Pesticides and Rove Beetles: *Are They Compatible?*

Scientists have studied the compatibility of pesticides and various biological control agents, but there is limited information specific to rove beetles. Research at Kansas State University studied the direct and indirect effects of pesticides on adult rove beetles.

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The rove beetle, *Atheta coriaria*, appears to be an effective biological control agent (natural enemy) of certain greenhouse insect pests, including fungus gnats, shore flies and thrips. Currently, *A. coriaria* is commercially available from several suppliers or distributors. The rove beetle is a soil-dwelling predator, 3-4 mm in length and dark brown to black in color. Adults are very mobile but tend to remain near the growing medium. The larvae are creamy white initially and turn yellow-brown in later instars. All life stages are extremely active and fast moving. Both the adults and larvae have been shown to consume the eggs and early instars of several insects in the family Nitidulidae (sap beetles), and the house fly (*Musca domestica*).

The use of pesticides (insecticides, miticides and fungicides) is still the primary means of dealing with insect and mite pests, and diseases in greenhouses. However, studies have been conducted to determine the compatibility of pesticides with natural enemies including predatory mites, predatory bugs and parasitoids. Despite this, there is limited information associated with the compatibility of pesticides with rove beetles. It has been shown that the insect growth regulator Adept (diflubenzuron) is not harmful to the first instar larvae and adults of the predacious rove beetle, *Aleochara bilineata*. The insecticides Dycarb/Turcam (bendiocarb) and Marathon (imidacloprid) are highly toxic to all life stages of *A. coriaria* under greenhouse conditions whereas the fungicide Cleary's 3336 (thiophanate-methyl) is not harmful to any of the life stages. In addition, the insect growth regulators Adept and Citation (cyromazine) are nontoxic to adults — although exposure to cyromazine results in more than 80 percent mortality of second-instar larvae.

None of these studies described above, however, evaluated either indirect or residual activity of pesticides. It's just as important to determine whether pesticides have any indirect effects on natural enemy behavior, including inhibition of feeding. Furthermore, there is minimal information quantifying time intervals (days or hours) that natural enemies can be released after pesticides have been applied. As such, we designed a study to determine the direct and indirect effects of various pesticide categories (fungicides, insect growth regulators, microbial insecticides, alternative insecticides, conventional insecticides, and plant-derived essential oils) on adult rove beetles.

The pesticides used in each experiment are presented in Table 1 (left) with their respective labeled rates. They were selected because, with the exception of Conserve (spinosad) and Aria (flonicamid), they may be applied to the growing medium to control either the larval stages of certain insect pests such as fungus gnats (insecticides) or soil-borne plant pathogens (fungicides).

Experiments 1 through 5 involve direct pesticide exposure, designed to assess the direct lethality of selected pesticides to rove beetle adults, and experiments 6 and 7 deal with delayed pesticide exposure.

Pesticides Used in Experiments

Common name (trade name)	Rate (per 100 gallons)
Azadirachtin (Ornazin)	8.0 fl oz
Azoxystrobin (Heritage)	0.5 oz
Bacillus thuringiensis subsp. *israelensis* (Gnatrol)	16.0 fl oz
Chlorfenpyr (Pylon)	5.2 mL
Chlorpyrifos (DuraGuard) — rate 1	0.25 fl oz
Chlorpyrifos (DuraGuard) — rate 2	0.50 fl oz
Clothianidin (Celero)	4.0 oz
Dinotefuran (Safari)	12.0 oz
Flonicamid (Aria)	2.39 g
Fosetyl-Aluminum (Aliette)	12.8 oz
Mefenoxam (Subdue Maxx)	1.0 fl oz
Metarhizium anisopliae strain52 (Tick-Ex) — rate 1	15.0 fl oz
Metarhizium anisopliae strain52 (Tick-Ex) — rate 2	29.0 fl oz
Soybean and rosemary oil (Indoor Pharm)	946.0 mL
Spinosad (Conserve)	6.0 fl oz
Thiamethoxam (Flagship)	8.0 oz
Water control	

Table 1.

Results

Direct Pesticide Exposure Experiments. In experiment 1 (Figure 1), none of the neonicotinoid-based insecticides evaluated — Celero (clothinidin, which is no longer available), Safari (dinotefuran) and Flagship (thiamethoxam) — were highly toxic to rove beetle adults. The insect growth regulator Ornazin (azadirachtin) was less directly toxic to rove beetle adults while the microbial insecticide Gnatrol (*Bacillus thuringiensis* subsp. *israelensis*) was not toxic compared to the water control.

In experiment 2, the fungicides — Heritage

(azoxystrobin), Aliette (fosetyl-aluminum) and Subdue MAXX (mefenoxam) — and the microbial insecticide Tick-Ex (*Metarhizium anisopliae* strain52) at both rates (15 and 29 fl. oz./100 gallons) were not directly harmful to rove beetle adults, with a mean range of 17.7 to 18.7 live rove beetle adults recovered among the treatments, including the water control.

Exposure to the designated pesticides affected feeding behavior, although the fungicides (Heritage and Aliette), microbial insecticide Tick-Ex and insect growth regulator (Ornazin) treatments did not affect the feeding ability of rove beetle adults (Figure 2). However, the microbial insecticide Gnatrol was significantly different from the water control.

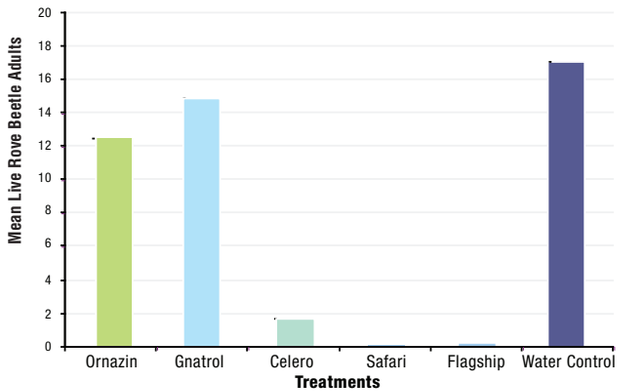

Figure 1. Effects of direct pesticide exposure on adult rove beetles (experiment 1)

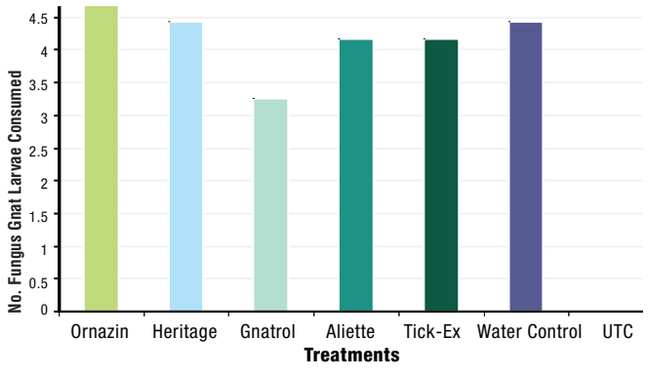

Figure 2. Effects of pesticides on adult rove beetle feeding habits

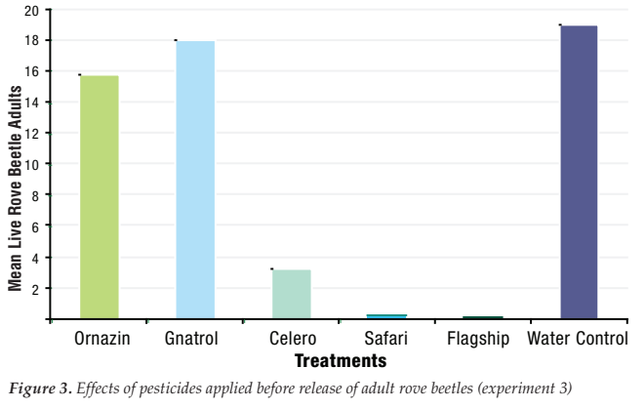

Figure 3. Effects of pesticides applied before release of adult rove beetles (experiment 3)

For experiment 3 (Figure 3), all three of the neonicotinoid-based insecticides (Celero, Safari and Flagship) were toxic when applied before release of the adult rove beetles. The insect growth regulator Ornazin and the microbial insecticide Gnatrol were nontoxic to the rove beetle adults. In experiment 4, none of the fungicide (Heritage, Aliette or Subdue MAXX) treatments or the microbial insecticide Tick-Ex were harmful to the adult rove beetles when applied to deli squat containers before release of the rove beetle adults. The mean range of live rove beetle adults recovered among the treatments, including the water control, was 17.5 to 18.6.

In experiment 5 (Figure 4), the results of Conserve (spinosad) and Aria (flonicamid) treatments were not significantly different from the water control. However, both rates of DuraGuard (chlorpyrifos, at .25 and .50 fl. oz./100 gallons) and Indoor Pharm, which contains both soybean and rosemary oil, negatively affected survival of rove beetle adults. Pylon (chlorfenapyr) was highly toxic to the rove beetle adults.

Delayed Pesticide Exposure Experiments. In experiment 6, for the 48- and 72-hour time intervals, results of the neonicotinoid-based insecticide treatments were significantly different from both the water control and the fungicide Subdue MAXX (Figure 5); however, after 96 hours, the survival rates with Celero, Safari and Flagship were all significantly higher than their respective 72-hour levels, and the survival rate for Celero had increased enough that it was no longer significantly less than either the control or fungicide survival rates.

The high rate of DuraGuard was significantly different from the other treatments in experiment 7 (Figure 6). In summary, for experiment 6 rove beetle adult survival increased when delaying release after application of the pesticides. Survival was enhanced when adults were released at least 96 hours post-application of the neonicotinoid-based insecticides.

Discussion

This study has demonstrated that certain pesticides — fungicides, insect growth regulators, microbial insecticides and alternative insecticides — are not directly toxic to the adult rove beetle, *A. coriaria*, but conventional insecticides and plant-derived essential oils are directly toxic when applied to the growing medium.

Fungicides. None of the fungicides tested (Heritage, Aliette and Subdue MAXX) were directly harmful to the rove beetle adults. This is important because greenhouse producers typically apply these fungicides to the growing medium to manage soil-borne plant pathogens such as Rhizoctonia, Pythium and Phytophthora. As such, the use of these fungicides should not disrupt existing biological control programs using rove beetles. Furthermore, Heritage and Aliette weren't even indirectly toxic to rove beetle adults, as we did not observe any significant feeding inhibition based on the ability of adults exposed to these fungicides to feed on fungus gnat larvae.

Insect growth regulator and microbial insecticides. Certain insect growth regulators have been shown to be nontoxic to natural enemies, including rove beetles. Adept, a chitin-synthesis-inhibiting insect growth regulator, did not negatively affect egg-hatch of the predacious rove beetle, *Aleochara bilineata*, and neither Adept nor Citation was harmful to *A. coriaria* adults. In our study, the insect growth regulator Ornazin was generally compatible with *A. coriaria* adults, and any subsequent negative effects may be due to the carriers or solvents present in the inert ingredients, not the actual active ingredient (because the product is formulated as an emulsifiable concentrate). In addition, the microbial insecticide Gnatrol, a strain active on fungus gnat larvae, was not directly harmful to *A. coriaria* although there appeared to be an indirect effect on feeding. Most of the studies associated with evaluating the impact of microbial insecticides derived from entomogenous bacteria on natural enemies have involved sprays of Dipel (*Bacillus thuringiensis* 'Berliner'). However,

this study demonstrated that Gnatrol is directly compatible with *A. coriaria*. In addition, the microbial insecticide Tick-Ex was not directly toxic to rove beetle adults. Neither Ornazin nor Tick-Ex was indirectly toxic to rove beetle adults, either, as we observed no significant feeding inhibition based on the ability of adults exposed to these pesticides to feed on fungus gnat larvae.

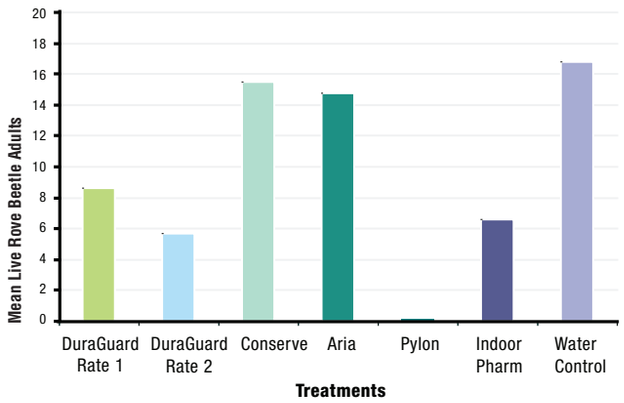

Figure 4. *Rove beetle survival when added 24 hours after pesticide application (experiment 5)*

Alternative insecticides. Neither Conserve nor Aria was directly harmful to rove beetle adults. Currently, Conserve and Aria are not labeled for applications to the growing medium. However, any residues from high-volume spray applications may inadvertently enter the growing medium and make contact with rove beetle adults.

Conventional insecticides. Conventional insecticides are typically toxic to most predacious rove beetles. In our study, both DuraGuard (insecticide) and Pylon (insecticide/miticide) were directly toxic to rove beetle adults. This is the first quantitative assessment indicating that both pesticides are not compatible with adult rove beetles. It was shown that both Dycarb/Turcam and Marathon (a neonicotinoid-based insecticide) are harmful to all life stages of *A. coriaria*. Neonicotinoid-based insecticides are widely used by greenhouse producers to control phloem-feeding insects such as aphids, mealybugs and whiteflies. The impact of these insecticides, including TriStar (acetamiprid) and Marathon, has been determined on certain above-ground predatory insects, but minimal information is currently available regarding their effects on below-ground predatory insects such as rove beetles. We found that all three neonicotinoid-based insecticides were extremely toxic (directly) to rove beetle adults. Nonetheless, it may be possible to apply these types of insecticides and then wait at least 96 hours — maybe even longer — before releasing rove beetle adults because it appears that exposure levels diminish over time. The growing medium may bind to the active ingredient, thus reducing the concentration of active ingredient that rove beetle adults may be

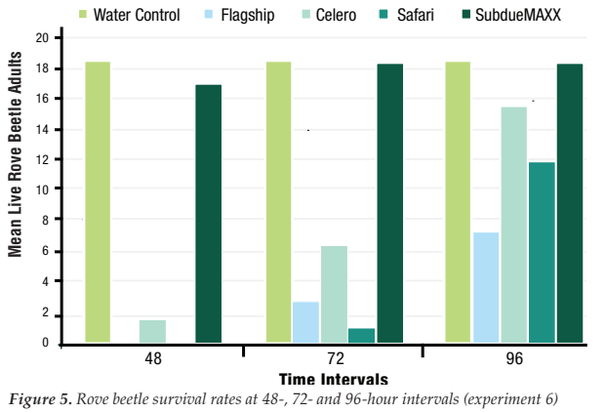

Figure 5. Rove beetle survival rates at 48-, 72- and 96-hour intervals (experiment 6)

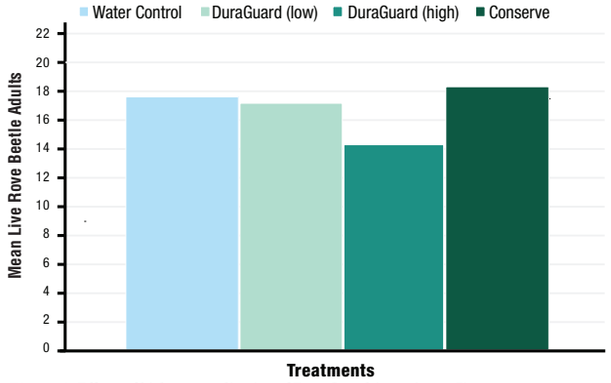

Figure 6. Effects of high rate application of DuraGuard (experiment 7)

exposed to. For example, growing media containing at least 30 percent bark (the medium in our study contained 50 percent composted pine bark) and other organic constituents may irreversibly absorb to the active ingredient of Marathon (imidacloprid) and prevent uptake of the active ingredient. Furthermore, exposure levels may decline after plants have taken up the active ingredient through the roots.

Plant-derived essential oil. The plant-derived essential oil product Indoor Pharm, which contains soybean and rosemary oil, appeared to somewhat directly affect rove beetle adults. Some plant-derived essential oils have been shown to be toxic to some above-ground predatory mites; however, minimal research exists on whether plant-derived essential oil products applied to the growing medium affect below-ground natural enemies. As such, our study is the first to evaluate the impact of a plant-derived essential oil product on a below-ground predatory insect like rove beetle.

Conclusion

This study demonstrated that certain pesticide categories — fungicides, insect growth regulators, microbial insecticides and alternative insecticides — are neither directly nor indirectly toxic to rove beetle adults when applied to the growing medium. However, conventional insecticides in the neonicotinoid chemical class (Celero, Safari and Flagship), DuraGuard, Pylon and the plant-derived essential oil product Indoor Pharm are directly harmful to rove beetle adults residing in the growing medium.

Furthermore, we have shown that after applying neonicotinoid-based insecticides to the growing medium it may be best to delay release of rove beetle adults for at least 96 hours (and possibly longer), which will result in greater survival. When using pesticides, it is important to determine their compatibility with *A. coriaria* to avoid compromising your biological control programs. GPN

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