E-268

The Effectiveness of Neonicotinoid Seed Treatments in Soybean

Neonicotinoid insecticides are highly water soluble, and plants can absorb them and move them through their "circulatory system" from the root zone up into leaves and other tissues. This quality has made neonicotinoids a popular insecticidal seed treatment of many crops (Figure 1). In 2011, more than 80 percent of corn, more than 50 percent of cotton, and about 40 percent of soybean acres were planted with neonicotinoid-treated seed, a total area described as "roughly the size of California." (Douglas and Tooker 2015). Neonicotinoid seed treatments of soybean rank only behind corn in total acreage.

This publication reviews the current research regarding the efficacy of these neonicotinoid seed treatments, their non-target effects, and the potential role for neonicotinoid seed treatments in soybean production.

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Figure 1. Neonicotinoid-treated soybean seed before soil covering.

Do Neonicotinoid Seed Treatments Work in Soybean?

Neonicotinoid seed treatments offer soybean plants a narrow window of protection — a maximum of three weeks after planting (McCornack and Ragsdale 2006). **As such, they can be useful for managing early-season pests in targeted, high-risk situations.**

Examples of such high-risk situations include:

- *Fields transitioning to soybean production from pasture, Conservation Reserve Program (CRP) land, or grassland to soybean production*. Such fields tend to have higher populations of long-lived soil pests, such as wireworms or white grubs, which cannot be controlled with foliar insecticides.

- *Fields with recently incorporated animal manure, green cover crops, or weeds*. These fields tend to be more attractive to seedcorn maggot, because females lay eggs in rotting organic material.
- *Second (double) crop or specialty (food-grade or seed) soybean.* During soybean aphid outbreaks, aphids may migrate from mature soybean plants to colonize later-planted plants in a double-crop situation. In food-grade or seed soybean, early-season insect pests can vector diseases that affect crop quality. For example, bean leaf beetle transmits bean pod mottle virus.

These high-risk scenarios are uncommon in northern states. Seed and seedling pests such as wireworms, white grubs, and seedcorn maggots rarely reach economically damaging levels in the vast majority of soybean fields (Figure 2). Adult bean leaf beetles are frequently encountered in newly emerged soybean, but they rarely cause more than cosmetic injury to plants (Figure 3). It is critical to remember that soybean plants are resilient and can tolerate considerable early-season damage without suffering economic loss.

Figure 2. Wireworm feeding seldom reaches economically damaging levels.

Recent field studies support this point: yield benefits attributed to neonicotinoid seed treatments are inconsistent or absent (Seagraves and Lundgren 2012; Gaspar et al. 2014, 2015).

The U.S. EPA extensively reviewed published and unpublished data regarding the yield benefits and concluded that "neonicotinoid seed treatments likely provide $0 in benefits to growers" (USEPA 2014).

Figure 3. Early-season bean leaf beetle feeding on untreated soybean seedlings (left) and on neonicotinoid seed-treated seedlings (right). This minor feeding does not reduce yield.

Seed Treatments Not Timed for Major Pests

Soybean aphid is the most important insect pest of soybean in northern states, and it is listed on labels for neonicotinoid seed treatments. Recall that neonicotinoid seed treatments protect soybean seedlings for a short time window after planting (approximately three weeks).

However, soybean aphid populations usually increase in midsummer during the late-vegetative and bloom stages of soybean (Hodgson et al. 2005, Ragsdale et al. 2007). In other words, populations increase to threshold levels weeks *after* the short window that neonicotinoid seed treatments protect plants (Figure 4).

A suite of predators and parasitoids (Figure 5) frequently suppress early-season aphid infestations before they reach threshold levels (Rutledge et al. 2004, Yoo and O'Neil 2008). Research has repeatedly demonstrated that following the well-established and widely implemented treatment threshold of 250 or more aphids per plant to time foliar insecticide applications remains the most effective and economical approach for soybean aphid management (Ragsdale et al. 2007, Johnson et al. 2009, Song and Swinton 2009).

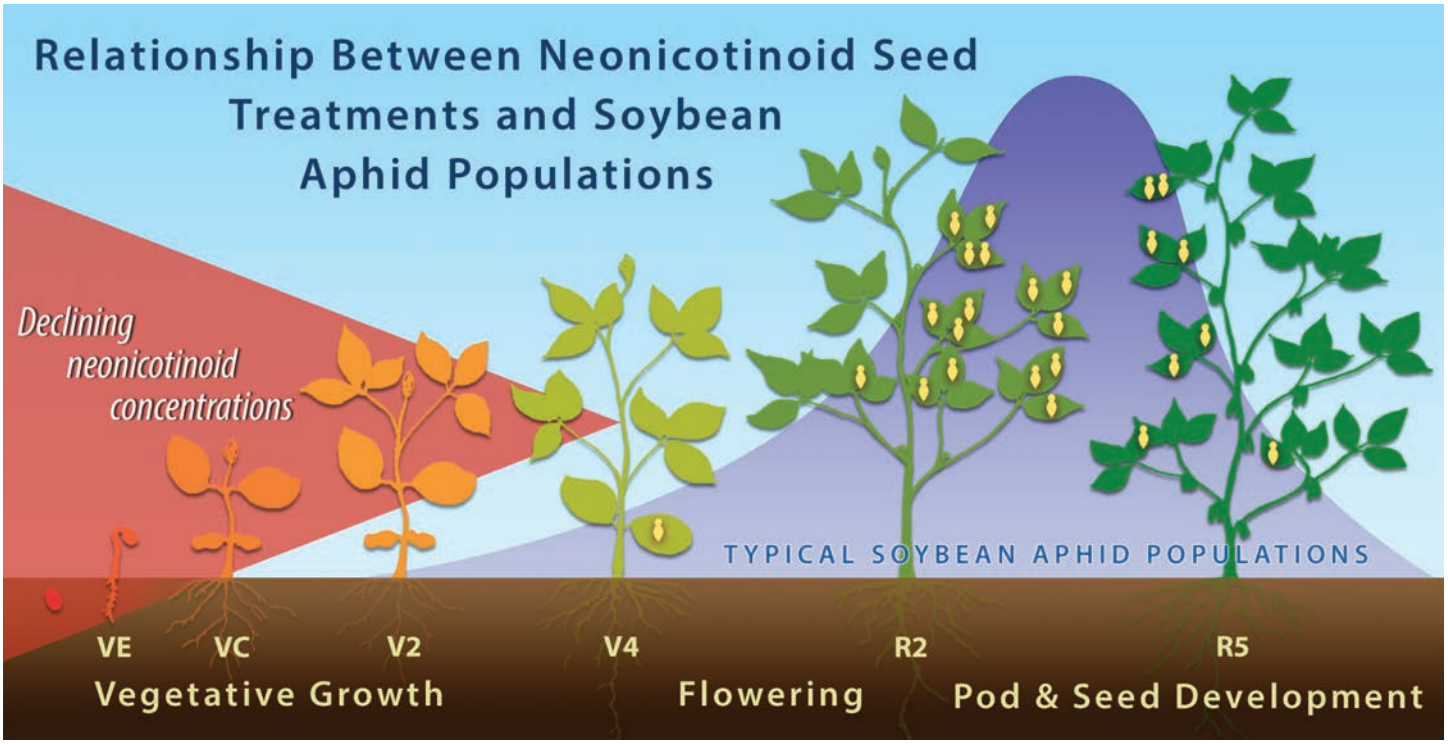

Figure 4. The relative concentration of the neonicotinoid thiamethoxam (the active insecticidal ingredient in CruiserMaxx® seed treatment) decreases rapidly after planting (represented by the red triangle). There is little or no insecticide remaining in soybean plants by the time soybean aphid populations typically begin to increase (represented by the purple-blue curve).

Figure 5. Predators, such as (A) an *Orius* nymph, (B) Asian lady beetle, (C) aphid midge larva, and (D) parasitic wasps typically suppress early-season infestations of soybean aphid.

To summarize: For typical field situations, independent research demonstrates that neonicotinoid seed treatments do not provide a consistent return on investment (Hodgson and VanNostrand 2012, 2013, 2014; Seagraves and Lundgren 2012; McCarville et al. 2014). **The current use of neonicotinoid seed treatments in soybean and other crops far exceeds pest pressures.**

Neonicotinoid Risks

Neonicotinoid seed treatments pose risks to **non-target organisms** in two main ways: off-target movement and environmental persistence. In **target pest populations**, neonicotinoid seed treatments pose the threat of resistance development.

Off-target Movement

Planter dust, which is generated during and shortly after planting neonicotinoid-treated seeds, contains high concentrations of neonicotinoid insecticides (Figure 6). Dust can move beyond field margins and land on flowers and other vegetation and potentially expose non-target insects (including honey bees and other pollinators) (Krupke et al. 2012, Stewart et al. 2014, Krupke and Long 2015).

Neonicotinoids are **highly soluble in water**, which facilitates movement beyond field borders via tile drainage and runoff. Studies also show that neonicotinoid contamination in water bodies has a negative effect on arthropod communities, which are the bases of local food webs (van Dijk et al. 2013, Hallmann et al. 2014, Hladik et al. 2014, Main et al. 2014).

Environmental Persistence, Biological Effects

Neonicotinoid residues from seed treatments may be found in the soil for months or even years after planting (USEPA 2003, Bonmatin et al. 2014). Researchers are currently exploring the possible effects of these residues. There is evidence that neonicotinoid residues disrupt biological control (Seagraves and Lundgren 2012, Douglas et al., 2014) or may be absorbed by the host plants of other insects, including milkweed (Figure 7), the food source for monarch butterfly caterpillars (Pecenka and Lundgren 2015).

Neonicotinoids can also make other organisms toxic. This phenomenon was documented in slugs, which are not sensitive to neonicotinoids, but ingest them when they feed on plants grown from treated seeds.

Figure 6. (A) Planter dust generated when planting treated seed contains a very high concentration of neonicotinoids that (B) can move off-target, and (C) potentially harm beneficial organisms.

When these "toxic" slugs are attacked by ground beetles, their principal natural enemies (Figure 8), the insecticide passes to the predator, disrupting biological control of the slugs and lowering yield (Douglas et al. 2015).

The same study demonstrated that in slug-infested fields, soybean grown *without* neonicotinoid seed treatments produced higher plant populations and yields than their treated counterparts. This study has important management implications, since slugs are emerging as a key pest in no-till cropping systems in many parts of the northern soybean production region.

Figure 7. Non-target plants (such as milkweed) can absorb neonicotinoid residues and affect non-target insects (such as monarch butterfly caterpillars).

Figure 8. Ground beetles typically control slug populations. But slugs that feed on plants grown from neonicotinoid-treated seeds can pass the insecticide to the beetles.

Resistance Development

Resistance is a potential consequence of consistent exposure to any pesticide. When growers repeatedly plant neonicotinoid-treated seeds in fields where no economic levels of target pests occur, the rate at which resistance will occur accelerates.

In addition, foliar neonicotinoids applied to soybean during the season will further increase pressure on pests to evolve resistance. Researchers have documented neonicotinoid resistance in several key pest species in other cropping systems (Bass et al. 2015).

Pest Management Recommendations

Most insect pests of soybean have well-established scouting guidelines and thresholds (Figure 9). Specific recommendations are available from university extension service websites and publications (consult your state extension service). When pest problems occur, the best management is based on an integrated approach that can include rotating crops, conserving natural enemies, using soybean varieties with resistance to pests (soybean aphid) or disease (bean pod mottle virus), and scouting and applying insecticides at established thresholds.

Figure 9. Scouting for insect pests is the tried and true approach.

Scouting and selectively using any insecticide (including neonicotinoid seed treatments) offers the long-term benefit of extending the useful lifespan of that product. Selective use also reduces short-term production costs.

Growers frequently face limited choices regarding seed treatments. Popular soybean varieties are often offered only with a pre-applied package of seed treatments. Growers who desire untreated soybean seed, or seed treated only with fungicides, should let their seed dealers know as early as possible when ordering seed for the next growing season.

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