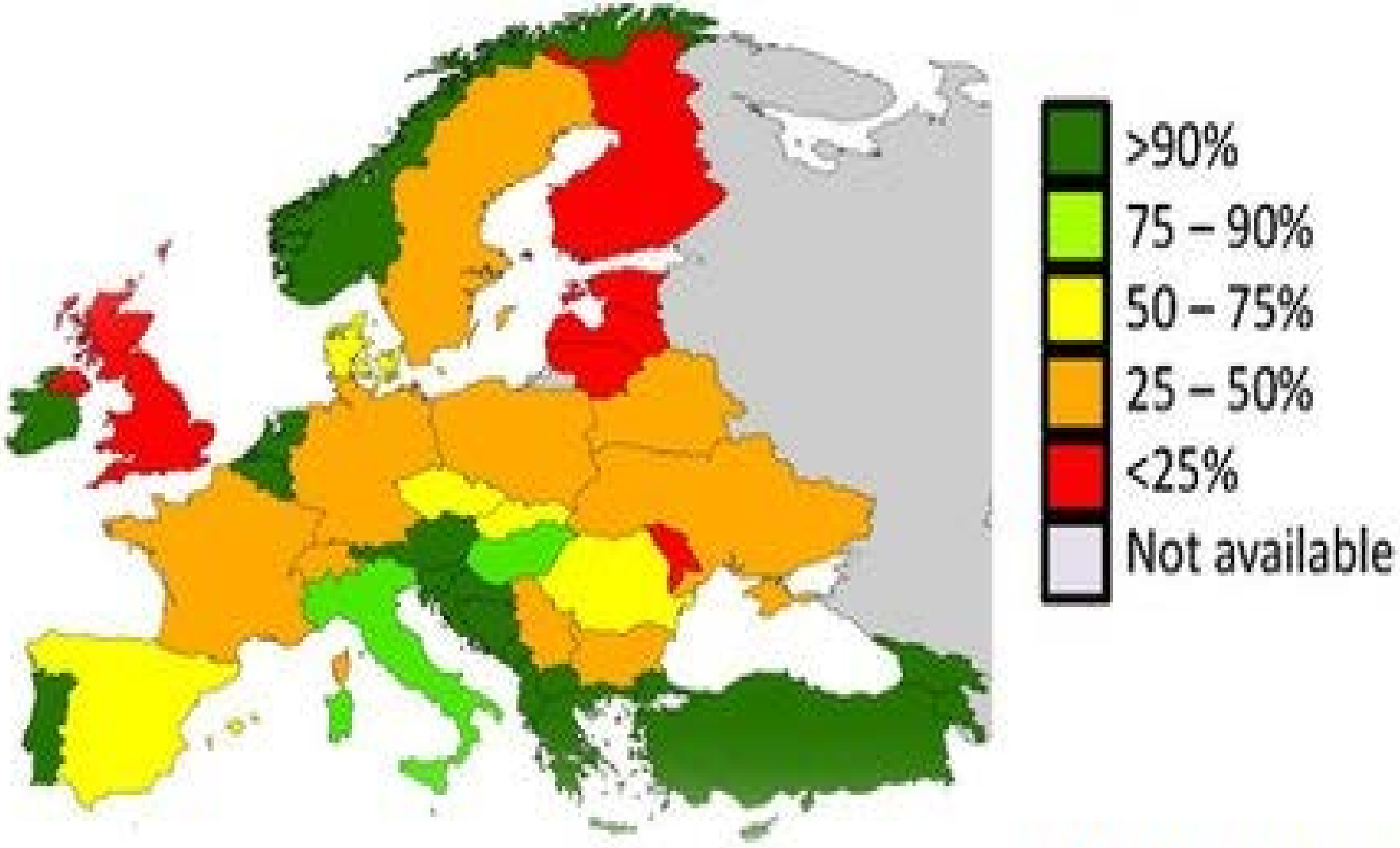
Digger bee: *Andrena*

So why should we care about bees?

January 8, 2014 In more than half of European countries, there are not enough honeybees to pollinate crops, according to new research. We face a catastrophe in future years unless we act now," said Prof Simon Potts, from the University of Reading, a co-author on the paper.

The number of honeybees in the UK and elsewhere has been in decline in recent years, with both pesticide use and disease being blamed for losses

Percentage supply of honeybees relative to demand



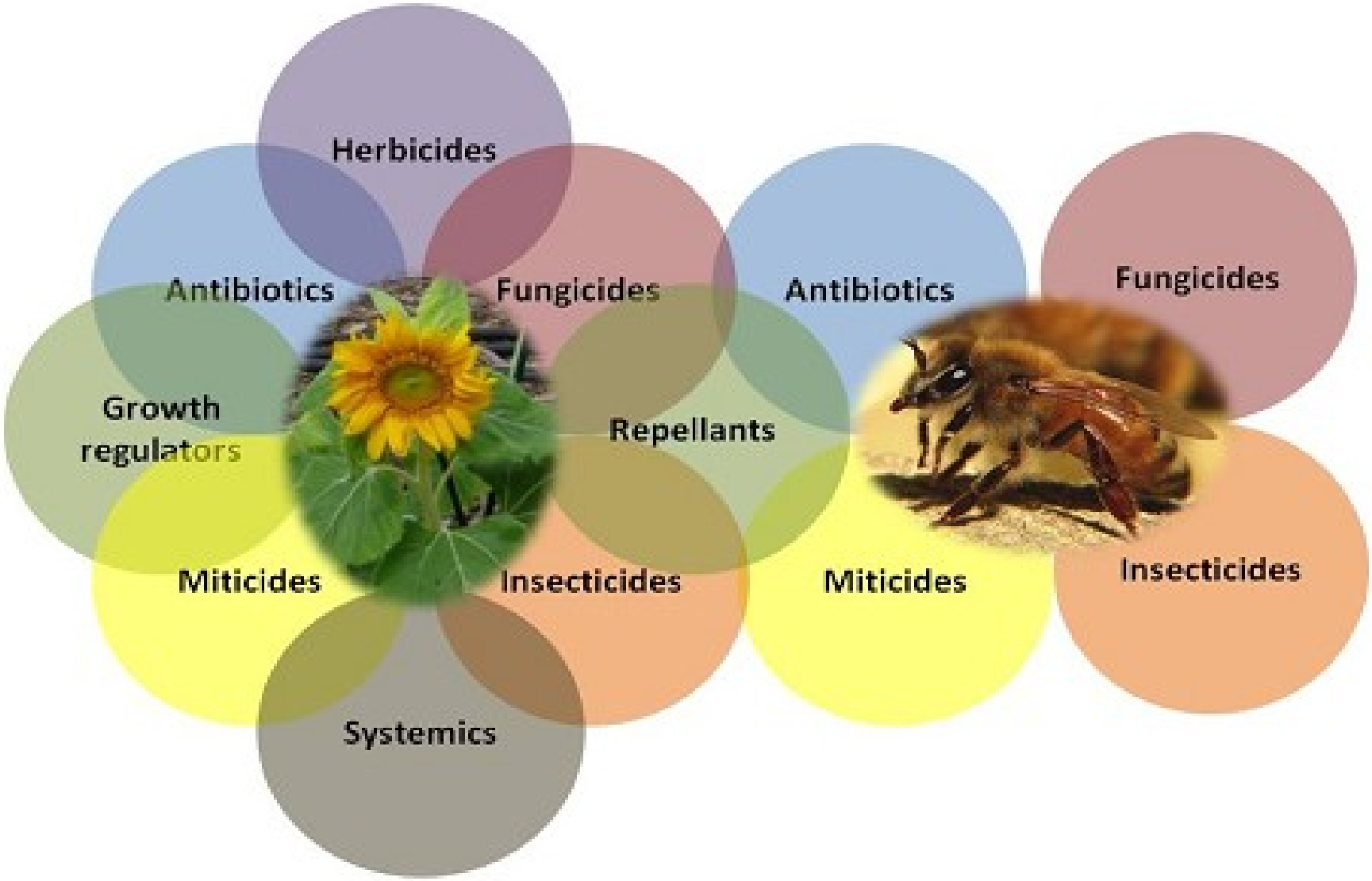
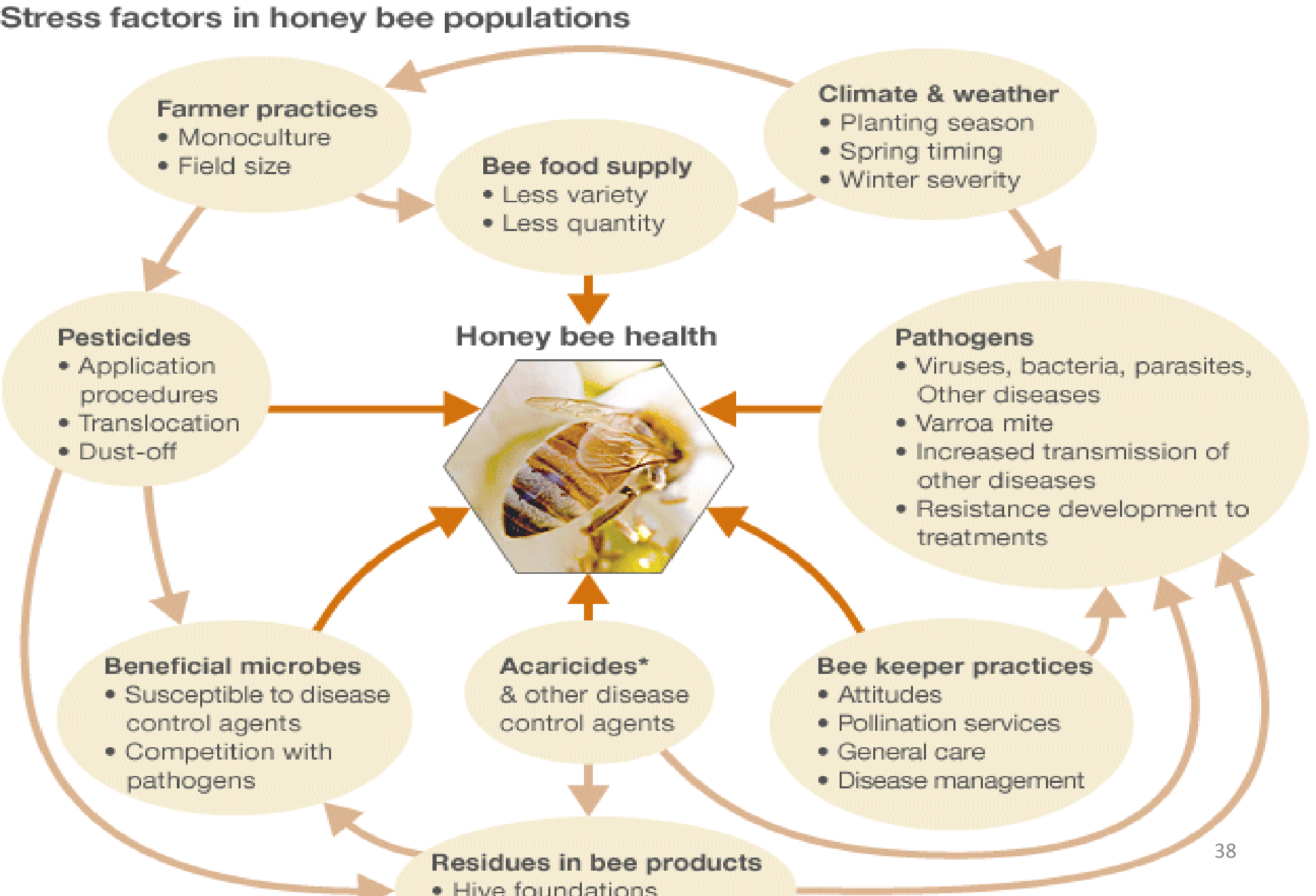


photo from Ohio State University

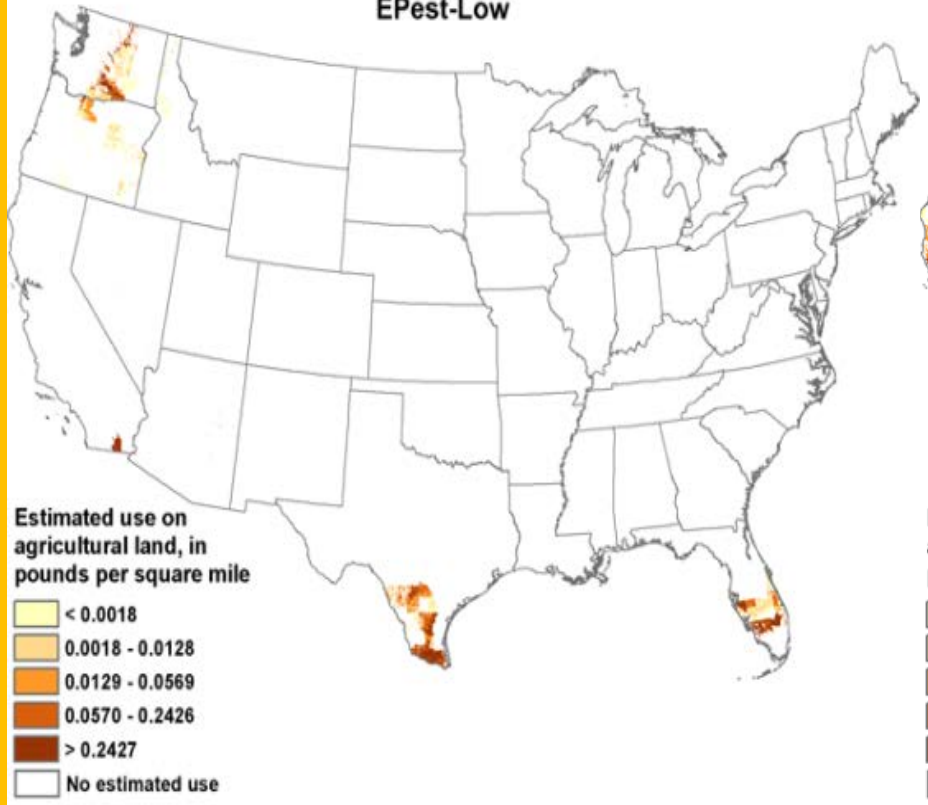
http://www.entomology.umn.edu/cues/pollinators/index.html

Many stresses contribute to CCD in honeybees



Estimated Agricultural Use for Imidacloprid , 1994

EPest-Low

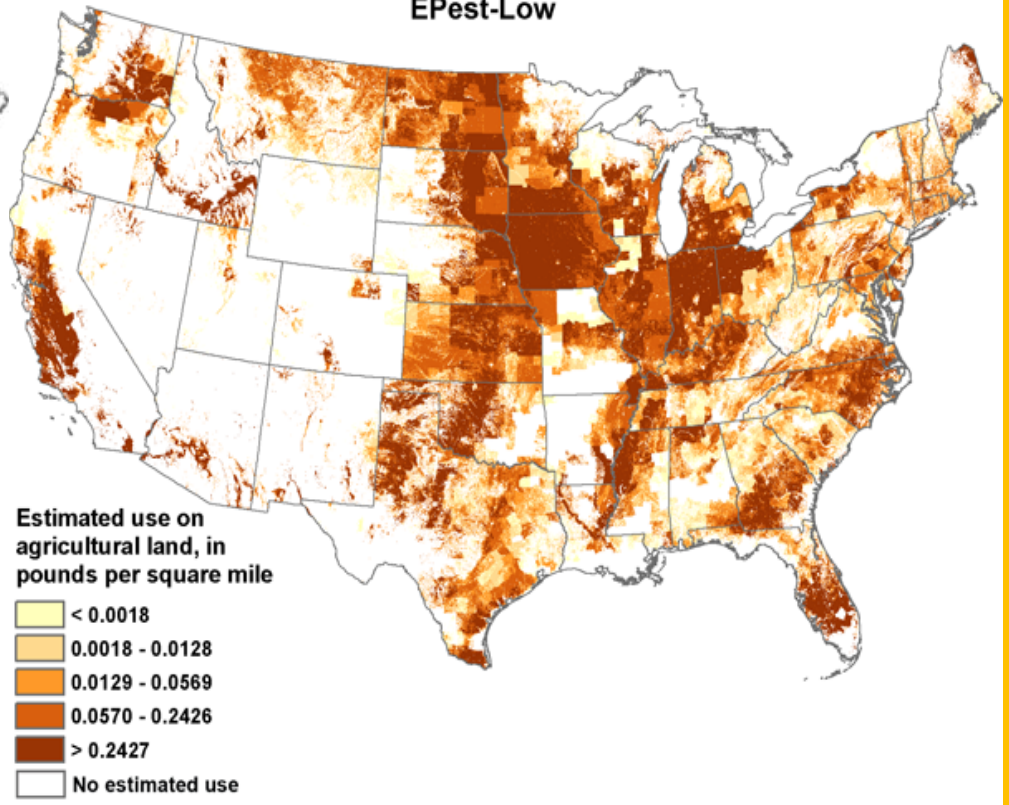


Estimated use on agricultural land, in pounds per square mile

- < 0.0018
- 0.0018 - 0.0128
- 0.0129 - 0.0569
- 0.0570 - 0.2426
- > 0.2427
- No estimated use

Estimated Agricultural Use for Imidacloprid , 2009

EPest-Low



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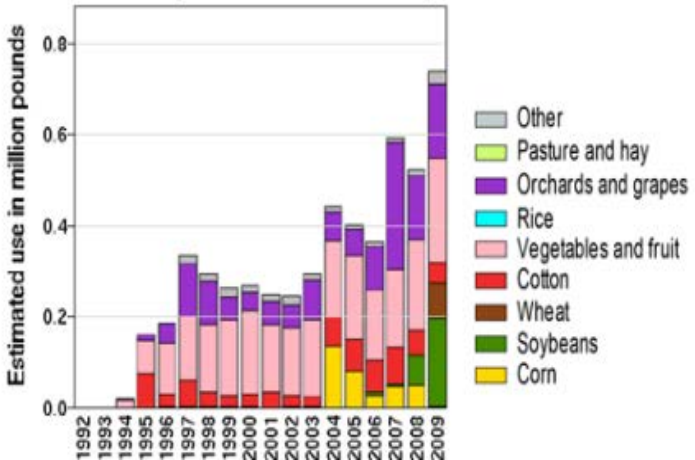
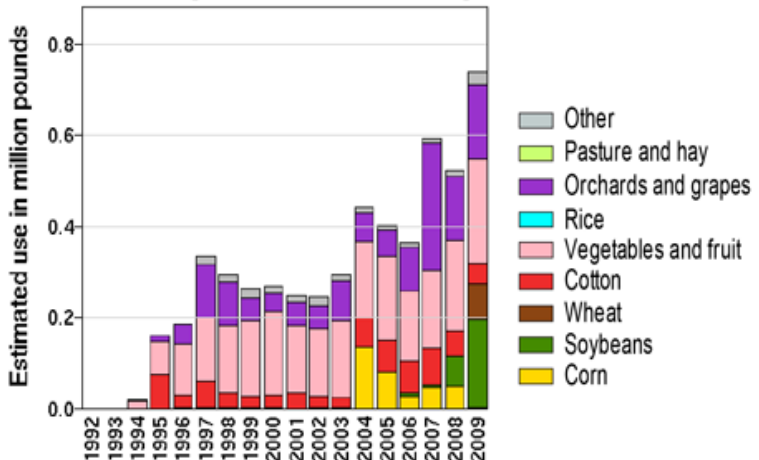
Use by Year and Crop



Use by Year and Crop



Threats to bees: insecticides

Organophosphates + Pyrethroids, are very toxic to bees.

Organophosphates

- **Dimethoate is highly toxic, LD_{50} 15 ng/bee**
- **Chlorpyrifos is toxic, LD_{50} 70 ng/bee**

Pyrethroids

- **Esfenvalerate is highly toxic, LD_{50} 15 ng/bee**
- **Cyfluthrin is highly toxic, LD_{50} 37ng/bee**
- **Permethrin is extremely toxic, LD_{50} 8 ng/bee**

Controversy over neonicotinyls and bees

- 2014 Eugene, Oregon bans neonicotinyl insecticdes in landscapes.

- 2013 June: European Union enacts a 2 year ban on neonicotinyl insecticides starting in December 2013.

- 2013 January: EFSA (European Food Safety Authority) concludes neonicotinyl treated-seed are a bee risk.

- 2012 March: US Beekeepers petition for clothianidin to be withdrawn from sale

Controversy over neonicotinyls and bees

- **2008-2011: Bee deaths are linked to the planting of neonicotinyl treated-seed crops.**

- **2009: California calls for a review of the effects of neonicotinyl insecticides on bees.**

- **2004-2009: New York restricts use of imidacloprid, thiamethoxam, dinotefuran, and clothianidin.**

- **1996: France bans imidacloprid use as treated-seed on sunflowers, Germany, Spain, Italy and Slovenia, follow**

Contact compared to systemic insecticides

Contact insecticides

- **Many used; sprayed on foliage**

- **Insect must eat lor walk on leaf to be killed.**
- **Toxicity lasts 1-3 weeks.**

- **Flowers that open after spraying do not contain insecticides.**

Contact insecticides

Pyrethroids

bifenthrin, cyfluthrin, permethrin

Microbial

***Bacilus thuringiensis* var. *kustaki, tenebrionis, israelensis*.**

***Beauveria bassiana,* spinosad**

Botanical

Neem, azadiractin

Insect growth regulator

hexathiazox, spruce spider mite

Contact insecticides

Unique mode of action, stops feeding

pyrproxyfen

Miticide

Bifenazate

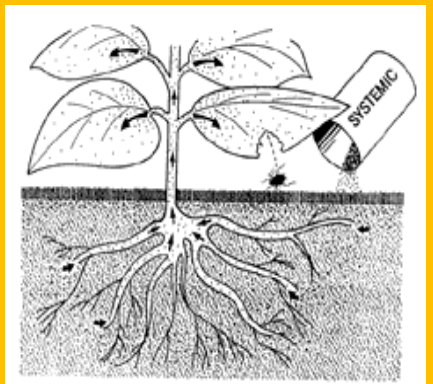
Turf and plants

Acelepryn, chlorantraniliprole

Contact compared to systemic insecticides

Systemic insecticides

- **Uncommon; treated-seed, soil drench, trunk-inject**
- **Insect must eat leaf, pollen, or nectar to be killed**
- **Toxicity can least for months to years, unknown**
- **Flowers that open will have the insecticide in pollen and nectar for months to years, unknown**



Systemic insecticides

Systemic

Organophosphates

aldicarb (Temik), oxamyl (Vydate), dimethoate (Cygon)

Neonicotinyl

imidacloprid (Marathon, Merit), clothianidin, thiamethoxam, dinotefuran

Novel mode of action

pymetrozine (Endeavor)

Translaminar, or local, systemic activity

Microbial- abamectin (Avid)
IGR- pyriproxyfen (Distance)
PR- chlorfenapyr (Pylon)
SP-spinosad (Conserve)
OP- acephate (Orthene)
C-Carbofuran (Furadan)

Neonicotinyl insecticide toxicity
Sublethal dose: more than 20 ppb (2ng/bee) reduces foraging, memory, and navigation

Aspirin 80mg = 80,000microg = 80,000,000ng

Lethal dose	Oral LD_{50} ng/bee in 20µL	Pollen/ nectar ppb (ng/.1gbee)	Reference
imidacloprid	3.7-40	37-400	Schmuck et al. 2001, EFSA 2013
clothianidin	3-22	30-220	Iwas et al. 2004, EFSA 2013
dinotefuran	23-47	230-470	EFSA 2013
thaimethoxam	5-30	50-300	EFSA 2013

Neonicotinyl insecticide use in 2011

143/442 US million acres use neonicotinyl insecticides

83+ million acres of corn have neonicotinyl treated-seed and honeybees use corn for pollen

Active ingredient (ai) in lbs			
	imidacloprid	clothianidin	thiamethoxam
MN	52,048	43,663	68,876
CA	348,247	3,812	30,687
US	700,000	1,2000,000	990,000

Residue in pollen and nectar, very few papers

Plant	Imidacloprid ppb	Reference
Sunflower (treated-seed)	2 nectar 4 pollen	Schmuck et al. 2001
Pumpkin (soil drench)	4 - 12 nectar 37 - 87 pollen	Dively & Hooks 2010
Milkweed (soil drench)	6000 ppb nectar	Krischik 2013
Eucalyptus tree (soil drench)	550 ppb nectar	Paine et al 2011
Horsechestnut tree (trunk injection)	5-283 blossom	Bayer, unpulished,Maus et al. 2004b
Serviceberry (soil drench)	1,038- 2,816 blossom	Bayer, unpublished, Doering et al. 2005a,b

Causes change	Residue level
Common landscape flower residue	6,000 ppb
Kills honeybees in one sip	158-185 ppb
Altering honey bee behavior	6-100 ppb
Altering bumblebee behavior	10-30 ppb .
LD50 imidacloprid LD50 clothianidin	40 ng/bee = 400 ppb 43 ng/bee

Neonicotinoids and bumblebees

- 0 ppb = control
  10 ppb = pollen from seed treatments
  20 ppb = NOEC from Bayer,
  but affects behavior
  50 ppb = Field pumpkin study
  100 ppb = Lower level found in
  landscape plants

- LD50 imidacloprid 4-40 ng/bee = 40-400 ppb
  LD50 \clothianidin 4 ng/bee = 40 ppb

What are bees?

- Most bees are solitary; honey bees, bumble bees, and some sweat bees are social.
- Among the social bees, only honey bee colonies are perennial (survive year to year).
- Solitary and social wasps are sometimes mistaken for bees. Social wasps have annual colonies like bumble bees.

Red-tailed bumble bee (*Bombus ternarius*)
Rob Routledge, Sault College, Bugwood.org

Common eastern bumble bee (*B. impatiens*)
David Cappaert, Michigan State University, Bugwood.org

Bumble Bees, *Bombus* spp., Order Hymenoptera Family Apidae

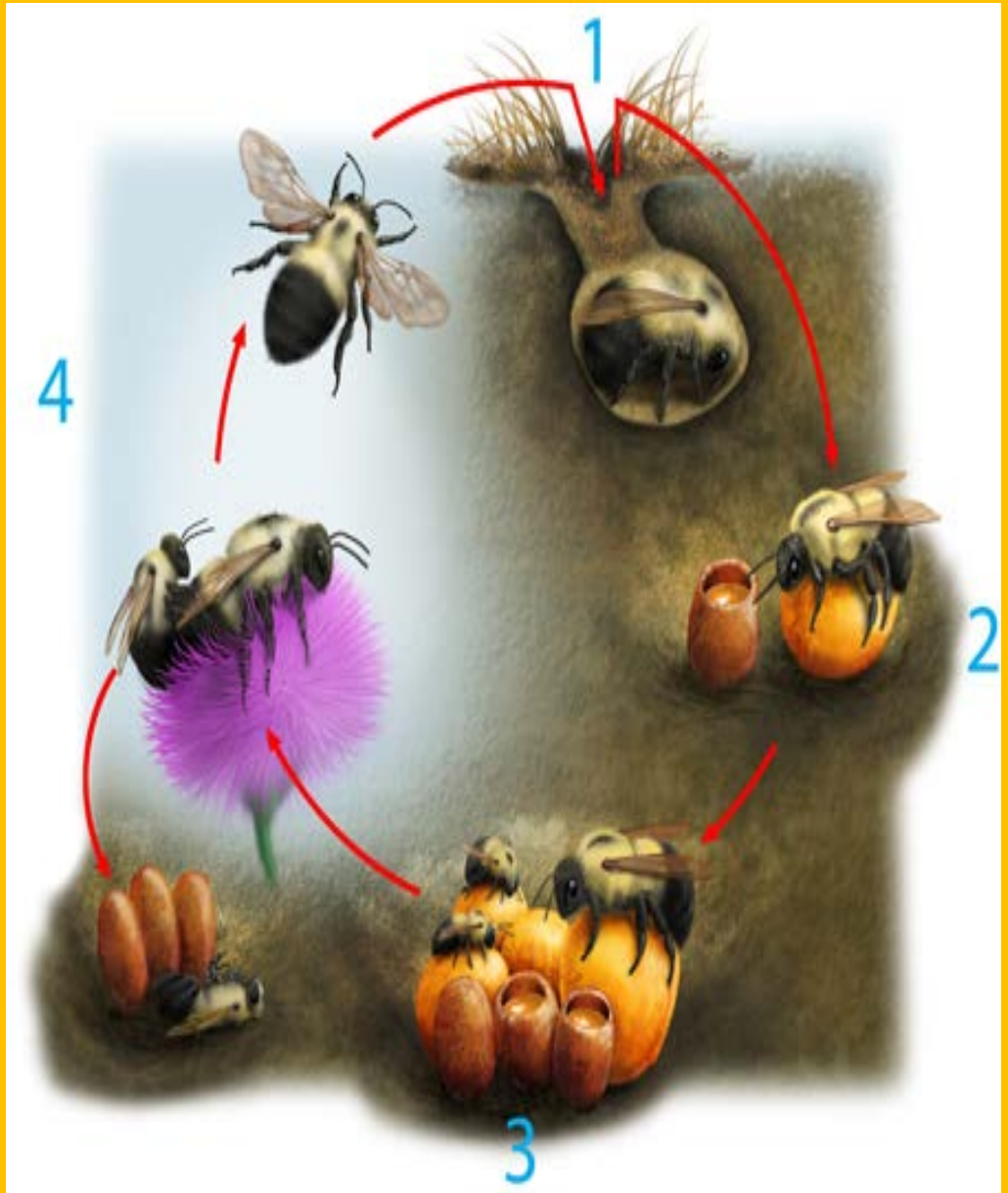
These large (10 to 23 mm), hairy bees are the only truly social bees native to the United States.

Colonies are annual.

Fecundated queens emerge in spring and begin colonies in the ground.

Queens mate with unrelated males before overwintering in the ground.

Bumble bee colony life cycle



1. A queen emerges from hibernation in spring and finds a nest site, such as an abandoned rodent burrow.

2. She creates wax pots to hold nectar and pollen, on which she lays and incubates her eggs.

3 In autumn the colony produces new queens and male bees.

4. Newly mated queens hibernate and the rest of the bees die.

Bumble Bee Colony

Inside a commercial bumble bee colony. Note capped brood cells, shiny "honey pots" full of nectar, and size difference between workers and two large queens (one is newly produced).

Honey bee (*Apis mellifera*)

Honey Bees, *Apis mellifera*, Order Hymenoptera, Family Apidae

Honey bees (native to Europe) are used for pollination (almonds, for example) and for honey, beeswax, and propolis production. They are 10 to 15 mm in length and possess corbiculae like bumble bees.

Honey bee colonies are perennial. New colonies form when an old queen swarms with a group of workers. Fertilized eggs are workers; males are unfertilized eggs.

Honey Bee Colony

Inside a honey bee colony. Note capped brood cells containing pupae and open brood cells with larvae (unlike bumble bees, who cap cells immediately after laying eggs).

Linden trees: Imidacloprid applied to linden to kill adult JB, but linden is a favorite bee plant

BEE LOOKALIKES

Paper wasps (like this *Polistes dominula*) make open nests; note larvae present in brood cells

Baldfaced hornets (*Dolichovespula maculata*) make enclosed nests

Social Wasps

The life cycle of social wasps is similar to that of bumble bees, except wasps are carnivorous.

Among the social wasps, the hornets, aerial yellowjackets, and paper wasps are the species usually found above ground, while most yellowjackets nest in the ground or in cavities . Females chew on wood to make into papery brood cells. Workers hunt caterpillars and other insects to feed the developing larvae.

Incident

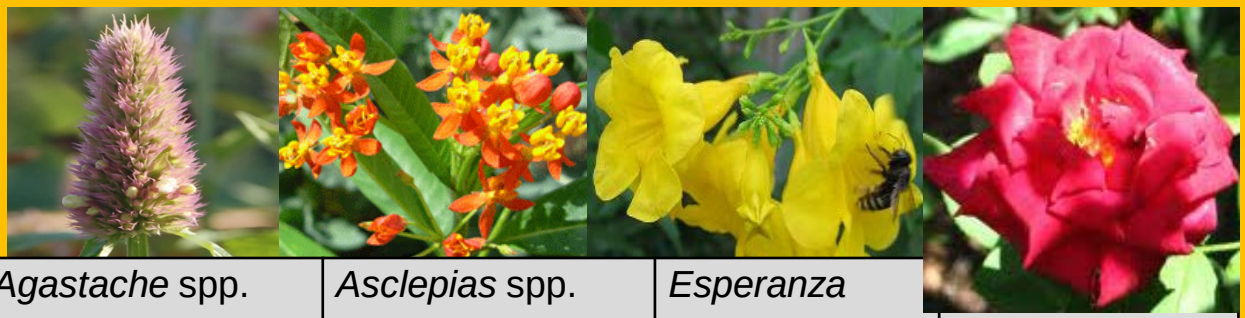
Residue data confirmed dinotefuran. Another bee kill occurred in Hillsboro, OR. Trees were covered in nets and dinotefuran was banned for 6 months until Jan 2014 in Oregon.

Incident

Around 25,000 bumblebees and others were found dead under trees at the Target store in Wilsonville, Oregon on Monday, June 17th. The neonicotinyl insecticide dinotefuran (label Safari) was applied pre-bloom according to label.

Dead in the parking lot, Bombus vosenesenskii

2011 Imidacloprid residue plants



Dose in mg/soil	Dead bees on *Agastache*	*Agastache* spp. **nectar ppb**	*Asclepias* spp. **nectar ppb**	*Esperanza* spp. **nectar ppb**	**pollen ppb**
0	0.6b	6b	3c	0c	26b
25	0.6b	52b	80c	8c	36b
50	0.5b	133b	175bc	21c	30b
300 1X 3 gal	1.1ab	1973b	1568bc	106c	95b
600 2X 3 gal	2.4a	5265ab	2950b	276b	332b

2009-2011 Imidacloprid residue rose

Dose in mg/soil Marathon 1%G	Rose 2009 field	Rose 2010 GH	Rose 2011 field
0	9d	0c	26b
25	na	5c	36b
50	na	7c	30b
Homeowner 1X, 270 mg	812c	na	na
Homeowner 2X, 540 mg	1648a	na	na
300 1X 3 gal	1175b	32bc	95b
600 2X 3 gal	na	161ab	332b
1200	na	268a	720a
	F=256, 0.0001	F=4.9, 0.0045	F=5.7, 0.0025

Bumble bee colonies in the greenhouse

Annual life cycle: *Bombus impatiens*

Queen starts colony in May

New queen + drone production in late summer

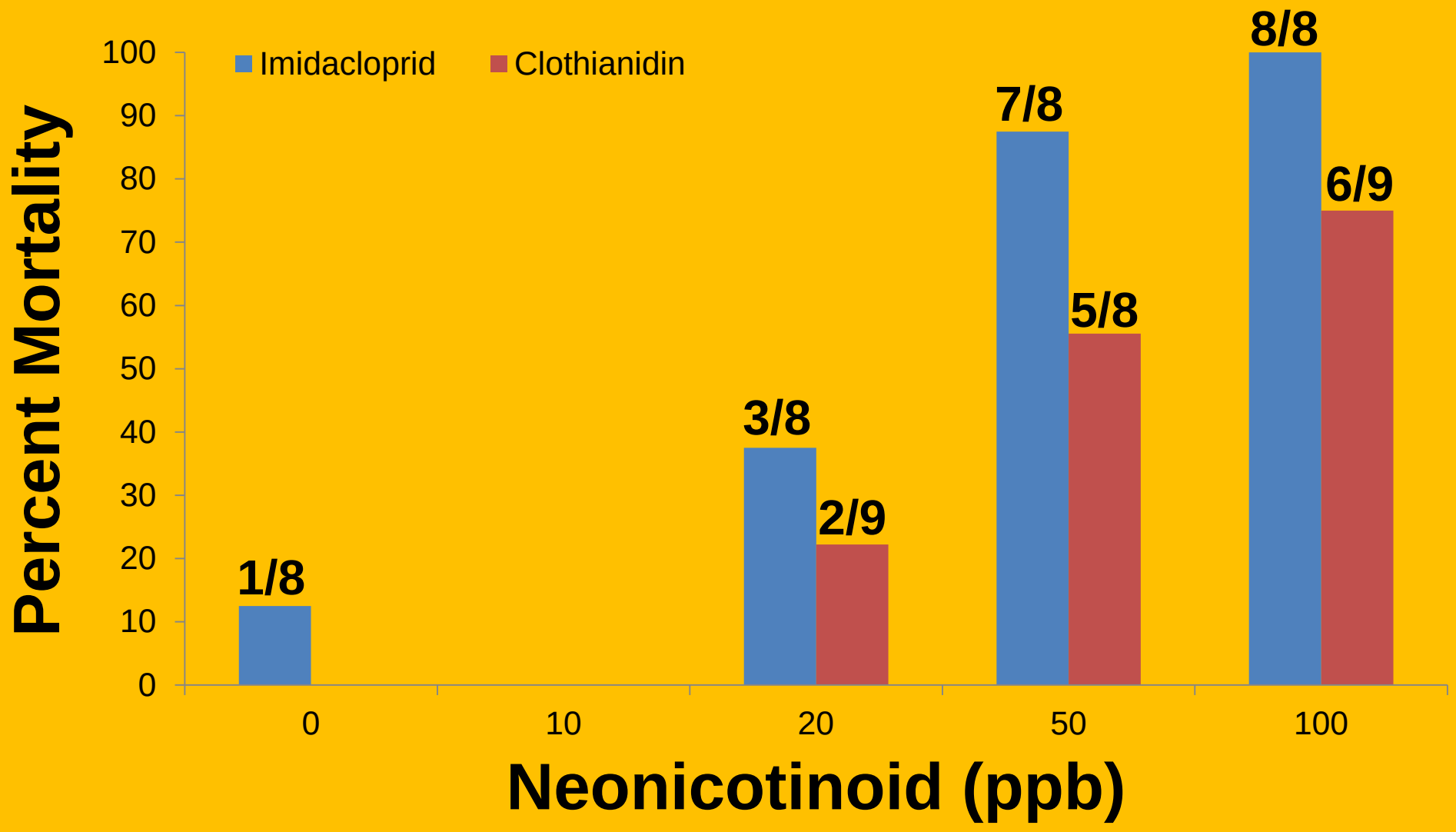
Mating in fall

Winter

Bumble bee colonies with flight box

Brood box **Flight box**

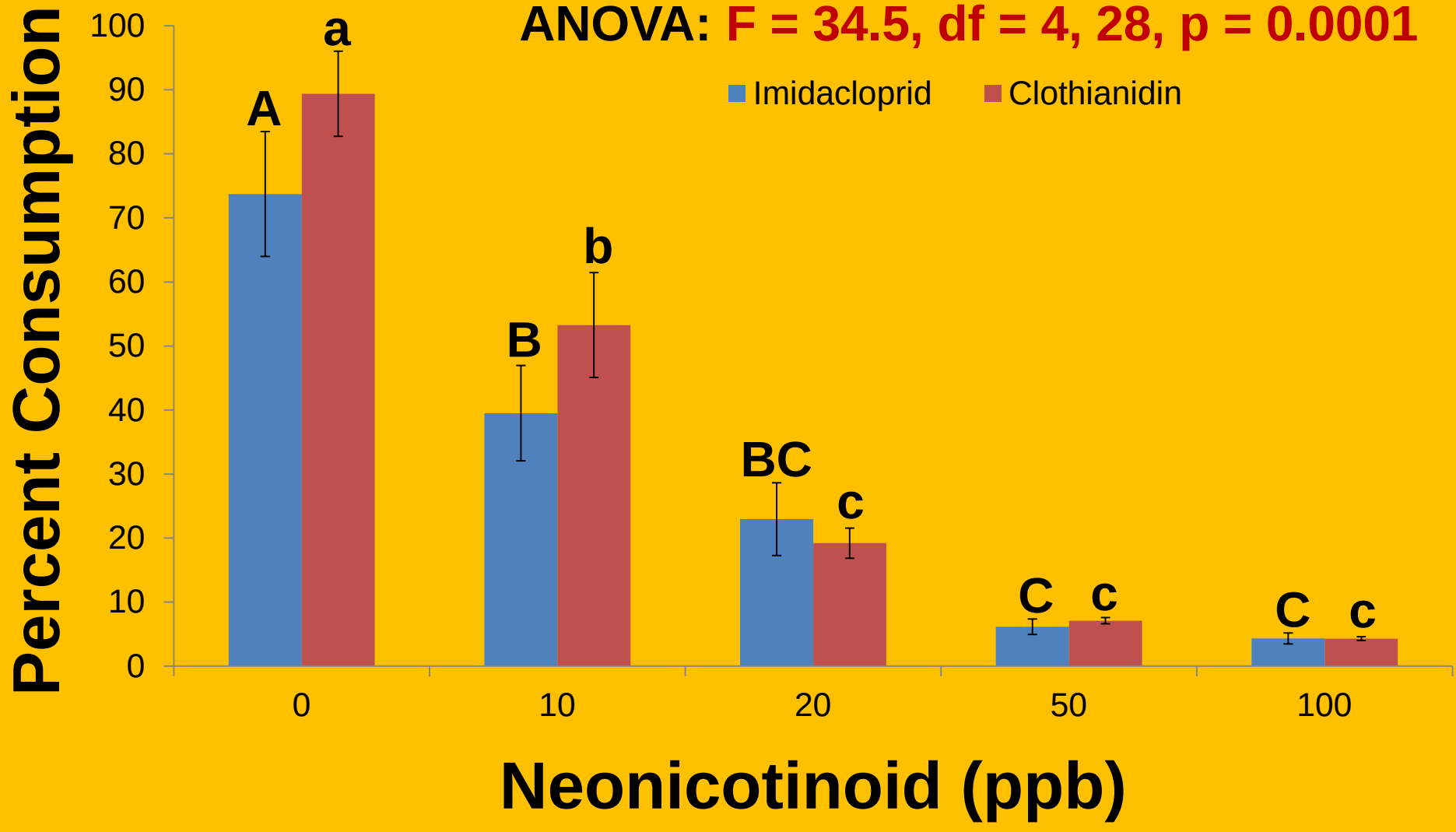
Queen mortality (week 8)



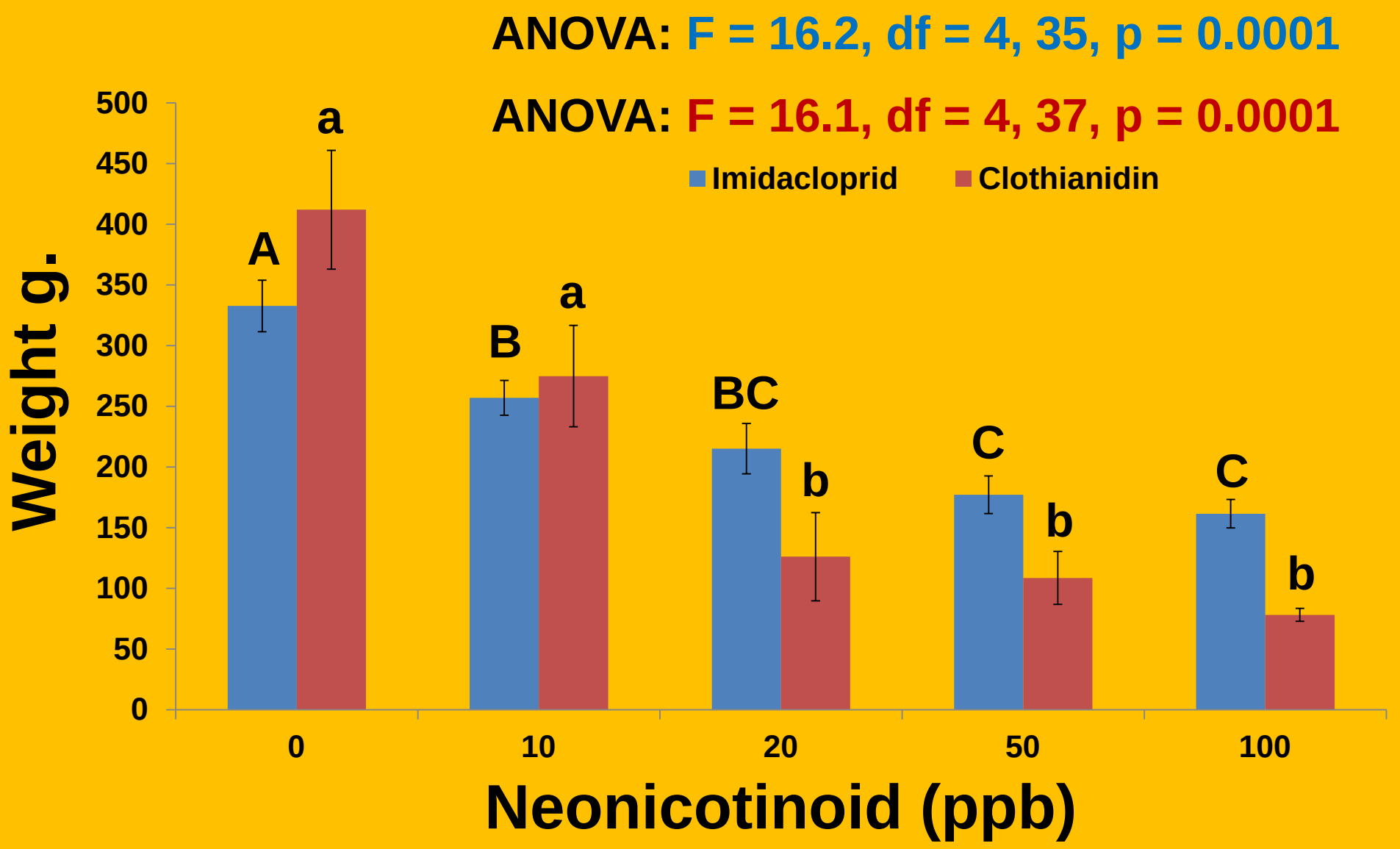
Sugar syrup consumption (Week 8)

ANOVA: F = 22.2, df = 4, 35, p = 0.0001

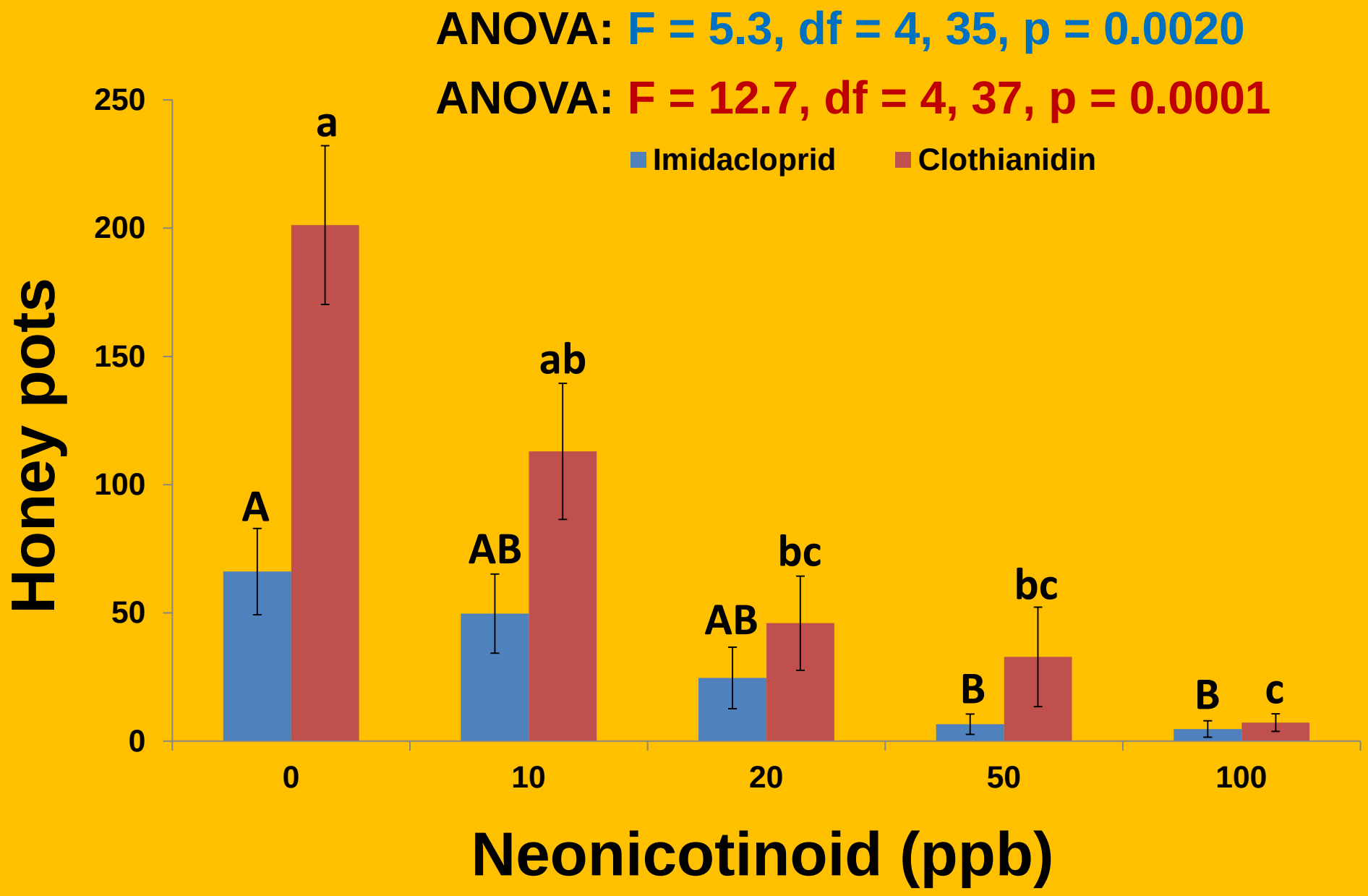
ANOVA: F = 34.5, df = 4, 28, p = 0.0001



Mean colony weight (final)



Mean number of honey pots (final)



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Landscape management linden trees

Cedarburg, WI
Annual Cost To Treat
Ash Trees
= $70,000
(city of 11,000)

Landscape Management

Economic and environmental risk from EAB

- **MN has the second largest population of ash trees in the US.**
- **Since 2002, EAB killed over 50 million ash trees.**
- **Estimated Ohio will spend as much as 1.3 billion dollars.**

Landscape Management

EAB life cycle

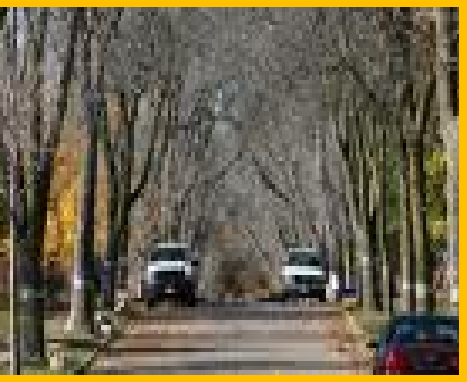
- Native to Asia
- 1-to 2 year
- Larvae feed under bark
- Adults emerge in May
- Asian ash defended with chemicals absent in NA ash.
- Landscape management is removal or insecticides.

Landscape Management

Three application methods

- Passive soil drench
- Soil injection
- Trunk injection

Landscape Management



St. Paul before

St. Paul after

- **St Paul and Minneapolis Park and Rec. Board (MPRB) issue permits for trunk injection on public property.**

- **Minneapolis passed a resolution asking homeowners to replace trees rather than treat on private property.**

- **Long term use of insecticides carries environmental risk.**

Landscape Management

Economic risk and high insecticide use from EAB

- **Insecticide use will continue for many years until effectiveness of biocontrol is determined**
- **Milwaukee, WI treated 33,000 trees with 1,300 liters ($475/liter). Estimates are 1.6 million for insecticide and personnel to treat the trees.**

Landscape Management

- **Movement away from tree of insecticide in water to surface or ground water.**
- **Uptake of insecticides from ash by other plants.**
- **Non-target effects on nectar/ pollen feeding insects.**

Landscape Management

- **Imidacloprid and dinotefuran used for EAB management are water soluble and can leach. NY declared imidacloprid a reduced risk insecticide on LI due to well contamination.**
- **CA initiated a review of imidacloprid's potential to move offsite and to harm non-targets.**
- **Both the EPA and MDA are interested in data that addresses these concerns.**

Landscape Management

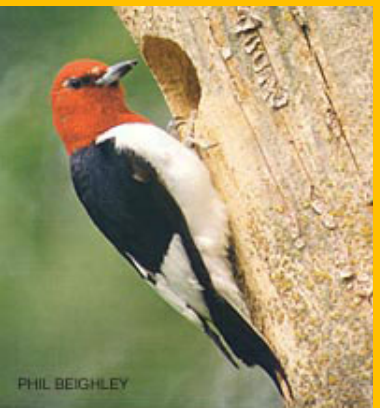
- **Imidacloprid and emamectin benzoate are toxic to birds and bees.**
- **Imidacloprid can be used on other trees, especially linden and maple, which are used by bees, sapsuckers, and hummingbirds.**
- **Emamectin benzoate is a restricted use insecticide due to hazards to applicators. It was previously registered for salmon and for cole crop. The Proclaim label states it is highly toxic to bees.**

Landscape Management

Woodpeckers remove EAB from trees

downy woodpecker

- **In some trees, woodpeckers have removed up to 95% of EAB larvae (Cappaert et al. 2005b).**
- **Birds are exposed to emamectin benzoate and imidacloprid when foraging for EAB on ash trees.**



red-headed woodpecker

Landscape Management :
Non-target consequences on bees, good bugs, and birds

yellow-bellied sapsucker

Its habit of making shallow holes in trees to get sap is exploited by other bird species, and the sapsucker can be considered a "keystone" species, one whose existence is vital for the maintenance of a community (Cornell Ornithology Lab).

Landscape Management

Colorado broad-tailed hummingbird

Hummingbirds are attracted to sapsucker holes

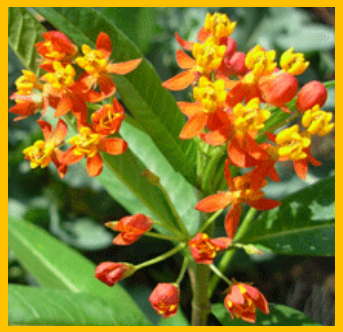
(MN DNR 1997 and Smitley et al. 2007).

Landscape management imidacloprid

1. Need to manage invasive species.
2. Imidacloprid and dinotefuran used for management can move with water away from target trees.
3. Amount of imidacloprid in plants growing under treated trees not researched.
4. Imidacloprid can be used on other trees, especially linden and maple.

2005, 2007, 2011 Imidacloprid residue buckwheat, milkweed

Dose in mg/soil Marathon 1%G	Buckwheat 2005 Nectar ppb	Milkweed 2007 Nectar ppb	2011 Milkweed Nectar ppb
0			**3c**
25	**na**	**na**	**80c**
50	**na**	**na**	**175bc**
Homeowner 1X 270 mg	**na**	**na**	**na**
Homeowner 2X 270 mg	**na**	**na**	**na**
300 1X 3 gal pot	**6000**	**6000**	**1568bc**
600 2X 3 gal pot	**12000**	**12000**	**2950b**
300 21 days later	**na**	**20000**	**na**
600 21 days later	**na**	**34000**	**na**
1200	**na**	**na**	**8337a**
	F=25.86, (2,22) 0.001	F=22.72, (2,6) 0.0016	F=25.8, 0.0001



2012 Imidacloprid residue canola pollen

Dose in mg/soil	April 5 2010, E June 1 flowers 1 app April	May 19, 2010, W July 2 flowers 1 app May	July 2, 2010, E August 18 flowers 2 app April+July	July 29, W Sept 15 flowered 1 app May
Black WI aust		0		0
Poncho blue invigor 601		0		0
Gaucho red invigor 701		0		0
0	0c	0b	0b	0b
4	0c	0b	313b	5b
8	14c	7b	179b	8b
80	461b	15b	342b	24b
160	2072a	341a	3860a	162a
	F=410, 0.0001	F=271, 0.001	F=7.5, 0.0002	F=70.6, 0.0001

2012 Imidacloprid residue canola soil

Dose in mg/soil	April 5 June 1 flowers 1 app April	May 19 July 2 flowers 1 app May	July 2 August 18 flowers 2 app April + July 6	July 29 Sept 15 flowered 1 app May 7
Seed trt no insect				51
Poncho	na	na	na	4
Gaucho	na	na	na	77
0	na	na	0	1316
4	na	na	1552	199
8	na	na	743	257
80	na	na	1816	517
160	na	na	9727	3913
			F=2.8, p=0.07	F=5.3, p=0.0009