# *The Facts About Systemic Insecticides and Their Impact on the Environment and Bee Pollinators*

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Is imidacloprid safe to use for controlling insect pests feeding on urban trees? Are insecticides like imidacloprid responsible for Colony Collapse Disorder of honey bees? This article will try to provide some guidance and respond to these questions.

### Neonicotinoid Insecticides and Arboriculture

Imidacloprid is one of a growing class of insecticides (neonicotinoids) that have, since the announcement of their discovery in 1989, become mainstays in agricultural, pest control and landscape pest management. Two active ingredients of this class are commonly used in arboriculture: imidacloprid (CoreTect, Merit or Xytect) and dinotefuran (Safari and Transtect). One of the reasons this class of insecticides has become so important is its selective mode of action: neonicotinoids target the same acetylcholine receptor on the insect nerve cell as nicotine (the active ingredient of tobacco), but unlike nicotine, do not bind well to the nerve cells of humans. Therefore, it is toxic to insects and relatively nontoxic to humans and animals, including birds. Other favorable environmental characteristics are that neonicotinoids are readily eliminated from the body by vertebrates, that they break down quickly upon exposure to sunlight, and that they bind tightly to organic matter in soil. Another, and probably their most important practical feature, is that they are systemic (move throughout the plant). Systemic neonicotinoids can be applied to trees using three different application methods; these include soil applications, systemic basal bark sprays and trunk injections. Each of these methods has its pros and cons. However, soil and basal bark sprays are commonly used because they are non-invasive to the tree, quick to apply and operationally predictable.

When applied to the soil around the root system of a plant, the insecticide is absorbed by the roots and transported in sap, where the insecticide can then reach every part of the plant. This is useful both for targeting sap feeders (both xylem feeders like sharpshooters, and phloem feeders like aphids) and insects that feed in the interior trunk and leaf tissues of trees, such as newly hatched emerald ash borer larvae or various leaf miners. In contrast to broad spectrum foliar spray insecticides, systemic applications of neonicotinoids, either as soil applications or basal bark sprays, are contained within the plant. This allows targeted control of the pest insects rather than also killing beneficial insect or mite species. Trials with the neonicotinoid dinotefuran have shown that a systemic basal bark spray will provide control of armored scale pests on evergreen trees while not impacting beneficial scale-consuming predatory beetles and parasitic wasps.

Systemic insecticides have proven their usefulness in arboriculture. Trees that would otherwise be impossible to spray because of their great height, extremely dense foliage, or location near sensitive ecological or human activities can be protected with systemic insecticides. For example, hemlock woolly adelgid has been controlled in hemlocks as tall as 140 feet on trees in the Greater Smoky Mountain National Park. It would be extremely difficult to achieve this level of control with non-systemic products. Furthermore, imidacloprid was found at nearly uniform concentrations in branch samples from all levels of the crown in these large trees. Sadly, these trees were only treated once (in 2002), and recently died because the treatment was not continued. Research has shown that the effective dosages for imidacloprid are exponentially related to the diameter of the tree trunk. As trees increase in size they require higher insecticide dosage rates to fully protect the tree. This has been demonstrated in research trials using soil applied imidacloprid on hemlocks for control of hemlock woolly adelgid[1] and on ash trees for control of emerald ash borer.[2] Exploring the relationship between minimum effective dosage and the size of trees for various insect pests should be a fertile subject for further study. A deep understanding of the dose/tree size/pest relationships can lead to optimal use of these insecticides in the environment and therefore reduce the risk of non-target impacts.

Soil applications of imidacloprid can result in more than one year of control, and low dosages are effective on certain pests. Some target pests (aphids, true bugs and adelgids) are extremely sensitive and require very low dosages. I treated tulip poplars at my workplace in 1995 with imidacloprid, and they have not required subsequent treatment. The rule of thumb for these sensitive pests is to not retreat until the pest population is observed to be increasing again. Unfortunately, borers require a much higher dosage in tissues to be effective, and any borers living in a tree jeopardizes the long-term health of the tree. Therefore, protection from tough-to-control borers warrants annual insecticide applications and higher treatment dosages.

### *Non-target effects and Colony Collapse Disorder*

Probably the first non-target impact observed with imidacloprid was spider mite outbreaks in treated crops (a phenomenon repeatedly observed in trees, too). Three hypotheses may explain this phenomenon; each explanation has some supporting data. (1) The insecticide is not poisonous to the mite, but causes secondary poisoning of predators that feed on the mites, (2) the insecticide acts as a "fertility drug" to the mites, and (3) the plant is so much healthier, that the mites can develop much better. From my own research, I have observed a transient outbreak in spruce spider mites that affect foliage for one year, which is more than compensated by the improved growth of the trees when no longer weakened by adelgids. These effects may be more pronounced when excessive dosages of imidacloprid are used relative to the size of the tree. Ecological studies of forest hemlocks treated with imidacloprid demonstrate that it can affect many components of the insect fauna associated with these trees.[4] Such an outcome should not be surprising –after all, these systemic insecticides are used precisely because they are potent insecticides. Hemipteran predators (such as minute pirate bugs) are certainly eliminated with the use of systemic neonicotinoid insecticides. These and other predatory bugs commonly feed on the sap of their target prey's host plant, and so are subjected to direct poisoning.[5]

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The other insects for which there is great concern regarding the potential for poisoning are pollinators. While any insect feeding on pollen or nectar could be exposed to the systemic insecticide, Colony Collapse Disorder (CCD) has focused concern on risk to honey bees. Although the symptoms of bee poisoning with this class of insecticides eerily resembles CCD (foraging bees become disoriented and do not return to the colony), a review of the incidence of CCD around the world points to three or four other factors being more likely explanations. (1) CCD has not diminished in countries where neonicotinoid insecticide use was curtailed,[6] (2) CCD is not found in Australia, where neonicotinoid insecticides are used, but where Varroa mite (a parasite and vector of bee viruses) is also not found,[6] (3) 96% of colonies with CCD have been found to harbor a complex of viruses, for which Israeli Acute Paralysis Virus is most strongly implicated; and hive equipment from CCD colonies can be disinfected through irradiation, which implicates involvement of a pathogen.[7] For tree species such as *Fraxinus* (ash trees) or hemlocks, which are not pollinated by

Kioritz Low Volume Soil Injection System

bees or that are not visited by pollinators, systemic treatments can be expected to have no impact on pollinator species.

The evidence pointing to other factors as likely causes for CCD does not leave neonicotinoid insecticides off the hook for their potential to poison bees; below are things that practitioners should consider:

- Neonicotinoid insecticides used in arboriculture are highly toxic to bees. For example, imidacloprid and dinotefuran have acute LD50s for bees of 18 and 75 ng per bee, respectively.
- Exposure of insects to low neonicotinoid concentrations (well below their acute LD50) can cause maladaptive and ultimately lethal behaviors. [9, 10, 11]
- Imidacloprid is readily metabolized in trees to imidacloprid olefin[3], which is 10 - 16 times more toxic to insects than the parent compound.[12]
- Peak concentrations of imidacloprid are not reached in some tree species until about 18 months after a soil application,[3, 13] which means that trees treated every year could accumulate concentrations toxic to bees over several years.[13]
- Arboricultural use concentrates these insecticides compared with agricultural uses. For example, the maximum dosage for treating two 32-inch dbh trees with some imidacloprid products is equivalent to treating one acre of agricultural crops.
- Higher concentrations in plant tissues may increase risk to pollinators. The goal for treating trees should be to use the lowest effective dosage.

Soil application of systemic insecticides to forest trees should be made to the organic A horizon of the soil.

Little is known about the actual concentrations of these insecticides in nectar or pollen from treated landscape trees. At this point, arborists should mitigate these concerns by adjusting how they treat trees, how often trees are treated, and by choosing the most appropriate product. Risk of bee poisoning integrates components of intrinsic toxicity (just how much of the insecticide is required to cause adverse effects in bees), and their degree of exposure to that poison.

Arborists can avoid exposing pollinators by avoiding treating tree species that are highly attractive to pollinators (linden, tulip poplar, Korean Evodia and catalpa, for example) with systemic insecticides. If trees attractive to pollinators do require treating with a systemic insecticide, dinotefuran applied immediately after bloom may be safer to use than imidacloprid products. Whereas imidacloprid can be detected in hemlock foliage for about eight years after soil injection[3], preliminary data from various tree species suggest that dinotefuran breaks down over the course of one growing season. Therefore, if the pest actively feeds following bloom of a tree species, then a dinotefuran application can quickly target that pest, and then it should dissipate so that it is not present in pollen or nectar at biologically relevant concentrations the next time that plant blooms.

### *Risk of soil applied neonicotinoids leaching into groundwater*

Another concern with soil applied systemic insecticides is that they may pose a risk of leaching to groundwater or to nearby ponds and streams. This is really a non-issue when using these products in most urban landscape soils. Both imidacloprid and dinotefuran bind to organic matter in the soil and most urban landscape soils with mature trees have higher than 3% organic matter. Therefore, there will be little risk of leaching as long as (1) there is a fair degree of organic matter in the soil

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(2% or greater), (2) the insecticide is not placed below the organic horizon of soil (as might happen with a deep root feeder probe), and (3) the insecticide is not applied in such concentrated "spots" that the active ingredient will exceed the binding capacity of the soil. Therefore, I suggest that practitioners use very shallow subsurface (2-4 inches) application of systemic insecticides, dispersed near the trunk of the tree. For high dose applications, expanding the area of soil treated near the base of the trunk of the tree may be important to guarantee that the binding capacity of the organic matter is not exceeded. A novel application technique to consider for high volume treatments is to use a hose-end sprayer to disperse the active ingredient around the base of the tree, which should then be incorporated with an additional light watering to wash the residues from the soil surface. In all of my experiments, I was unable to cause imidacloprid to leach more than a few inches through an organic soil layer found under forest hemlocks, even with one inch per day of water flow through soil columns[1]. Dinotefuran has much lower organic matter binding than imidacloprid, and so it does pose a greater risk for leaching (though this risk may not be great). However, dinotefuran can be successfully applied as a basal bark spray. It is surprising how quickly this active ingredient is absorbed through the bark and is then transported to the foliage. My trials have demonstrated this approach to be equivalent to soil injection of the same quantity of product, and in conditions where the soil is dry, compacted or excessively wet, a trunk spray can be more effective than soil injection. While neonicotinoids should not be applied to trees growing directly in water or to areas where surface water is present there is little risk of these products leaching into groundwater when applied correctly to most soil types across the United States.

Imidacloprid and dinotefuran are very effective tools for managing many insect pests of landscape and forest trees. Choosing the right product for the job and applying the product carefully can protect both the trees that your customers value and the environment.

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*(Editor's Note: Dr. Richard Cowles has been a scientist at the Connecticut Agricultural Experiment Station for 15 years, where he works on turf, nursery, forestry and small fruit pest management. He has worked with systemic insecticides to manage tree pests for 19 years, mostly funded by the USDA Forest Service.)*

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