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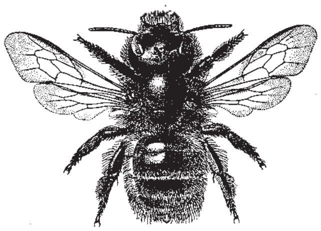
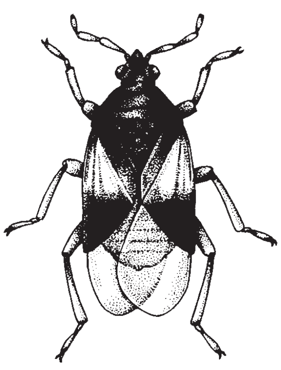
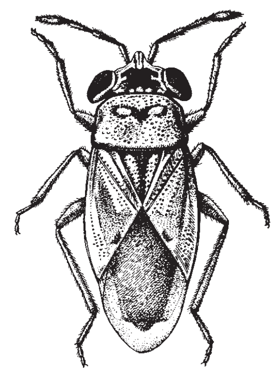
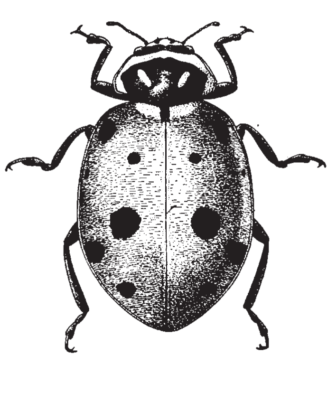
Neonicotinoids, Bees, Birds and Beneficial Insects









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Neonicotinoids, Bees, Birds and Beneficial Insects

By William Quarles

About one-third of managed honey bee colonies in the U.S. are dying each year (van Engelsdorp et al. 2012; NAS 2007). Bumble bees and other native bees are also dying (Whitehorn et al. 2012). Part of the problem is exposure to systemic insecticides called neonicotinoids. Insecticides are normally applied in ways to mitigate their impact on bees, but mitigation strategies are not possible with systemics because they are always present in the plant. Each year, over 146 million acres (59 million ha) of crops in the U.S. are treated with neonicotinoids. This represents about 45% of the total cropland, and acreage is increasing each year (Stokstad 2012; Spivak et al. 2011; Quarles 2011; Quarles 2008).

Found Everywhere

Neonics are used in field crops, orchards, parks, landscapes, backyard gardens, on ornamentals, lawns, pets, and in structural pest control. Neonics are applied as foliar sprays, soil drenches, granules, tree injections, and as seed treatments. Some of them are extremely persistent, providing a big window of possible exposure. They can remain active in soil for more than a year after application, or for several years inside trees. Neonics are found in pollen and nectar of treated plants, in leaf litter, soil and water. The problem is that they are found everywhere, even in bee friendly plants produced by horticultural nurseries (Goulson 2013; Hopwood et al. 2013).

Beneficial Insects

Widespread exposure to neonicotinoids is killing beneficial insects such as ladybugs and parasitic wasps. Beneficial insects are killed by acute exposure to neonic sprays and by chronic exposure to poisoned prey and the poisonous pollen and nectar of systemically treated plants (Hopwood et al. 2013). The economic effect is substantial. Biocontrol is worth more than $4 billion a year to agriculture, and honey bees plus native bees provide up to $19 billon of pollination services. The value provided by these insects far exceeds the $2.6 billion of neonicotinoid sales (Losey and Vaughn 2006; Jeschke et al. 2011).

Birds Also Killed

Neonicotinoids are also killing birds. A major route of exposure is through seed treatments. Some birds can be killed by eating just one poisoned seed (Mineau and Palmer 2013). Most of U.S. corn, soybeans, cotton, cereals, sugar beets, sunflowers, oilseed rape and other crops are grown with neonicotinoid seeds (Elbert et al. 2008). Though seed treatments prevent pesticide drift and the environmental problems of sprays, the vast acreage of exposure is becoming a problem (Goulson 2013).

Pollute Water

About 2-20% of a seed treatment is absorbed by the plant. The rest is either blown into the air by seed drills, or remains in soil. The toxic airborne dust from seed drills can kill flying bees and ultimately pollutes non-target plants and soil. Seed treatments and soil drenches are finally washed away into ground and surface water (Goulson 2013; Krupke et al. 2012).

Neonicotinoids allow growers to ignore good farming methods and IPM approaches in favor of systemic protection. With the IPM method, pesticides are applied only after pests appear and economic thresholds are reached. But seed treatments are applied before pests are seen, and may not be needed. This approach can lead to unnecessary expense and no improvement in yield in years of low pest pressure (Gray 2011; Seagraves and Lundgren 2012).

This article reviews the some of the environmental problems caused by neonicotinoids, and the next article suggests IPM alternatives.

Honey bees, *Apis mellifera*, can be killed by neonicotinoids.

Photo courtesy of Kathy Keatley Garvey

What are Neonicotinoids?

Neonicotinoid pesticides are analogs of the neurotoxin nicotine, and some of their actions are similar. They are neurotoxins that interfere with the acetylcholine nervous system that is essential for life. They disturb nerve function by binding to nicotinic receptors. They bind more strongly to nicotinic receptors in insects and are thus more toxic to insects than mammals. This selectivity caused regulators to view them favorably (Tomizawa and Casida 2003).

Neonicotinoids also show invertebrate species selectivity, which can be either a blessing or a curse. They are especially effective for sucking pests such as aphids, whiteflies, planthoppers, and thrips. They also provide protection from borers, caterpillars, beetles, and the corn rootworm (Elbert et al. 2008). But honey bees and parasitic wasps are extremely sensitive, and neonicotinoids will not kill pest mites or ticks. So careless treatments with neonics can kill bees and lead to pest mite explosions (Jeschke et al. 2011; Szczepaniec et al. 2013).

In the U.S. there are now six commercially available neonicotinoids: imidacloprid, clothianidin, thiamethoxam, acetamiprid, dinotefuran, and thiacloprid. They differ somewhat in water solubility, systemic action, selectivity and persistence. As we see in Table 1, imidacloprid, clothianidin and thiamethoxam are more acutely toxic to bees and are the most persistent.

The selectivity, systemic action, and persistence that made them popular are now causing problems. They are killing birds, bees, and beneficials, and due to overuse and persistent exposure, some of the insect pests are becoming resistant (Jeschke et al. 2011; Mineau and Palmer 2013).

Problems with Bees

Bees can be killed by neonicotinoid foliage sprays, by poisonous dust from seed planting machines, by treated irrigation water, and by exposure to poisonous pollen and nectar from systemically treated plants (Quarles 2011; Goulson 2013; Blacquiere et al. 2012; Hopwood et al. 2012; Krupke et al. 2012).

Environmental problems with pesticides can be dramatic. In June of 2013, about 50,000 bumble bees were killed when linden trees in Oregon were sprayed with the neonicotinoid pesticide dinotefuran (Black and Vaughn 2013). In May of 2008, about 50% of honey bees in the German state of Baden-Wurttemberg were killed by the neonicotinoid pesticides clothianidin and imidacloprid, which had been applied to seeds. According to the manufacturer, farmers applied these pesticides without using the adhesives recommended to keep the pesticides localized to seeds (EPA 2008; Hopwood et al. 2012).

Bees Extremely Sensitive

Bees are extremely sensitive to neonics and can be exposed for long periods to plants full of systemic toxins. As we see in Table 1, just 3-4 billionths of a gram (3-4 ng) of imidacloprid or clothianidin is enough to kill a honey bee. Neonics can impact bee populations through direct mortality and through sublethal effects on behavior, such as impaired memory, learning and foraging. Impaired foraging can lead to poor nutrition, and pesticides may directly impact bee immune systems, making them more susceptible to disease. In addition, sublethal pesticides interfere with brood development and shorten lifespans of adults (Henry et al. 2012; Pettis et al. 2012; Wu et al. 2011; Desneux et al. 2007).

Lethal Doses in the Fields

Flying bees are killed by aerially dispersed seed coatings and talc from seed planting machines (Krupke et al. 2012; Marzaro et al. 2011; Tapparo et al. 2012; Girolami et al. 2012). Poisonous dust from planting machines can also contaminate flowers, pollen, and leaf surfaces of non-target plants, soil, and water. Pesticide persistence guarantees longterm exposure (Goulson et al 2013).

Bees may be killed by guttation water from treated plants. Corn excretes droplets of water along leaf margins called guttation drops. For about three weeks after emergence, droplets from seed-treated corn contain concentrations of neonicotinoids lethal to bees (Girolami et al. 2009). Levels in guttation fluid can be 254 times the bee LD50 for imidacloprid, 280 times the LD50 for clothianidin and 48 times the LD50 for thiamethoxam (Thompson 2010). Lethal guttation drops are also found in melon crops with neonicotinoid soil treatments (Hoffman and Castle 2012).

Exposure in Bee Hives

Bee exposure to pesticides is widespread. Mullin et al. (2010) checked a large number of commercial bee hives for pesticides. Hives from 23 states including Florida, California, Pennsylvania and migratory bees from East Coast colonies were analyzed. Wax, pollen, and bees were highly contaminated with pesticides. There were 121 different pesticides and metabolites in 887 wax, bee, and pollen samples, averaging about 6 pesticides per sample.


Commercial hives are heavily contaminated with pesticides.

Photo courtesy of Kathy Keatley Garvey

Mullin et al. (2010) found bee pollen in hives contained imidacloprid at a median concentration of 20 ppb (ppb is parts-per-billion) and a maximum concentration of 206 ppb. These levels are known to impact the health of bees. A total of 43 pollen samples (12%) out of 350 contained neonicotinoids or their metabolites. Mullin et al. were analyzing hives foraging on specialty crops such as citrus, apples and others that do not use seed treatments. Where bees forage on crops such as corn, canola, or sunflowers that use neonicotinoid seed treatments, 50% of pollen samples carried by honey bees can be contaminated with these pesticides (Krupke et al. 2012; Lu et al. 2012; Blacquiere et al. 2012).

Nurse bees feed contaminated pollen to larvae. Sublethal concentrations of neonicotinoids and other pesticides in brood comb can delay development of adult bees. Delayed

Table 1. Toxicity of Neonicotinoids to the Honey Bee, *Apis mellifera**

Neonicotinoid	Oral LD50 (ng/bee)	Contact LD50 (ng/bee)	Soil Half Life (days)
Clothianidin	2.8-3.79	22-44	148-1,155
Imidacloprid	3.7-81	17.9-243	40-997
Thiamethoxam	5	24-29	25-100
Dinotefuran	7.6-23	24-61	138
Thiacloprid	8,510-17,300	14,600-38,830	1-27
Acetamiprid	8,850-14,520	7,100-8,091	1-8

*from Hopwood et al. 2012, Laurino et al. 2011. One nanogram (ng) is one-billionth of a gram.

development can make the bees more susceptible to mites. Pesticides in the brood comb also shorten life span of adult bees (Wu et al. 2011).

Sublethal and Lethal Effects

Sublethal effects such as reduced feeding have been found in adult bees upon ingestion of 6 ppb or less of imidacloprid. Reduced feeding could lead to poor nutrition. Longterm feeding of 4-40 ppb impairs olfactory learning, which is associated with finding food (Decourtye et al. 2001; 2004).

Toxicity is cumulative, and one experiment showed 50% mortality when adult bees were fed 0.1 to 10 ppb imidacloprid for 10 days (Suchail et al. 2001ab). Other experiments have shown that mortality starts at feeding levels between 24-48 ppb (Decourtye et al. 2004). Field tests have shown that hives can be killed by feeding at 20 ppb (Lu et al. 2012).

Cause Disease

Sublethal exposure to neonicotinoids can depress immune function in bees and other wildlife, leading to diseases. Imidacloprid and clothianidin trigger production of proteins that suppress immune function, making bees more susceptible to deformed wing virus. Bees exposed to imidacloprid are more susceptible to infections with the *Nosema* pathogen. Beetle grubs treated with imidacloprid are more easily killed by pathogenic nematodes (Pettis et al. 2012; Kopenhofer et al. 2002; di Prisco et al. 2013). Other examples can be found in Mason et al. (2013).

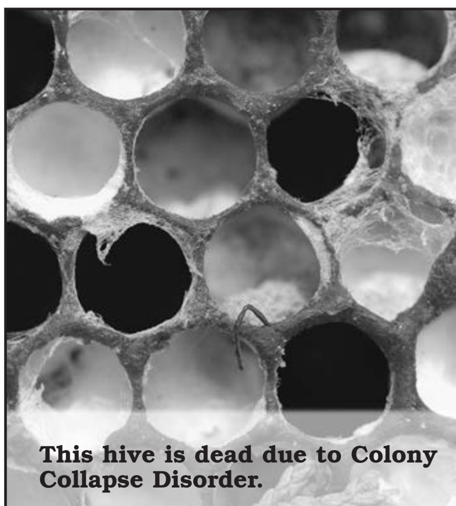
Synergism and Larval Exposure

Careless use of fungicides is adding to problems with neonics. Fungicides such as chlorthalonil are often sprayed on flowering plants. Adult bees are not killed, but foragers take contaminated pollen and nectar to the hive to feed larvae. Bee larvae are more sensitive than adult bees to pesticides. Zhu et al. (2014) found that realistic hive exposures of chlorthalonil could make some insecticides seven times more toxic to bee larvae.

A number of other studies have noted the synergistic interaction of fungicides with neonics (Schmuck et al. 2003; Isawa et al. 2004), and other insecticides (Johansen 1977; Atkins 1992; Pilling and Jepson 1993). Sublethal exposures of neonics can be amplified by synergistic interactions with fungicides and other pesticides, poisoning larvae and eventually killing bee colonies (Zhu et al. 2014).

Exposure to Nectar and Pollen

Bees can be exposed to contaminated nectar and pollen of neonic treated plants. Chronic doses can accumulate because bee metabolism and elimination of neonicotinoids such as imidacloprid (IMD) is slow. One of the IMD metabolites is twice as toxic as IMD (Chauzat et al. 2006). Metabolism is complex and thiamethoxam is actually converted by metabolism into clothianidin (Hopwood et al. 2012; Krupke et al. 2012).



This hive is dead due to Colony Collapse Disorder.

Photo courtesy of Kathy Keatley Garvey

Imidacloprid (IMD) is often applied as a seed treatment. Average concentration in pollen of seed-treated sunflowers, corn, and rape is usually 10 ppb or less, but individual plants can have 18 ppb or more. Flowers can have higher concentrations than pollen, amounts in nectar are usually less than 5 ppb (Laurent and Rathahao 2003; Fossen 2006; Bonmatin et al. 2005). Average amounts from several seed treatment studies are 6.1 ppb in pollen and 1.9 ppb in nectar (Goulson 2013).

Seed treatments of neonicotinoids can cause sublethal effects (Boily et al. 2013). At the least, field realistic levels in nectar from seed treatments can reduce expected performance in adult honey bees by between 6 and 20% (Cresswell 2011). Sublethal concentrations in the hive interfere with brood development (Wu et al. 2011).

Exposure Greater from Soil Treatments

Relatively small amounts of neonics appear in pollen and nectar from seed treatments. But neonicotinoids are also used as foliar sprays, as soil drenches, and for treating landscape ornamentals as well as crop plants. Amounts used on ornamentals lead to residues 12-16 times greater than found on crop plants (Hopwood et al. 2012). Concentrations up to 66 ppb are found in pollen, and up to 23 ppb in nectar (Goulson 2013). Soil treatments in eucalyptus led to concentrations of 660 ppb in pollen (Paine et al. 2011). Foliar sprays during flowering could have disastrous results. Up to 147 ppb of neonics have been found in pollen of flowering pumpkin, and concentration in nectar was up to 11 ppb (Goulson 2013).

They Never Return

Yang et al. (2008) found that concentrations of imidacloprid of 40-50 ppb in sugar water were enough to cause impaired foraging of honey bees in the field. Nectar concentrations from seed treatments are lower than this, but even if nectar concentrations are low, fairly large chronic doses can be delivered. A bee ingests 20-30 µl of nectar each time, and the half life of IMD is about 4.5 hrs, making chronic accumulation possible. Since bees ingest average nectar loads of 40 mg, and eat about 11.5 mg/hr, about 2 ng of imidacloprid can be accumulated from feeding for 3 hrs at 50 ppb. Imidacloprid is metabolized by bees into toxic metabolites that can also accumulate (Suchail et al. 2003; 2004; Cresswell 2011; Faucon et al. 2005; Quarles 2011).

The relatively small amount in pollen and nectar can disorient bees and lead to field losses. Henry et al. (2012) treated honey bees with sublethal 1.3 ng doses of thiamethoxam. About 10% of treated bees released in familiar surroundings failed to make it back to the hive. About 32% of treated bees released in unfamiliar surroundings failed to return. Field impact studies often put hives immediately adjacent to treated fields to assess effects. This study shows that this method would tend to underestimate pesticide induced foraging impairment (Henry et al. 2012; Quarles 2011).

Schneider et al. (2012) found that 26% of foragers did not return after oral doses of 1 ng (one-billionth of a gram) of clothianidin, and 79% did not return after 2 ng. Matsumoto (2013) found that successful homing flights of honey bees were reduced at doses of 1/10 the LD50 of clothianidin and dinotefuran.

Bumble Bees also Affected

Sublethal doses of IMD have been shown to affect bumble bee foraging. After 9 days of foraging in sunflowers treated with IMD, about 10% more bumble bees were lost in the field compared to bumble bee foragers in untreated fields (Taséi et al. 2001). Larson et al. (2013) sprayed clothianidin on lawns with flowering clover. Concentration of the pesticide in clover nectar was about 170 ppb. There was decreased bumblebee foraging,

Bumble bee, *Bombus* sp.

From Nixon 1954

increased mortality, and no new queens were produced.

Whitehorn et al. (2012) fed 25 bumble bee colonies in the laboratory for 14 days on pollen containing 6 ppb imidacloprid and sugar water containing 0.7 ppb. Colonies were then left to forage in the field for six weeks. After six weeks, treated colonies weighed 8-12% less than untreated controls. The weight drop was likely due to pesticide induced impairment of food gathering efficiency. Treated colonies also had on average about 85% fewer queens.

Delayed Mortality

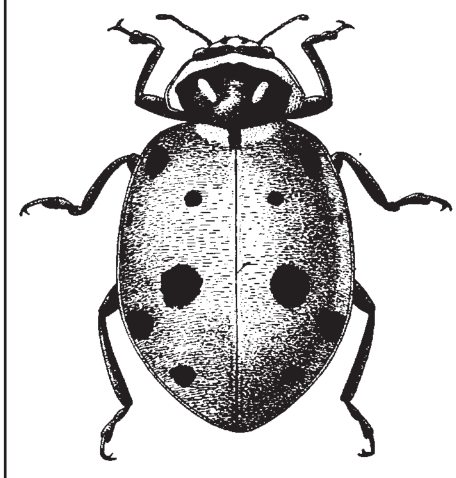
Most of the bee toxicity experiments are done either on individual bees or on hives monitored for a limited amount of time. Lu et al. (2012) chronically dosed summer bees with imidacloprid, then stopped. Mortality was delayed for several months.

Bees were fed high fructose corn syrup containing 20, 40, 200, and 400 ppb imidacloprid. About 23 weeks (nearly 6 months) after the last dose, 15 of 16 of the treated hives were dead. Dead hives had no bees, but still had food. Summer bees were fed imidacloprid, and the winter bees died.

This kind of delayed mortality mimics some of the manifestations of Colony Collapse Disorder. The lowest feeding dose was 20 ppb. Earlier experiments had shown no effect on overwintering bees when summer bees were fed 5 ppb of imidacloprid in sugar syrup. There were four untreated control hives, and three of four survived (Faucon et al. 2005; Lu et al. 2012).

Bans in Europe

The adverse effects of neonicotinoids on bees have led to several bans in Europe. In 1994, about three years after imidacloprid was introduced, French beekeepers noticed large losses of bees. These bees had been foraging in sunflower crops whose seeds had been treated with imidacloprid. Imidacloprid on sunflowers was banned in France in 1999, followed by a ban of use on corn in 2004. Germany and Italy banned neonics on corn in 2008. The possible connection between



Convergent lady beetle, *Hippodamia convergens*

bee destruction and neonics led to a two-year ban of some neonics in the European Union in 2013 (Hopwood et al. 2012; EPA 2013).

Effects on Beneficials

That broadspectrum pesticides can have effects on beneficial insects such as ladybugs is not new or surprising. However, because of the multiple routes of application, beneficials can be exposed to neonicotinoids in a number of different ways. Because of persistence, neonics provide both acute and chronic exposures. Also, neonics are more toxic than older pesticides to some beneficials (Cloyd et al. 2009; Hopwood et al. 2013).

Beneficials are killed by exposure to foliage sprays of neonicotinoids and exposure to residues. They are killed through secondary poisoning when they ingest aphids and other pests that have been poisoned with neonicotinoids. Soil applications of neonicotinoids lead to relatively high systemic concentrations in plant nectar, leading to death of parasitoids (Krischik et al. 2007). Soil applications also kill ground dwelling beneficials such as ground beetles and earthworms. Even seed treatments can have an impact on beneficial populations (Seagraves and Lungren 2012).

Exposure to Sprays and Residues

Spray applications of the neonics dinotefuran, acetamiprid, and clothianidin are highly toxic to the parasitoid *Leptomastix dactylopii* and the mealybug destroyer, *Cryptolaemus montrouzieri.* These beneficials provide mealybug biocontrol (Cloyd and Dickinson 2006).

Predatory bugs such as nymphs and adults of the soldier bug, *Podisus maculiventris*, are killed by imidacloprid sprays (De Cock et al. 1996). Contact with label rates of acetamiprid, thiamethoxam, and imidacloprid can kill all life stages of the lady beetle, *Harmonia axyridis* (Youn et al. 2003). These beneficial insects kill a wide range of insect pests.

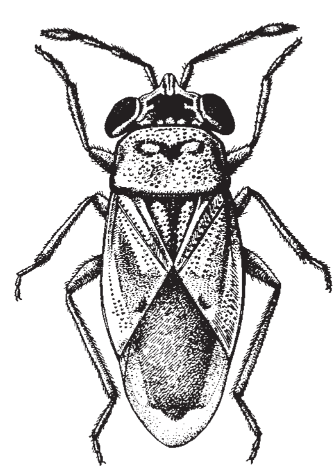
Poisonous Prey

Cottony cushion scale poisoned by systemic or foliar treatments of citrus with imidacloprid is toxic to the predatory vedalia beetle, *Rodolia cardinalis*. Adult survival, progeny, and larval development are reduced (Grafton-Cardwell and Gu 2003).

Imidacloprid soil treatments of bean plants produce aphids, *Aphis fabae*, that are toxic to predatory lady beetles, *Hippodamia undecimnotata*. There is increased mortality, decreased longevity and egg production (Papachristos and Milonas 2008).

Soil Treatments

Soil treatments of neonicotinoids can kill beneficials that dwell in the soil. Imidacloprid is toxic to earthworms at 2.3 to 3.48 ppm in dry soil (Wang et al. 2012), and sprays of imidacloprid or clothianidin to turf at label rates can significantly reduce earthworm populations (Larson et al. 2013; Kunkel et al. 1999).



Big-eyed bug, *Geocoris punctipes*

Soil treatments can cause problems with predatory ground beetles. Neonicotinoid soil drenches are more toxic than the organophosphate chlorpyrifos to the beneficial soil predator *Atheta coriaria* (Cloyd et al. 2009). Beneficial ground beetle populations can be reduced by 84% by imidacloprid granules applied to turf. After a year, populations still had not recovered (Peck 2009).

Killed By Systemics in Plants

Until recently, many professionals believed neonicotinoids applied by soil drenches were safe for beneficials. But because neonicotinoids are systemic, root uptake leads to insecticides in leaves, pollen, and nectar. Some beneficials are killed when they ingest poisoned pollen, nectar, and plant tissues to supplement their diet (Hopwood et al. 2013).

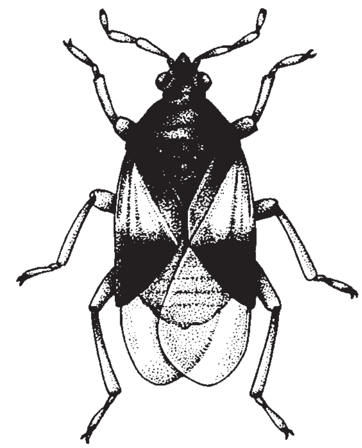
Various experiments have shown there is 96% mortality of bumble bees foraging on flowers of treated tomato, 38% mortality of ladybugs foraging on treated sunflowers, and 86% mortality of adult lacewings foraging on flowers of systemically treated buckwheat. Imidacloprid concentration in the buckwheat flowers was 15 ppb (Rogers et al. 2007).

Another experiment showed that buckwheat treated with imidacloprid soil drenches contained 16 ppb of imidacloprid in the flowers. About 88% of the parasitoids, *Anagyrus pseudocci*, that fed on nectar showed poisoning symptoms and 100% of them were dead within seven days (Krischik et al. 2007).

Adult Monarch butterflies, *Danaus plexippus*, feed on plant nectar. Though research has not been published, it is likely that migratory butterflies may be affected by systemic neonicotinoids (Goulson 2013).

Eucalyptus trees, *E. rudis*, treated with soil applications of imidacloprid at label rates had 660 ppb of imidacloprid and its toxic metabolites in the nectar five months after the application. This amount is well above lethal concentrations for honey bees. Parasitoids, such as *Aventianella longoi* and *Syngaster lepidus* are killed by the nectar. Concentrations in the nectar were 2-3 times the LC50 for the parasitoids (Paine et al. 2011).

Citrus leaves treated with systemic applications of imidacloprid and thiamethoxam are toxic to predators and parasitoids. Contact with treated leaves kills parasitoids such as *Aphytis melinus* and *Encarsia formosa* within four days, predators such as the minute pirate bug, *Orius insidiosus* and the bigeyed bug, *Geocoris punctipes* die within ten days (Prabhaker et al. 2011).



Pirate bug, *Orius insidiosus*

Systemic applications of imidacloprid in citrus kills parasitoids such as *Aphytis melinus* that are helpful for scale control (Grafton-Cardwell et al. 2008).

Seed Treatments

Though soil treatments are more deadly, seed treatments can have an effect on beneficial insects. As discussed earlier, concentration of imidacloprid in pollen from seed treatments in crops such as corn and sunflowers, can range from 2 to 20 ppb. Amounts in leaves and flowers can be higher. Some beneficials need to supplement their diet by feeding on plants, and this can be deadly (Quarles 2011).

Seagraves and Lundgren (2012) found that soybean seed treatments of neonicotinoids had little effect on pests such as soybean aphids, but significantly reduced numbers of generalist predators such as nabid bugs and lacewings. Soybean yields were not improved, and thiamethoxam reduced the beneficial predator population by 25%.

Seed treatments can kill ladybugs that supplement their diets by feeding on the developing plants. About 72% of *Harmonia axyridis* larvae on treated corn plants developed neurotoxic symptoms, and most of them died. Plants grown from clothianidin treated corn seeds killed 80% of the exposed larvae; thiamethoxam plants killed 53% (Moser and Obrycki 2009).

There was 100% mortality in 17 of 18 species of beneficial carabid ground beetles exposed to corn seedlings sprouted from neonicotinoid seeds. Ground beetles such as *Harpalus pensylvanicus* are predators of the corn rootworm and many other destructive pests (Mullin et al. 2005).

Other Effects

Spider mites, *Tetranychus urticae*, are not susceptible to neonicotinoids. Neonicotinoids may reduce natural inducible plant defenses against arthropods, leading to mite infestations in several unrelated plant species (Szczepaniec et al. 2013).

Bobolink, *Dolichonyx oryzivorus*, is in decline.

Effects on Birds

Grassland birds are in decline, and about 25% of species protected by the Migratory Bird Treaty Act are in trouble. At least 72 million birds are directly killed by pesticides in the U.S. each year, and sublethal effects are probable in 10 times that many. So pesticides may be affecting nearly a billion birds a year (USFWS 2002; Mineau and Palmer 2013).

Organophosphate and carbamate insecticides often had disastrous and dramatic effects on birds. In 1992, when these were in widespread use, lethal toxicity from insecticides was the best predictor of grassland bird decline (Mineau and Whiteside 2013).

Neonicotinoids have not resulted in mass bird killings. But neonicotinoids may be steadily killing smaller numbers below reportable limits. Kills of less than 200 of a flocking species, 50 songbirds, or 5 raptors do not have to be reported to the EPA. The major risk is seed treatments; one imidacloprid treated corn seed, 3-4 cereal seeds, or 4-5 canola seeds can be lethal to the average bird. About 1/10 of a lethal dose can cause chronic and reproductive effects (Mineau and Palmer 2013).

Seeds are buried by seed drills, but spills occur, and some bird species dig up seeds and plants. Goulson (2013) estimates that accessible seeds provide enough pesticide to kill about 20 birds/acre (50/ha). If only 2% of that number are killed, at least 59 million birds could be killed by neonicotinoids each year.

The toxicity of neonicotinoids to birds is underestimated by the EPA due to neonic species selectivity. There can be a 10-fold difference in toxicity, according to species. The northern bobwhite, *Colinus virginianus*, is not very sensitive to neonicotinoids, and that is the species the EPA uses for regulatory decisions (Mineau and Palmer 2013).

Effects on Water Creatures

Neonicotinoids are water soluble and have often been found in surface water and groundwater. Starner and Goh (2012) found imidacloprid in 89% of water samples taken from California rivers, creeks and agricultural drains. Concentrations exceeded EPA guidelines in 19% of the cases. Neonicotinoid selectivity may be causing underestimation of their effects on aquatic creatures. Imidacloprid is 3,800 times more toxic to *Hyalella azteca* than to the water flea, *Daphnia magna*, used as a test organism by the EPA (Goulson 2013; Mineau and Palmer 2013).

Conclusion

Neonicotinoids are poisoning bees, birds and beneficial insects and polluting water. Though other insecticides can also have detrimental effects, neonicotinoid problems are amplified by the vast amount of acreage treated. There has been a partial ban in Europe, and the EPA is currently reevaluating neonicotinoids in the U.S. A temporary ban on some uses could give bees, birds, and beneficials time to recover while the EPA makes a final determination. Growers would also benefit through mitigation of pest resistance, and reduced costs. Where neonicotinoid use is suspended, IPM methods can protect crops.

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Protecting Bees, Birds, and Beneficials from Neonicotinoids

By William Quarles

Neonicotinoids are used on turfgrass and pets, in home gardens, nurseries, orchards, in structural pest control, and in commercial agriculture. Veterinary uses are no threat to wildlife, and structural pest control applications do not usually threaten bees, birds, and beneficials, as most treatments are applied inside. However, perimeter sprays applied outside for ant control can pollute water, and if applied carelessly to areas of flowering clover, can kill bees. You can ask your structural pest control company not to use perimeter sprays. You can also take care of ant problems yourself by combining sanitation, exclusion, and ant baits (Quarles 2007; Larson et al. 2013).

We can protect bees, birds, and beneficials by avoiding pesticides, including neonicotinoids, in a home and garden situation. We can emphasize cultural practices that reduce or eliminate pests, and when pests appear, apply biopesticides or least-toxic materials (Olkowski et al. 2013; Quarles 2013).

We can make sure that plants we buy from horticultural nurseries have not been treated with neonicotinoids. Because these pesticides are systemic, they could introduce contaminated pollen and nectar into your backyard (Hopwood et al. 2012).

Much of the neonicotinoid use in the U.S. is on field crops and in commercial agriculture (Jeschke et al. 2011). We can help reduce agricultural use of neonicotinoids by buying organic food.

To help with bee, bird, and beneficial survival, we can make intelligent plant choices. If we plant natives when possible, choose species that provide pollen and nectar for bees and beneficials, and plant trees that provide shelter for birds, we can turn our backyard into a wildlife paradise. Our local action can have a global effect (Quarles 2008b).

Photo courtesy of Gary McDonald

Yellow-faced bumble bee, *Bombus vosnesenskii*

From Nixon 1954

Bumble bees, *Bombus* sp., can be encouraged by planting floral resources.

Home and Garden

Neonicotinoids are sprayed on lawns to kill beetle grubs and other pests. Applications of this type will kill bumble bees and soil nesting native bees, and can have an impact on earthworms (Larson et al. 2013). The best way to avoid spraying neonics on a lawn is to replace it with native plants or alternative landscaping. This approach is outlined in the BIRC publication, *Rethinking the American Lawn* (Quarles 2009).

One alternative is mowed pathways in native meadowgrasses and wildflowers. America is blessed with a number of strikingly beautiful wildflowers such as California poppy, *Eschscholtzia* sp.; black-eyed susan, *Rudbeckia* spp., purple blazing stars, *Liatris* spp., and others. Seed mixtures are available to suit the needs of your climate (Daniels 1999). Mowed, gravel, or flagstone pathways can be integrated with strategically placed raised beds containing vegetables and herbs. Sheet mulching can be used to convert part of your lawn to planting beds (Quarles 2008a).

If you need to keep your lawn, there are cultural methods and least toxic pesticides to deal with most lawn pests. Common pests are grubs, billbugs, chinch bugs, cutworms, mole crickets, and sod webworm. Cultural controls such as proper fertilization and watering; physical controls, such as traps; and biological controls such as nematodes, *Bacillus thuringiensis* (BT), and beneficial fungi, can be integrated with least-toxic chemical controls such as neem, insecticidal soap, natural pyrethrins, and spinosad (Quarles 2006).

Ornamentals

Neonicotinoids are applied as soil drenches and foliar sprays to protect ornamental shrubs and trees. Foliar sprays can be especially destructive, an example is the

Mason bee, *Osmia* sp.

Photo courtesy of Gary McDonald

50,000 bumble bees killed by dinotefuran sprays on Oregon linden trees in 2013 (Black and Vaughn 2013).

Neonics are applied in these situations especially for sucking insects such as aphids, thrips, and whiteflies (Elbert et al. 2008). As an alternative, insecticidal soap and biopesticides can be combined with biological controls. Strong streams of water can help dislodge some of these pests (Quarles 2004ab; Olkowski et al. 2013). Predaceous mites are commercially available for thrips, predatory midges eat aphids, parasitoids and predators are available for whiteflies. Sources of commercial biocontrols can be found in the BIRC publication *IPM Practitioner's Directory of Least Toxic Pest Control Products* (BIRC 2013).

Systemic neonics also provide some protection for chewing insects such as caterpillars. BT treatments or spinosad can control these problems. Trees under attack by destructive insects such as the emerald ash borer, *Agrilus planipennis*, are injected with neonics for systemic protection. The biopesticide neem is also effective and has fewer destructive effects on bees (Elbert et al. 2008; Hahn et al. 2013; Quarles 2002; Quarles 2005ab; Swiadon and Quarles 2004).

Vegetable Garden

Neonics are used as foliage sprays and soil drenches to protect fruit trees. Foliage sprays of neonics are

Tidytips, *Layia platyglossa*

Photo courtesy Gary Monroe

often used on vegetables such as broccoli (Jeschke et al. 2011). Neonics and other destructive pesticides can be avoided if you raise your fruit and vegetables organically (Bradley 1995; Ellis and Bradley 1992).

Cultural techniques such as companion planting, incorporation of compost into soil, can be combined with physical controls such as traps and row covers, and least-toxic pesticides such as soap and neem. In emergency situations of aphids and caterpillars, applications of *Bacillus thuringiensis* (BT), spinosad or natural pyrethrins can help keep pest populations in check (Bradley 1995; Ellis and Bradley 1992; Olkowski et al. 2013).

Provide Habitat

We can protect bees, birds, and beneficial insects from neonicotinoids by providing food, water, and nesting sites in our backyards and in crop production areas. Pollinator protection could easily be added to a number of existing wildlife conservation programs. The

California poppy, *Eschscholzia californica*

Photo courtesy Br. Alfred Brousseau

Humane Society and the Audobon Society both have Urban Wildlife Sanctuary Programs. There is also Bay Friendly Landscaping in the San Francisco Bay Area, the Backyard Wildlife Sanctuary Program in Washington State and others (see Resources). By making our backyards sanctuaries, we can improve the quality of life for pollinators, urban wildlife and ourselves (NAS 2007).

What to Plant

We can avoid pest problems by choosing the right plant for the right place and emphasizing native plants. Over a long period of time, native plants have adapted to the local pests and diseases. When exotic invaders show up, we can use organic and IPM methods, biopesticides and other environmentally friendly approaches (Quarles 2004ab; Olkowski et al. 2013).

To increase bee populations, we can increase floral resources. According to Cane et al. (2008), "in our cities and towns where most of the native plant communities have been displaced by pavement, buildings and lawns, our flower gardens can become important cafeterias of native bees." Since bees are major pollinators, we should give them what they need. Generally, bees need floral sources of nectar and pollen, nesting sites, water, and a pesticide free environment (Black 2008). Bees like flowers, sunlight, warm temperatures, and open spaces. Most species prefer to forage when soil and air temperatures are greater than 55°F (12.8°C). Some limit activity to one, or a few species of flowers, while others such as the honey bee have a wide range of hosts (Linsley 1958).

Plantings for bee gardens include attractive plants such as scorpion weed, *Phacelia* spp.; sunflower, yarrow, mints, borage, bachelor's button, blackeyed susan and others (Quarles 2008b). Bee plants can also provide nectar for adult Monarch butterflies, *Danaus plexippus,* that are endangered due to herbicides and destroyed habitat (Quarles 2011a).

Forage Constantly Available

Social bees such as honey bees have perennial colonies. When foraging plants are not available, they feed on stored honey and pollen in the hive. Native bees are driven by the seasons. Solitary bee queens overwinter, then establish a nest in the spring. Because they do not have extensive food stores, forage must be constantly available. Floral resources must have overlapping flowering periods, so that something is constantly in bloom (Wojcik et al. 2008). Wildflower seed mixes are commercially available that can provide forage in open areas (see Resources). Perennials and annuals in planting beds should be chosen with flowering periods in mind. When restoring habitat, native plants are preferable because native bees generally prefer native plants (NAS 2007; Frankie et al. 2002; Black 2008).

High Density Planting

With flower plantings, high density is best for bees. Frankie et al. (2002) found attraction was increased when large numbers of flowering plants were growing in close proximity. Flowering areas need to be about 1 meter (3.2 ft) in diameter to draw in diverse species of bees. Bees most often seen were the honey bee, *Apis mellifera*; bumble bees, *Bombus* spp., and leafcutter or mason bees (*Megachile* spp. and *Osmia* spp.).

Native Bees, Native Plants

Native bees tend to visit native plants (Schmidt 1980; Frankie et al. 2002; Schindler et al. 2003). This may be because exotics generally produce less pollen and nectar than natives. Or perhaps, coevolution of the native bees and plants caused the preference. Bees attracted vary with the flower species. Bumble bees and sweat bees (Halictidae) often frequent California poppy, *Eschscholzia californica.* Blackberries attract "a wide variety of leafcutter bees, bumble bees, and honey bees." Dusty Miller, *Centaurea cineraria*, attracts megachilids. Cosmos attracts "large anthophorid bees of the family Apidae" (Frankie et al. 2002). The USDA, and a number of private organizations have produced lists of flowering plants that function as attractive bee gardens (see Resources). A list of plants attractive to native bees can be found in Tables 1 and 2.

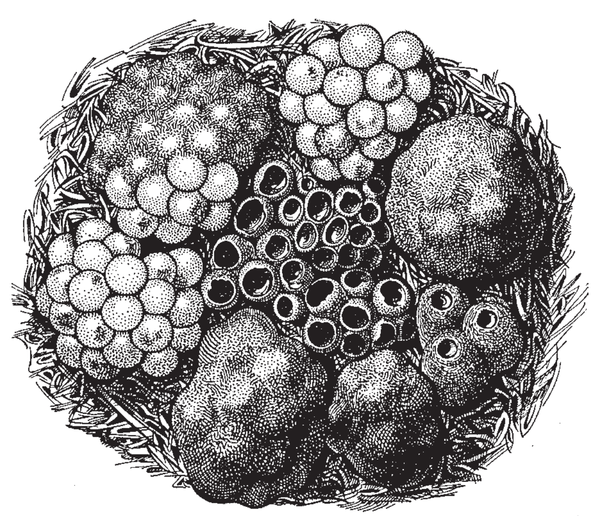
Provide Nesting Sites

Most North American native bees nest in the ground. Sweat bees (Halictidae) and the Adrenidae family dig holes in the ground; bumble bees, *Bombus* spp., like to nest in abandoned rodent burrows. Sunny open horizontal areas of well drained soil are preferred, but some species nest vertically in banks of soil. Any sunny area in your backyard can be converted to a nesting site by removing vegetation and mulch (NAS 2007; AAPA 1999).

About 10% of native bees, such as carpenter bees, *Xylocopa* spp., mason bees, *Osmia* spp., and some leafcutters, *Megachile* spp. nest in wood. Just having wooden fences can provide sites for twig nesting bees. You can make nests also by drilling 3/16 to 5/16 inch (5 to 8 mm) diameter holes about 4 to 6 inches (10 to 15 cm) deep in a 4x4 inch (10 by 10 cm) or 4x6 inch (10 by 15 cm) block of wood. Holes should be 1/4 inch (6 mm) apart. Nest blocks should be attached to posts and trees three to six feet off the ground in areas shaded from afternoon sun. Or you can just fill a coffee can, milk carton, or PVC pipe other container with drinking straws 1/4 to 3/8 inches (6 to 9.5 mm) diameter. Entrance holes should be placed horizontal, and the nests should be protected from rain (NAS 2007; AAPA 1999; Greer 1999).

Avoid Pesticides

We should avoid not only neonicotinoids, but other pesticides. Pollinators such as bees, and other beneficial insects such as ladybugs, lacewings, and parasitic wasps are easily killed by insecticides. For a number of reasons, beneficials are more vulnerable to insecticides than are insect and mite pests (Croft 1990). Herbicides



From Nixon 1954

Bumble bee nest. Spheres are cocoons containing bee larvae. Open cocoons in the center are used for storing honey.

can destroy flowering plants that otherwise feed pollinators. Chemical fungicides are often synergistic with insecticides, and combinations are especially lethal to bees. Cultural methods and microbial fungicides are less damaging alternatives (Quarles 2008ab; 2004ab; 2005ab; 2013).

When possible, chemical pesticides should be avoided altogether by growing organic gardens, lawns, and landscapes, and switching to organic farm production. (Note: There are many articles about alternatives to pesticides listed on the BIRC website at www.birc.org). Insecticides should not be applied while a crop is in bloom or while bees are foraging. Some application times are better than others. Night applications are best, as bees are not foraging.

However, favorable application times depend on the species. Early morning applications that spare honey bees will kill bumble bees out for a morning snack. Bumble bees and other ground nesters are also more at risk from pesticides such as imidacloprid and clothianidin applied to lawns and turf for grub control (NAS 2007; Schacker 2008).

Many microbial pesticides can be used safely with bees. Microbial pesticides have such low toxicity, that honey bees have been used to apply *Bacillus subtilis* and *Beauveria bassiana* in organic cropping situations. Targeted insecticides such as *Bacillus thuringiensis* (BT), *Chromobacterium* sp., and least toxic insecticides such as soaps, oils, or quickly degraded botanicals minimize damage to pollinators. Though BT might have an impact on the larval form of butterflies, it is usually applied to plants that butterflies do not utilize (NAS 2007; Quarles 2004ab; Quarles 2006; Quarles 2013).

Plants for Birds

Birds need trees and shrubs for shelter. Plants that provide seeds, berries, or fruit are also attractive. Sunflower, *Helianthus* sp.; *Cosmos* sp., purple coneflower, *Echinachea* sp., manzanita, *Arctostaphlos* sp., crabapple, *Malus* sp., elderberry, *Sambucus* sp., cotoneaster, and blackberry are attractive to birds. Extensive lists can be found on the internet and helpful advice can be found at your local horticultural nursery (Roth 1998; Adams 1998).

Insectary Plants for Beneficials

Protecting pollinators has many rewards. Many of the same plants that feed pollinators such as bees, birds and butterflies will also provide refuge for biocontrol agents such as ladybugs and lacewings. You can have both better pollination and fewer pests feeding on your garden. Insectary plants used to conserve beneficial insects include native annual wildflowers such as California poppy, *Eschscholzia californica*; buckwheat, *Eriogonum*; and tansy leaf, *Phacelia tanacetifolia*. Other possibilities include umbelliferous herbs such as coriander, chervil, and fennel, garden flowers such as sweet alyssum, *Lobularia maritima*; yarrow, *Achillea millefolium*; baby blue eyes, *Nemophila* and tidy tips, *Layia platyglossa* (Quarles and Grossman 2002). Sweet alyssum and phacelia have so much pollen, they are planted in organic lettuce fields to attract syrphid flies for aphid control (Chaney 2007).

Perennials such as California lilac, *Ceanothus* spp.; yarrow, *Achillea millefolium*; coyote bush, *Baccharis pilularis*; and perennial grasses are also good food sources. These plantings have something in bloom all year, so native bees and beneficials have a constant food supply (Long et al. 1998).

Roadside Restoration and Vacant Lots

Seed mixes containing native plants such as black-eyed Susan, *Rudbeckia hirta*; butterfly weed, *Asclepias tuberosa*; bergamot, *Monarda* sp., and similar plants compete with weeds along roadsides, reducing herbicide applications (see Resources). Wildflowers used in these mixes also increase biocontrol and provide forage for migrating butterflies (Quarles 2003). For instance, roadside native plantings in Iowa showed a 5-fold increase in butterfly abundance. Native plants also crowded out weeds and reduced the number of corn borers, *Ostrinia nubilialis* in nearby cornfields (Quarles 2003; Harper-Lore and Wilson 2000; Ries et al. 2001).

Populations of Monarchs, *Danaus plexippus*, have seen massive losses, partly due to pesticides.

Photo courtesy Glenda Denniston, UW Madison, Lakeshore Nat. Preserve

Roadsides restored with native plants in Iowa had greater numbers of native bees and greater bee diversity. Nearby traffic did not bother the bees. Most important were the floral resources and availabilty of ground nesting sites. There are millions of acres along roadsides that could be used to support native bees. The vegetation planted could also improve roadside weed management (Harper-Lore and Wilson 2000; Hopwood 2008).

Plantings of milkweed, *Asclepias* spp., should be included in roadside restoration. The milkweed habitat for the Monarch butterfly, *Danaus plexippus*, has been destroyed by overuse of herbicides (Quarles 2011a).

Vacant lots should also be seeded with wildflower mixes and milkweed. If owners are contacted, they should be happy to help reduce blight in urban areas.

Table 1. Flowering Plants Attractive to Native Bees*

Common Name	Genus	Family
Bachelor's button	*Centaurea cyanus*	Asteraceae
Blackeyed susan	*Rudbeckia hirta*	Asteraceae
Bluebells, scorpion weed	*Phacelia* spp.	Hydrophyllacea
Blueberry, cranberry, huckleberry	*Vaccinium* spp.	Ericaeceae
Borage	*Borago officianalis*	Boraginaceae
Bush clover	*Lespedeza* sp.	Fabaceae
Catmint	*Nepeta cataria*	Lamiaceae
False heather	*Cuphea hyssopifolia*	Lythrraceae
False indigo	*Baptisia fruticosa*	Fabaceae
Goldenrod	*Solidago* spp	Asteraceae
Mexican sunflower	*Tithonia rotundifolia*	Asteraceae
Mints	*Mentha* spp., *Salvia* spp.	Lamiaceae
Purple coneflower	*Echinacea purpurea*	Asteraceae
Redbud	*Cercis* spp.	Fabaceae
Sedum, stonecrop	*Sedum* spp.	Crassulaceae
Squash, gourd, pumpkin	*Cucurbita* spp.	Cucurbitaceae
Sunflower	*Helianthus* spp.	Asteraceae
Tansy or Fever Few	*Tanacetum* spp.	Apiaceae
Yarrow	*Achillea millefolium*	Asteraceae

*From Cane et al. 2008 and Greer 1999.

Flowering buckwheat, *Eriogonum* sp.

Table 2. California Native Plants that Attract Bees*

Common Name	Scientific Name	Color	Notes
Bird's eye	*Gilia tricolor*	Purple, yellow	Blue pollen
Buckwheat	*Erigonium fasciculatum*	White, pink	Also attracts butterflies and other beneficials
California gilia	*Gilia achillefolia*	Blue	Plant in dense clumps
California poppy	*Eschscholzia californica*	Yellow, orange	Plant in large patches
Chinese houses	*Collinsia heterophylla*	Purple	Large patches
Coyote mint	*Monardella villosa*	Purple, white	Limit summer water
Elegant clarkia	*Clarkia unguiculata*	Purple, pink	Plant in dense clumps
Elegant madia	*Madia elegans*	Yellow	Flowers open morning and afternoon
Globe gilia	*Gilia capitata*	Blue, purple	
Gumplant	*Grindelia*	Yellow	Attractive megachilids
Hedgenettle	*Stachys ajugoides*	Pink	Spring plant
Lindley Blazing Star	*Mentzelia lindleyi*	Yellow, orange	Needs little water
Phacelia grandiflora	*Phacelia grandiflora*	Blue	Lots of pollen
Sunflower	*Helianthus gracilientus*	Yellow	Large bees
Tansy phacelia	*Phacelia tanacetifolia*	Purple, blue	Attracts diversity

*From Frankie et al. 2008


Wild sunflower, *Helianthus* sp.

Photo courtesy of Tony Morosco

Commercial Orchards

Neonicotinoids are applied as foliage sprays and soil drenches in orchards. As an alternative, biopesticides, pheromone mating disruption, and insect growth regulators can be used. Cultural methods, such as the use of cover crops, can be employed (Flint and Roberts 1988; Quarles 2013).

Field Crops

Neonicotinoid seed treatments are used on most of U.S. row crops such as corn, soybeans, canola, and sunflowers (Jeschke et al. 2011). Seed treatments are the latest manifestion of the pesticide treadmill resulting from agribusiness farming—vast fields of unsustainable monocultures supported by genetically modified plants, synthetic fertilizers, pesticidal seed treatments, and massive use of glyphosate and other herbicides. IPM methods have been abandoned, not because they are ineffective or less profitable, but because agribusiness has convinced farmers that this approach is simpler and less labor intensive (Kremen et al. 2002; Gray 2011, Pimentel et al. 2005; Liebman et al. 2008, Quarles 2011a).

Fungicidal seed treatments are needed because aerial sprays of glyphosate on GMO crops are encouraging plant disease. If a farmer is already using fungicidal seed treatments, adding insecticides to the mix adds to cost, but not to labor. Often, neonicotinoids are not needed, and may not increase yields (Johal and Huber 2008, Seagraves and Lundgren 2012).

Break Up Monocultures

Large monocultures cause many of the problems associated with conventional agriculture. Extensive unbroken acreage of the same crop, such as corn or cotton, encourages arthropod pests (insects and mites) that specialize in these crops (Root 1973; Elton 1958; Andow 1991). Because pest populations expand more rapidly than beneficial populations in these situations, broad-spectrum pesticides are applied. These pesticides then cause problems such as target pest resistance, pest resurgence, and secondary pest outbreaks that are all too familiar (DeBach and Rosen 1991).

Monocultures can be replaced by intercropping, hedgerow plantings, and plant diversity. Diversity can be introduced into a field by stands of flowering insectary plants (Bugg et al. 1998; van Emden 1962; van Emden 1965), encouraging flowering weeds at field boundaries (Nentwig 1998; Bugg et al. 1987) planting cover crops (Bugg et al. 1996), or simply rotating crops in smaller fields so that each field is always adjacent to a different and complementary crop (Altieri 2004).

Say it with Flowers

As we saw above, home gardens can benefit from planting of floral resources that feed bees and beneficial insects. Bees and beneficials can also be nurtured and encouraged through field plantings of flowers containing abundant pollen and nectar (Bugg et al. 1998). Yellow flowers and plants such as tansy leaf, *Phacelia tanacetifolia*, are particularly attractive to syrphids (van Emden 1965; White et al. 1995).

Native annual wildflowers, buckwheat, *Eriogonum* sp.; toadflax, *Linaria* sp.; umbelliferous herbs such as coriander and chervil, and garden flowers such as sweet alyssum, *Lobularia maritima;* baby-blue-eyes, *Nemophila* sp.; and tidy-tips, *Layia platyglossa* all attracted numerous beneficial braconid wasps, lady beetles, pirate bugs, spiders and other natural enemies (Quarles and Grossman 2002).

White sweet alyssum has been used to protect against aphids in California lettuce fields. parasitic wasps are attracted by plentiful, small flowers which provide easy feeding for the tiny beneficials (Chaney 1998; Altieri 2004).

Hedgerow Plantings

Hedgerows can provide shelter from the wind, barriers to pest invasion, and food and shelter for beneficial insects, birds, and bees. As well as annuals, perennial species can provide food sources and habitat for bees,


White rows of flowering alyssum, *Lobularia maritima*, feed beneficial insects that provide biocontrol.

Photo courtesy of William Chaney

Resources

Flowering Plant Lists and Seeds

Cornflower Farms, www.cornflowerfarm.com
Native American Seeds, www.seedsource.com
Plants Attractive to Native Bees, USDA, http://www.ars.usda.gov/research/docs.htm?docid=12052
Selecting Plants for Pollinators, Pollinator Partnership, http://www.pollinator.org
Urban Bee Gardens, University of California, Berkeley, http://nature.berkeley.edu/urbanbeegardens/
Wildflower Farm, www.wildflowerfarm.com
Xerces Society Seeds, www.xercessociety.org/pollinator-seed

Organizations

American Bird Conservancy, www.abcbirds.org
Audubon Society, www.audobon.org
American Association of Professional Apiculturists, www.masterbeekeeper.org
Backyard Wildlife Sanctuary Program, http://wdfu.wa.gov/living/backyard
Bay Friendly Gardening, www.bayfriendlycoalition.org
California Native Plant Society, www.cnps.org
Golden Gate Audubon, www.goldengateaudobon.org
Humane Society, Backyard Sanctuary Program, www.hsus.org
National Wildlife Federation, www.nwf.org
North American Butterfly Association, www.naba.org
North American Pollinator Protection Campaign, www.nappc.org
Pollinator Partnership, www.pollinator.org
Xerces Society, www.xerces.org

Monitoring and Identifying Pollinators

Bee Identification, http://www.discoverlife.org/20/q?search=Apoidea
Monitoring bees, http://online.sfsu.edu/~beeplot/
Monitoring butterflies, www.monarchwatch.org
Monitoring birds, Audubon Society Christmas Bird Count, http://audubon2.org/birds/cbc/hr/graph.html; Breeding bird survey, http://www.mbr-pwrc.usgs.gov/bbs/bbs.html

Bees and Equipment

Sweep Nets, Bee Collection Materials—BioQuip Products, 2321 Gladwick Street, Rancho Dominguez, CA 90220; 310/667-8800, Fax 310/667-8808; www.bioquip.com
Beekeeping Equipment—Dadant & Sons, 51 S. 2nd St., Hamilton, IL 62341-1399; 888/922-1293, 217/847-3324, Fax 217/847-3660; www.dadant.com
Honey bees—Brushy Mountain Bee, 610 Bethany Church Rd., Moravian Falls, NC 28654; 800/233-7929; Draper's Super Bee Apiaries, RR#1, Box 97, Millerton, PA 16936; 800/233-4273; Glorybee, 120 N. Seneca Rd., Eugene, OR 97402; 800/456-7923
Bumble bees—Hydro-Gardens, Inc., PO Box 25845, Colorado Springs, CO 80936; 800/634-6362, 719/495-2266, Fax 719/495-2266; www.hydro-gardens.com
Mason bees—Knox Cellars, 25724 NE 10th St., Redmond, WA 98053; 425/898-8802; www.knoxcellars.com
Mason bees and leafcutters—International Pollination Systems, 16645 Plum Road, Caldwell, ID 83605; 800/990-1390; www.pollination.com.

birds, and beneficials. In California, hedgerows about 3 m (9.8 ft) wide along field margins have been planted with common yarrow, *Achillea millefolium*; coyote bush, *Baccharis pilularis*; elderberry, *Sambucus mexicana*; California lilac, *Ceanothus griseus*; perennial buckwheat, *Eriogonum giganteum*; toyon, *Heteromeles arbutifolia*, and coffee berry, *Rhamnus californica*. Perennial grasses included, purple needlegrass, *Nassella pulchra*, California melic, *Melica californica*; blue wildrye, *Elymus glaucus*; and creeping wildrye, *Leymus triticoides* (Long et al. 1998; Bugg et al. 1998).

Larger populations of beneficials are found in fields with hedgerows rather than weedy field margins. About 78% of insects found in hedgerows are beneficials. Beneficials also travel into crops to provide biological control (Pisani-Gareau et al. 2013; Morandin et al. 2011; Long et al. 1998; Bugg et al. 1998).

Close to Home

Since neonics are systemics, they appear in food. According to the USDA Pesticide Data Program, imidacloprid was detected in about 36% of lettuce samples tested, 26% of sweet bell peppers, and 20% of cherry tomatoes. Acetamiprid was found in 26%, and thiacloprid was found in 13% of baby food pears; thiamethoxam in 17% of hot peppers; dinotefuran in 12% of cantaloupes (USDA 2011).

By protecting bees, birds and beneficials from neonicotinoids and other pesticides and buying organic food, we will be protecting ourselves.

William Quarles, Ph.D., is an IPM Specialist, Executive Director of the Bio-Integral Resource Center (BIRC), and Managing Editor of the IPM Practitioner. He can be reached by email, birc@igc.org.

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