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Systemic Nicotinoid Toxicity against the Predatory Mirid *Pilophorus typicus*: Residual Side Effect and Evidence for Plant Sucking

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The predatory mirid *Pilophorus typicus* (Heteroptera: Miridae) is a potential biological control agent against *Bemisia tabaci* (Hemiptera: Aleyrodidae), but the sucking for host plant is unknown. To investigate collaboration use of *P. typicus* and nicotinoid granules and to confirm the sucking for pepper plant, residual harmful toxicity of 4 nicotinoids: acetamiprid; imidacloprid; nitempyram; and thiamethoxam on *P. typicus* adult were investigated at 7, 14 21, 28 and 35 d after treatment of the nicotinoid granules. The systemic toxicity of these nicotinoids was found to be moderately or seriously harmful. The residual toxicity was persistent for 35 d after application at the growing points of the pepper plant. The mortality of *P. typicus* due to the 4 nicotinoids was significantly higher than that due to the control treatment, which indicated that *P. typicus* sucked the active ingredient of the nicotinoid granules along the nutrition and/or water from the growing point of pepper plant. For this reason, *P. typicus* will be one of zoophytophagous mirids.

INTRODUCTION

A sweet potato whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), is one of the most significant pests in vegetables of the world (Nauen *et al.*, 2002; Horowitz *et al.*, 2004). Applications of nicotinoid spray and granule are principal control strategies for controlling the *B. tabaci*, but this whitefly indicates the resistance to pesticides such as nicotinoids (Nauen *et al.*, 2002; Horowitz *et al.*, 2004). At the present, the alternative or helpful control agents than nicotinoids are necessary for controlling the *B. tabaci*.

A predatory mirid, *Pilophorus typicus* Distant (Heteroptera: Miridae), is one of the most significant candidates as an alternative and/or helpful control agent for controlling *B. tabaci* in vegetable greenhouse (Nakahira *et al.*, 2010; Nishikawa *et al.*, 2010). For this reason, the side effects of vegetable spray pesticides on survival of *P. typicus* have been investigated by the dipping them into pesticide solutions (Nakahira *et al.*, 2010). In the past study, acute toxicity of a nicotinoid, flonicamid, was lethal on *P. typicus*, but systemic effects of residual nicotinoid toxicity have not been investigated against *P. typicus*.

A predatory mirid, *Macrolophus caliginosus* (Wagner) (Heteroptera: Miridae), a commercial biological control agent in Europe, caused the damage to tomato by the sucking on the growing point (Perdikis and Lykouressis, 2002; Lucas and Alomar, 2002; Sinia *et al.*, 2004; Sanchez *et al.*, 2004), but the sucking of *P. typicus* against plant has not been investigated. Nicotinoid granules are generally applied into soil at planting, and the toxicity is sucked by the plant via the root and stem. For this reason, residual toxicity of nicotinoid will be useful for the investigation of *P. typicus* sucking against the plant.

In this study, to probe the possibility of helpful use of *P. typicus* for nicotinoid applications, and to confirm the sucking of *P. typicus* on growing point of pepper plant, the systemic effect of residual nicotinoid toxicity on *P. typicus* adult was investigated.

MATERIALS AND METHODS

Peppers (*Capsicum annuum* L. var. *grossum*) were planted in a greenhouse to investigate the effect of the residual toxicity of nicotinoid granules on the *P. typicus* adult. Five planting holes (diameter, 9 cm; depth, 9 cm) were dug in each of the 5 adjacent ridges (length, 4.0 m; width, 0.8 m; interval, 0.8 m) in a greenhouse. Granules of 4 nicotinoids (Table 1) were applied into each of the 5 holes in 4 of the ridges. As a control, no nico-

Table 1. Active ingredients (AI), trade names, AI ratios (%), and quantities (g) of the nicotinoid granules used for treatment in this study

AI	Trade name	AI ratio	Treatment quantity
Acetamiprid	Mospiran®	2.0	0.5
Imidacloprid	Admire®	1.0	2.0
Nitenpyram	Bestguard®	1.0	2.0
Thiamethoxam	Actara 5®	0.5	1.0

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Table 2. Residual toxicity of 4 systemic nicotinoid granules for the *P. typicus* adult

Active ingredient	Days from planting	Corrected mortality and mortality of control (%)			Toxicity	Persistence
		1 d	3 d	5 d		
Acetamiprid	14	75.0abc	92.9a	92.9a	+	D
	21	66.7abc	69.0a	66.8a	+	
	28	63.3abc	79.3a	79.2a	+	
	35	36.7c	67.9a	66.7a	±	
Imidacloprid	14	50.0bc	92.9a	96.4a	+	D
	21	66.7abc	96.6a	96.3a	+	
	28	70.0abc	93.1a	95.8a	+	
	35	83.3ab	100a	100a	++	
Nitenpyram	14	92.9ab	100a	100a	++	D
	21	83.3ab	100a	100a	++	
	28	93.3ab	100a	100a	++	
	35	96.7a	100a	100a	++	
Thiamethoxam	14	85.7ab	100a	100a	++	D
	21	63.3abc	96.6a	100a	++	
	28	76.7abc	100a	100a	++	
	35	86.7ab	96.4a	100a	++	
Control	14	6.7d	6.7b	20.0b		
	21	0d	3.3b	10.0b		
	28	0d	3.3b	20.0b		
	35	0d	6.7b	10.0b		

Means followed by different letters were significantly different between the corrected and control mortalities at 1, 3, and 5 d after exposure to pepper plant growing points by the Steel–Dwass test ($P<0.05$).

tinoid granules were applied to the 5 holes of 1 ridge. A young pepper plant (height, approximately 45 cm) was planted into the holes of all 5 ridges. Three growing points on the stem of each pepper plant (15 cm from the top) in the five ridges were cut 14, 21, 28, and 35 d after planting. These portions were individually dipped in a 100 ml water–containing flask in the laboratory. The gap between the flask mouth and growing point was covered with Parafirm® to prevent drowning of the *P. typicus* adult. Fifteen flasks containing stems with growing points were individually transferred to respective plastic containers (diameter, 10 cm; height, 20 cm) at every collection date. *P. typicus* adults were cultured in the laboratory on defrosted Mediterranean flour moth *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs as food and kalanchoe *Kalanchoe blossfeldiana* Poelln (Saxifragales: Crassulaceae) branches with leaves as an oviposition substrate. Ten *P. typicus* adults that emerged within 9 d from this laboratory culture were transferred to each plastic container. The 10 *P. typicus* were offered with the moth eggs attached sticky paper strip (length, 4.0 cm; width, 1.5 cm) within the container. The containers were maintained under a photoperiod of 16 h light and 8 h dark per day at 25 °C. Death of the insects was observed 1, 3, and 5 d after their transfer into the plastic containers.

The calculated mortalities of the adult were corrected for control mortality according to the method of Abbott (1925). The corrected mortalities were used to determine the harmfulness of the each pesticide. The level of harmfulness was evaluated on day 5 using the following scale (Hassan *et al.*, 1987): not harmful (–), mortality (M) < 30%; slightly harmful (±), 30% ≤ M < 80%; moderately harmful (+), 80% ≤ M < 99%; and seriously harmful (++), 99% ≤ M. The residual harmfulness was evaluated on day 5 as follows (Hassan *et al.* 1987): short–term persistent (A), <5 d; mildly persistent (B), 5–15 d; moderately persistent (C), 16–30 d; long–term persistent (D), >30 d.

RESULTS AND DISCCUSION

Zoophytophagous mirids have advantage such as longevity extension and reproduction increase than true predator as biological control agents (Perdikis and Lykouressis, 2002; Lucas and Alomar, 2002; Sinia *et al.*, 2004; Sanchez *et al.*, 2004). The zoophytophagous mirids cause the advantages by their sucking the plant nutrition and/or water from the host plant. In this study, the mortality of *P. typicus* due to the 4 nicotinoids was significantly higher than that due to the control treatment (Table 2), which indicated that *P. typicus* sucked the active ingredient of the nicotinoid granules along the nutrition and/or water from the growing point of pepper plant. For this reason, *P. typicus* will be one of zoophytophagous mirids.

The mortality of *P. typicus* due to acetamiprid was significantly lower than that due to nitempyram at 35 d after the granular nicotinoid treatment of the plants and 1 d after exposure of the mirid to the plant growing points (Table 2). Thus, the residual toxicity of acetamiprid was the lowest for *P. typicus* among the four nicotinoids studied, but was categorized as persistent. The residual toxicity of imidacloprid, nitempyram, and thiamethoxam for *P. typicus* were also categorized as persistent (Table 2). The systemic toxicities of the four nicotinoids were moderately or seriously harmful at 35 d after granule treatment (Table 2). For this reason, the helpful use of *P. typicus* for the four nicotinoid applications will be difficult because of the residual and harmful toxicity.

Fuguls *et al*. (1999) studied the residual toxicity of a nicotinoid, imidacloprid, against two zoophytophagous mirids, *M. caliginosus* and *Dicyphus tamaninii*, by the spray treatment for the host plants. In their study, the residual toxicity was moderately persistent, becoming harmless by 21 days after treatment for *M. caliginosus* and by 30 days after treatment for *Dicyphus tamaninii*. In this study, the systemic toxicity of the 4 nicotinoids for *P. typicus* was found to be seriously harmful and persistent over 35 d (Table 2). These differences in residual toxicity of nicotinoids for zoophytophagous mirids may indicate an importance of pesticide formulation and its application method for the side effect against zoophytophagous mirids.

A zoophytophagous mirid, *P. typicus*, is an alternative biological control agent than the four nicotinoids, but not be helpful biological control agents of the nicotinoids in the residual periods. The nicotinoid granules are important to reduce the whitefly in early period from planting. Thus, the inundative rather than inoculative release strategy of *P. typicus* should be established to suppress rapidly *B. tabaci* as an alternative control agent of the nicotinoids.

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