Can Systemics Insecticdes Be a Conservation Biological Control Tool: Survival of Beneficial Insects after Exposure to Commonly Used Contact and Systemic Insecticides

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Insect pests cause significant economic losses to nursery crops. North Carolina's green industry reported $91 million in annual losses due to insect pests and plant diseases (NCDA 2005). Because consumers are expected to have low acceptance of plant damage (Glasgow 1999 and Klingeman et al. 2000) insecticides are perceived as necessary to control pests throughout nursery crop production cycles (Cloyd 2009). Contact insecticides can be broad spectrum, and because they are applied to thoroughly cover the plant and pests, can cause non-target losses of natural enemies that would otherwise provide additional insect control. In addition, some contact insecticides can exacerbate arthropod pests of ornamental plants by causing an outbreak of secondary pests (Frank and Sadof 2011, Raupp et al. 2001). For example, Frank and Sadof (2011) found 50% more maple spider mites and 50% fewer natural enemies when airblast sprayer were used to make applications of contact insecticides for granulate ambrosia beetle control compared to directed wand applications.

Systemic insecticides offer selective pest control largely by limiting insecticide exposure to pest insects (i.e., pests feeding on host plants). In a nursery system however, beneficial insects can be exposed to systemic spray and drench residues, as well as poisoning by feeding on pesticide-exposed prey. For example, imidacloprid increased spider mite outbreaks on elm trees by poisoning natural enemies and increasing spider mite fecundity (Szczepaniec et al. 2011). Experiments in various production systems have shown a range of effects of systemic insecticides on beneficial insects. Efforts to control brown planthoppers, *Nilapabata lugens*, using systemic pymetrozine did not effect *Agelena difficilis* spiders, but was moderately toxic to another natural enemy plant bug, *Cyrtorhina lividipennis* (DeJin et al. 2010). Acephate was the least toxic aphicide to predators and parasites in a study of 10 contact and systemic insecticides (Bayoun et al. 1995). Bruck et al. (2009) found that spirotetramat, a xylem- and phloem-mobile insecticide, had low antagonistic effects with natural enemies. However, imidacloprid was highly toxic to adult and larval 12-spotted ladybird beetle, *Coleomegilla maculata lengi*, a natural enemy of Colorado potato beetle *Leptinotarsa decemlineata* (Lucas 2004). The authors are unaware of research on the effect of systemic insecticide use during nursery production on natural enemies.

The objective of this research was to investigate the comparative effects of systemic and contact insecticides on natural enemies in a nursery production system in order to determine if systemic insecticides offer a more sustainable insecticide option.

Field Experiment: Systemic and contact insecticides were applied to field-grown trees in a nursery planting [systemic: imidacloprid (Marathon® II) and dinotefuran (Safari® 20 SG); contact: bifenthrin (Talstar® Select) and carbaryl (Sevin®SL)] and a water control on April

28, 2011. Insecticides were selected as either commonly used in Tennessee and/or recommended against scale pests of nursery crops. Imidacloprid was applied at 6 ml per dbh, and dinotefuran was applied at 0.126g per dbh (plants were 1/3" dbh), the drench rate for both products. Bifenthrin was applied at 40 fl. oz./per acre and carbaryl was applied at 1 qt. per 100 gallons. Rates for systemics were based on dbh guides on systemic pesticide labels and plants were estimated to be 4 ft^2 for bifenthrin. A test run with water prior to the experiment determined that 500 ml would cover upper and lower surfaces. For all pesticides, 500 ml per plant was sprayed on the upper and lower leaf surfaces using a CO_2 backbpack sprayer. For the systemics, 500ml was also drenched onto the base of the plant and within a 2-ft^2 area around the trunk using a plastic liter bottle with holes drilled in the lid. A total of 1L of product was applied to each systemic treatment plant. Leaves of plants receiving the systemics were sprayed with the backpack sprayer so that they were completely covered with pesticide to ensure that insects would be caged to a leaf with a comparable amount of pesticide residue and to achieve a worst-case scenario of treatment overspray. Prior to pesticide applications, one pitfall trap was installed 18-in. from the base of each plant.

Following pesticide application, cages containing beneficial insects were individually placed around a branch or leaf so that each treated tree had three cages. Each cage contained either 10 adult *Orius* (minute pirate bug), 10 *Aphidius* parasitic wasps, or 10 *Coleomegilla* lady beetles. Each cage had a 10 ml vial with wick of honey-water and glycerol solution (5% v/v) as a food source. Survival of caged beneficial insects was assessed every 48 hr following insecticide application through May 6, 2011. Simultaneously, pitfall trap collections measured presence and type of ground-dwelling arthropods every 48 hr through May 6, 2011, and thereafter on May 13, 2011 and May 24, 2011 (15 and 22 DAT). The experiment was a completely randomized design split-plot with sampling, insecticide is the whole plot (tree), and beneficial insect is the subplot. The experiment was conducted on two-year-old planting *Liriodendron tulipifera* seedlings. Plants selected for the study at the UT Forest in Morgan Co., Tenn. had approx. 1-in caliper diam. and were between 4.0 and 5.5 ft tall. *Aphidius* results are reported for 144 hr after application only.

There was a significant interaction of treatment and insect species for the first two data collection periods, p-value <0.0001. On April 30, 48 hr after pesticide application, carbaryl killed more lady beetles than bifenthrin and imidacloprid, which killed more beetles than either dinotefuran or water controls (Table 1). Significantly fewer *Orius* survived when imidacloprid or bifenthrin were applied (Table 2).

On May 2, 2011, after 96 hr post-pesticide applications, carbaryl, bifenthrin and imidacloprid-treated foliage yielded lower numbers of surviving lady beetles than either dinotefuran or water controls (Table 3). Fewer *Orius* were alive on bifenthrin-treated leaves than all other treatments and dinotefuran had a greater number of surviving insects than any other treatment, including water controls (Table 4). Because there were no apparent interactions 144 hr after application, May 4 data were pooled among insects. Fewer insects survived following exposure to imidacloprid, bifenthrin and carbaryl treatments than dinotefuran, which in turn had lower survival than insects exposed to water alone (Table 5).

For pitfall trap data when all beneficial insects were pooled, counts did not differ based on insecticide treatment, with the exception of 4 DAT when dinotefuran treatments yielded more beneficial insects than all other treatments, including controls (Figure 1). The total number of arthropods per pitfall trap varied by treatments except on 15 and 22 DAT (Figure 2). At 2 DAT dinotefuran treatments yielded more arthropods than either imidacloprid, bifenthrin or the controls. At 4 and 6 DAT, bifenthrin yielded fewer insects than all other treatments (except imidacloprid on 6 DAT). By 8 DAT, bifenthrin treatments had fewer arthropods than dinotefuran. There was no difference in number of all spiders in pitfall traps regardless of date (Figure 3). The total number of ants did not differ among treatments except on 4 DAT when dinotefuran treatments yielded more ants than any other treatment (Figure 4).

These data represent our intitial efforts to understand the complex interaction between pesticide, environment, and beneficial insect in a nursery production system. Based on these results, insecticide effect on beneficial insect varied with insect species, pesticide, and days after application, as might be expected. Both ground-dwelling and flying insects were affected. Safari® 20 SG appeared to generally be the least toxic and Sevin®SL and Talstar® Select were generally the most toxic pesticides. More research is needed to fully understand the effects of pesticide choice on natural enemy populations.

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Table 1. Number of surviving lady beetles on April 30, 2011 after 48 hr caged to trees sprayed with contact and systemic insecticides.

Insecticide	Lady beetle (ranked)
Imidacloprid	57.7 b
Dinotefuran	98.4 a
Bifenthrin	59.2 b
Carbaryl	18.5 c
Control	107.9 a

Table 2. Number of surviving *Orius* on April 30, 2011 after 48 hr caged to trees sprayed with contact and systemic insecticides.

Insecticide	*Orius* (ranked)
Imidacloprid	29.2 b
Safari	79.4 a
Talstar	38.8 b
Sevin	70.4 a
control	83.4 a

Table 3. Number of surviving lady beetles alive on May 2, 2011 after 96 hr caged to trees sprayed with contact and systemic insecticides.

Insecticide	Lady beetle (ranked)
Imidacloprid	55.6 b
Dinotefuran	67.9 a
Bifenthrin	49.1 b
Carbaryl	20.1 c
Control	66.1 a

Table 4. Number of surviving *Orius* on May 2, 2011 after 96 hr caged to trees sprayed with contact and systemic insecticides.

Insecticide	*Orius* (ranked)
Imidacloprid	24.6 b
Dinotefuran	35.4 a
Bifenthrin	4.9 c
Carbaryl	25.4 b
Control	21.1 b

Table 5. Number of insects surviving on May 4, 2011, after 144 hr caged to trees sprayed with contact and systemic insecticides, lady beetle, *Orius* and *Aphidius* pooled.

Insecticide	All insects

	(means)
Imidacloprid	4.3 c
Dinotefuran	6.1 b
Bifenthrin	3.1 c
Carbaryl	2.3 c
Control	7.7 a

p-value 0.0008

Figure 1. Mean total number of beneficial insects per pitfall trap by date after systemic and contact insecticide application.

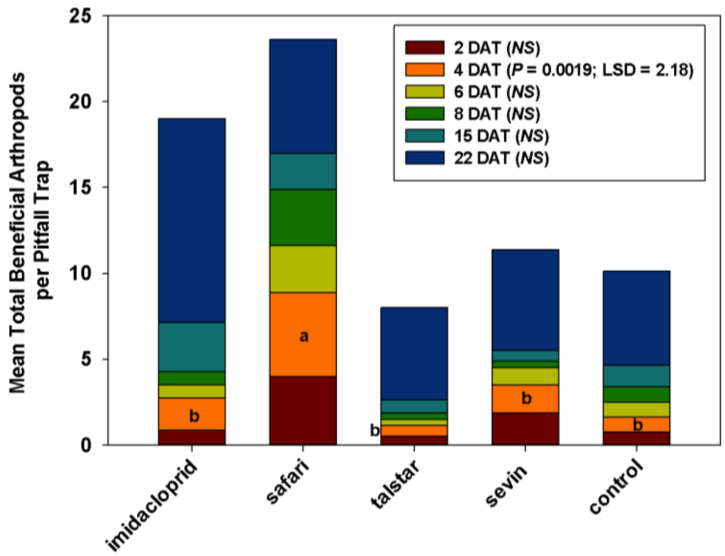


Figure 2. Mean total number of arthropods per pitfall trap by date after systemic or contact insecticide application

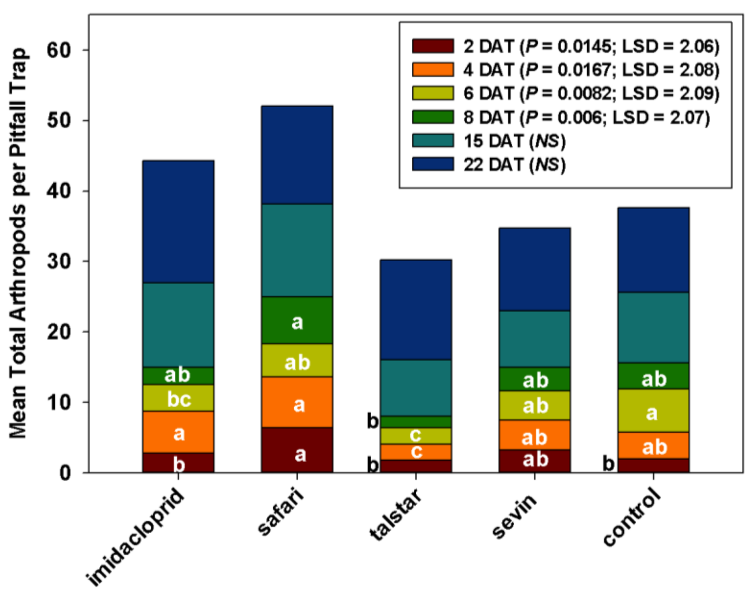


Figure 3. Mean total number of spiders per pitfall trap by date after systemic or contact insecticide application

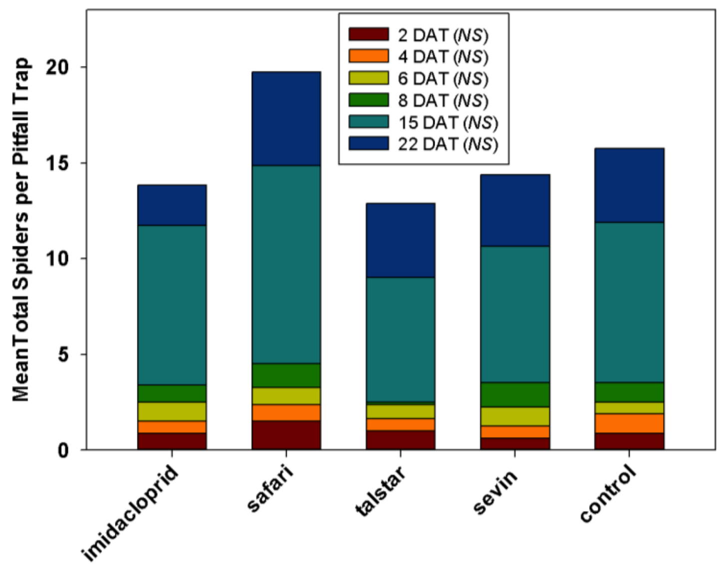
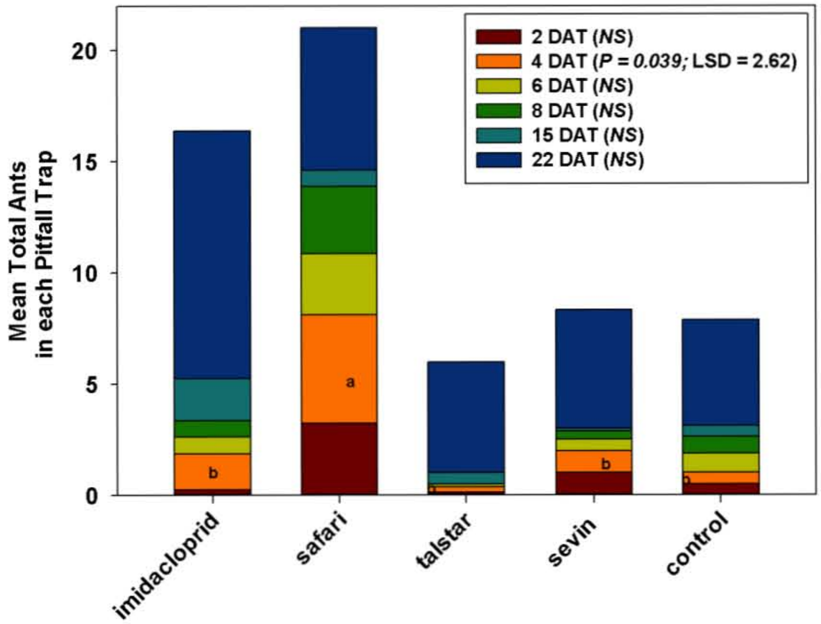


Figure 4. Mean total number of ants per pitfall trap by date after systemic or contact insecticide application



Mean Total Ants in each Pitfall Trap
0
5
10
15
20
2 DAT (NS)
4 DAT (P = 0.039; LSD = 2.62)
6 DAT (NS)
8 DAT (NS)
15 DAT (NS)
22 DAT (NS)
a
b
b
imidacloprid
safari
talstar
sevin
control