Neonicotinoid Pesticides and Honey Bees

WASHINGTON STATE UNIVERSITY EXTENSION FACT SHEET • FS122E

Introduction

Recently, concern has been raised regarding the impact of a common class of pesticide known as neonicotinoids (pronounced neo-nih-CAH-tin-oids) on honey bees, (*Apis mellifera*, Figure 1) and native bee pollinators. Many people feel the decline in honey bee populations known as Colony Collapse Disorder (CCD) is directly linked to the increased use of these products.

In this paper, we will discuss the use of neonicotinoids as well as declines in honey bee populations. Finally, we will review what is currently known about the relationship between neonicotinoid pesticides and honey bees.

Figure 1. Honey bee on apple blossom. Bees are an important component of Washington's seven-billion-dollar apple industry. Much of the food we eat is dependent on honey bees for pollination. Photo courtesy of Nik Wiman, Oregon State University.

What are Neonicotinoids?

Neonicotinoids are systemic insecticides that are taken up by a plant through either its roots or leaves and move through the plant just like water and nutrients do. These insecticides provide very effective control of piercing and sucking insects. Over the last few years, the neonicotinoid class of insecticides has become important for use in agriculture and home landscapes. There are currently more than 465 products containing neonicotinoids (often called "neonics") approved for use in the state of Washington. Approximately 150 are approved for use in the home or garden.

Neonicotinoids are relatively safe for use around people, animals, and the environment (Mohamed 2009; Tomizawa 2004). Because of their effectiveness and relative safety, neonicotinoids have become one of the fastest growing classes of pesticides used in agriculture as well as in home and garden products (Jeschke and Nauen, 2008).

One of the main advantages for using neonicotinoid products is that they move systemically within the plant, thus reducing the direct pesticide exposure to both the applicator and the environment. Ironically, it is this systemic action that makes the neonicotinoids a problem for honey bees and other pollinators: because a neonicotinoid pesticide spreads within the entire plant, it can also be found in the nectar and pollen of the flowers.

Bee Exposure

In laboratory experiments, researchers have documented several neonicotinoid products that are toxic to bees. Depending on the amount of exposure to neonicotinoids, the effect on bees can be either sub-lethal or lethal. The sub-lethal effects of neonicotinoids include impaired learning behavior, short- and long-term memory loss, reduced fecundity (fertility and reproduction), and altered foraging behavior and motor activity of the bees. Researchers have documented similar issues with other pesticides including some products used by beekeepers to control Varroa, a parasitic mite of the honey bee. Neonicotinoids have also been implicated, along with some fungicides, in either depressing bees' immune systems or increasing their susceptibility to biological infections (Wu et al., 2012; Pettis et al., 2013).

Exposure levels from dust created during planting of neonicotinoid-treated seed are known to have a devastating lethal impact on honey bees. However, this mode of exposure can be avoided and more work needs to be done on controlling levels of dust during planting. A more pressing concern is the chronic exposure of bees to neonicotinoids in nectar and pollen, as well as in water expressed from plants via a process known as guttation, that is picked up by foraging bees and brought back to the hive.

As is evident from the articles cited in Table 1, a great deal of research is currently under way, in both Europe and the United States, looking very intently at the effects of neonicotinoids on honey bees. Researchers at the University of Minnesota, Washington State University, and Washington Department of Agriculture are specifically looking at the issue of neonicotinoids in urban areas.

Declines in Honey Bee Populations

The sudden disappearance of honey bees from hives has been reported by beekeepers and researched by scientists for decades and called "Disappearing Disease" (Wilson and Menapace 1979). In 2006 the widespread appearance of this phenomenon in the United States was noted and referred to as Colony Collapse Disorder by researchers, beekeepers, and the media. This increase in colony losses also corresponded to increased use of neonicotinoid pesticides (Johnson et al. 2010; Cresswell et al. 2012). This has led to speculation that there is a causative relationship between the increased use of neonicotinoids and widespread decline in bee populations (Suryanarayanan 2013). However, it is important to look at all the variables associated with CCD.

Reports of dramatic declines in honey bee colonies have been widely reported in the United States and Europe (Mullin et al. 2010). FAO data reveal that, globally, there has been an approximate 45% increase in managed colonies (as opposed to wild or feral colonies) since 1960 (Aizen and Lawrence 2009). The definitive cause for the declines in the United States and Europe has yet to be fully understood. More than sixty-one variables have been associated with CCD, although none have been clearly identified as the definitive cause of the phenomenon (VanEngelsdorp, D., 2009). Some of the major factors associated with the decline in honey bee stocks in the United States include the Varroa mite, pesticides, pathogens, loss of habitat, and nutritional deficiencies. One additional stress placed on honey bees in some regions are the intense management strategies (that is, large congregations of bees are fed pollen substitute and sugar syrup) needed to ensure strong colonies for certain crop pollination requirements, such as almond pollination in California in late winter (mid-February through mid-March).

Researchers have ruled out individual stressors such as long distance hauling of bees on tractor-trailers (Ahn et al. 2012). However, recent studies have indicated additional concerns about the "feedlot" feeding widely practiced by commercial beekeepers. Beekeepers' reliance on high-fructose corn syrup and sucrose in these feedlot situations, where tens of thousands of bee hives are kept prior to their movement into fields and orchards, may significantly reduce the bees' ability to detoxify pesticides (Mao et al. 2013). Similarly, because the ingestion of protein may increase bee susceptibility to some pesticides, beekeepers' reliance on pollen substitutes may also make adult bees more susceptible to decline (Geraldine Wright, unpublished data).

Varroa Mite

The Varroa mite *(Varroa destructor*, Figure 2*)* plays a major role in overall losses of managed honey bee colonies in the United States—not only the actual direct impact of the mite, an ectoparasite (an external parasite) that affects adults, pupae, and larvae by feeding on hemolymph (the circulatory fluid of insects, comparable to blood), but also the chemical control measures used by beekeepers to control the mite. Both registered and unregistered chemical products are widely used by beekeepers to control the mite. Without treatment, Varroa-infested honey bee colonies in temperate climates typically die within two years.

Often the highest levels of pesticides found in beeswax and pollen from commercial honey bee colonies are of those products used by beekeepers to control this mite (Wu et al. 2011; Mullin et al. 2010). Regardless of the levels of pesticides found in the colonies, sub-lethal effects of many pesticides, including some mite control products and neonicotinoids, have been shown to cause memory impairment of honey bees at field-realistic levels. (Williamson and Wright 2013).

Figure 2. Varroa mite,* Varroa destructor*, on a honey bee. This parasitic mite is a major threat to the United States honey bee industry. This pest is directly and indirectly responsible for the loss of tens of thousands of honey bee colonies every year. Photo courtesy of the Electron and Confocal Microscopy Laboratory, Agricultural Research Service, U. S. Department of Agriculture (USDA/ARS).

European Concerns

The supposition of a direct link between the decline of honey bees and native bees and the increased use of neonicotinoids has yet to be conclusively substantiated. Use of neonicotinoid insecticides has not been proven as a primary or even secondary cause of bee population decline. However, based on current evidence, the European Union has opted to take a cautious approach and has suspended

Table 1. Partial list of selected journal articles and their effects on honey bees (neonicotinoids are highlighted in red).

Authors/Date	Pesticide(s)	Species	Setting	Application	Exposure Range	Effects Tested
Creswell et al. 2012	neonics	*A. mellifera*	n/a	oral	n/a	casual to decline
	Significance: Neonics not implicated in decline.					
	Comments: A review using epidemiology criteria.					
Elston et al. 2013	thiomethoxam, propiconazole	*B. terrestris*	lab	oral	thiomethoxam (1, 10ug/kg) propiconazole (23, 230 mg/kg)	colony initiation, food consumption
	Significance: thiomethoxam: @ 10ug/kg = no larvae; propiconazole: no population effect.					
	Comments: Both reduced food consumption.					
Henry et al. 2012	thiomethoxam	*A. mellifera*	field	oral	1.34 ng/bee	homing success (foraging)
	Significance: Differences in post exposure homing failure between treated and control.					
	Comments: Author's note: This field realistic rate doubles the probability of forager death on any given day.					
Krupke et al 2012	various neonics and fungicide; clothianadin, thiomethoxam, metochlor, azoxystrobin, tri.	*A. mellifera*	field/lab	n/a	0 to 52 ppb soil, 4 to 15,030 ppm in talc, 0-4 ppb in field pollen, 0-88 ppb returning forager pollen, etc.	n/a
	Significance: Showed possible routes of exposure from planting and plant expression; found at higher levels in dead and dying bees.					
	Comments: Indicated possible side effect of seed treatments.					
Laycock et al. 2012	imidacloprid	*B. terrestris*	lab, nestbox	oral	imidacloprid variable, 0 to 125 ug/L	ovary development, fecundity
	Significance: Dose-dependent decline in fecundity: 1 ug/L reduced fecundity by 1/3; no effect on ovary development except at highest dosage.					
	Comments: Fecundity reduction at "environmentally realistic" dosages.					
Matsumoto 2013	clothianadin, dinotefuran, etofenprox, fenitrothion	*A. mellifera*	lab/field	topical	variable (0.5 to 0.025 LD50)	behavioral/homing success
	Significance: clothiandin/dinotefuran at 0.1 LD50 and greater; etofenprox at 0.25 LD50, fenitrothion = n.s.					
	Comments: 2 neonics, 1 pyrethrin, 1 organophosphate (OP).					
Schneider et al. 2012	imidacloprid, clothianadin	*A. mellifera*	field	n/a	imidacloprid 0.15 to 6 ng/bee; clothianadin 0.05 to 2 ng/bee	foraging
	Significance: Not at "field relevant" doses. imidacloprid >0.5 ng/, clothianadin >1.5 ng/ reduced foraging and longer flight times.					
	Comments: Sub-lethal foraging effects.					
Tapparo et al. 2012	various neonics imidacloprid, clothianadin, thiomethoxam, fipronil	*A. mellifera*	field/lab	n/a	Varied: planter exhaust dust, caged bees, etc. foraging bees over field/planting showed mean clothianadin 78–1240 ng/bee; thiomethoxam 128–302 ng/bee	
	Significance: Similar to Krupke study—high exposure of bees possible during planting.					
	Comments: Used as seed treatments. Fipronil banned in France following evidence of bee kill during planting.					
Whitehorn et al. 2012	imidacloprid	*B. terrestris*	lab/field	oral pollen and sugar water	Pollen 6 ug/kg, 12 mg/kg (low and high); Sugar water 7 ug/kg, 14 ug/kg (low and high)	growth rate, queen production
	Significance: Difference in number of queens produced; control = 13.7, low 2.0 and high 1.4 queens.					
	Comments: Authors: Trace levels of neonics can have a string of negative consequences for queen production.					

Table 1 (continued). Partial list of selected journal articles and their effects on honey bees (neonicotinoids are highlighted in red).

<table>
<tr><th>Authors/Date</th><th>Pesticide(s)</th><th>Species</th><th>Setting</th><th>Application</th><th>Exposure Range</th><th>Effects Tested</th></tr>
<tr><td rowspan="3">Williamson et al. 2013</td><td>imidacloprid
coumaphos</td><td>A. mellifera</td><td>lab</td><td>oral</td><td>Sucrose 10 nmol l^{-1}, 100 nmol l^{-1} and 1 μμmol l^{-1}</td><td>short and long term memory</td></tr>
<tr><td colspan="6">Significance: Imidacloprid, coumaphos, and a combination of the two compounds impaired the bees’ ability to differentiate odor during the memory test.</td></tr>
<tr><td colspan="6">Comments: Exposure to sublethal doses significantly impairs foraging with subsequent pollinator population decline.</td></tr>
<tr><td rowspan="3">Cresswell et al. 2013</td><td>imidacloprid</td><td>A. mellifera
B. terrestris</td><td>lab</td><td>oral</td><td>125 g L-1 imidacloprid, 98 g kg-1</td><td>feeding a locomotion</td></tr>
<tr><td colspan="6">Significance: Imidacloprid did not affect the behavior of honey bees but did reduce feeding and locomotor activity in bumble bees.</td></tr>
<tr><td colspan="6">Comments: Authors attribute the differential behavioral resilience of the two species to the observed difference in bodily residues.</td></tr>
</table>

the use of neonicotinoids in 2013 for at least a two-year period, while they reassess its impact on bees.

The growing body of evidence (see References and Further Reading lists) does provide justification for taking a closer look at neonicotinoids and encouraging caution in their use. As of this writing, there are insufficient data to suggest that neonicotinoids are a substantial contributor to the decline of either native bees or honey bees. The value and benefit of neonicotinoids—when used as prescribed on the product label—to agriculture, professional landscapers, and homeowners, are that of a relatively safe and effective product, and this should be kept in mind when considering changes in availability or restrictions for this class of pesticides.

Summary

Neonicotinoids do have a negative effect on honey bees and other insect pollinators including important species of native bees such as bumble bees, mason bees, and others. However, it is unclear whether neonicotinoids have a significant lethal or sub-lethal effect on bees at realistic field levels. The real concern is the acute exposure of bees to neonicotinoids from exposure to airborne dust during planting. However, there is growing concern for chronic exposure through nectar, pollen, and water picked up by foraging bees and carried back to the hive. The best means of minimizing adverse effects may be by increasing people’s awareness of the potential issues through educational forums and via improvements in the instructions on the pesticide label.

Ongoing research is increasing our understanding of the impact of these types of pesticides on bees. For now, the best recommendation is to carefully follow the product label, be judicious in your application, and avoid applying any insecticide product when bees are actively foraging in or near the target area.

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