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ORIGINAL ARTICLE

Post-exposure temperature influence on the toxicity of conventional and new chemistry insecticides to green lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae)

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Abstract *Chrysoperla carnea* (Stephens) is an important biological control agent currently being used in many integrated pest management (IPM) programs to control insect pests. The effect of post-treatment temperature on insecticide toxicity of a spinosyn (spinosad), pyrethroid (lambda cyhalothrin), organophosphate (chlorpyrifos) and new chemistry (acetamiprid) to *C. carnea* larvae was investigated under laboratory conditions. Temperature coefficients of each insecticide tested were evaluated. From 20 to 40 °C, toxicity of lambda cyhalothrin and spinosad decreased by 2.15- and 1.87-fold while toxicity of acetamiprid and chlorpyrifos increased by 2.00 and 1.79-fold, respectively. The study demonstrates that pesticide effectiveness may vary according to environmental conditions. In cropping systems where multiple insecticide products are used, attention should be given to temperature variation as a key factor in making pest management strategies safer for biological control agents. Insecticides with a negative temperature coefficient may play a constructive role to conserve *C. carnea* populations.

1. Introduction

In cropping systems, the green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) is considered a key predator (Lingren et al., 1968). *C. carnea* is a valuable predator as an element of integrated pest management (IPM) activities to control economic pests. It is commercially available and widely used because it can adapt to different agro-ecosystems

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(Tauber et al., 2000). As a potential predator and bio-control agent in Pakistan, *C. carnea* is largely dispersed where insecticides are commonly utilized for insect pest control (Mohyuddin et al., 1997; Sayyed et al., 2010).

Different *Chrysoperla* species have shown tolerance or resistance against different insecticides which makes it well-suited for various IPM systems (Pree et al., 1989). Natural enemies of insect pests such as *C. carnea* may build up insecticide resistance similar to their host insects. However, they become resistant little by little due to arrangement of biochemical, biological and ecological factors (Roush and Daly, 1990). Direct contact to insecticides or feeding upon insecticide treated hosts are two general modes of resistance development (Wu and Miyata, 2005; Wu et al., 2004). *C. carnea* from Pakistan has been found resistant to many groups of insecticides (Pathan et al., 2008, 2010).

In the field, temperature has a prominent effect on insecticide effectiveness. It is a key factor of the environment which acts as a controlling and lethal factor (Fry, 1947). Temperature affects different biological traits of insects such as fertility, fecundity, survival, adult life-span (Yang et al., 1994; Dreyer and Baumagartner, 1996; Infante, 2000) and sex-ratio (Zheng et al., 2008). Temperature coefficient of any insecticide may be calculated to find the temperature-toxicity association.

Insecticides with a positive temperature coefficient become more toxic with the increase in temperature, whereas, those with a negative temperature coefficient become more toxic at lower temperatures (Glunt et al., 2013). Pyrethroid and organophosphate insecticides, for example, usually have a negative and positive temperature coefficient, respectively (Musser and Shelton, 2005). However, some investigations have also shown differences in the toxicity within a given insecticide class (Muturi et al., 2011) between temperature levels tested and insect species (Boina et al., 2009; Muturi et al., 2011). The current study compared the effects of post-treatment temperature on the effectiveness of four insecticides from different insecticide classes against *C. carnea* larvae.

2. Materials and methods

2.1. Insects and insecticides

C. carnea population was collected from cotton, *Gossypium hirsutum* L., from Muzaffargarh District of Punjab, Pakistan. *C. carnea* adults (200–400) were collected with the help of ventilated plastic vials as mentioned previously (Pathan et al., 2008). Adults were kept in ($12 \times 12 \times 20$ cm) plastic jars with artificial diet including yeast, honey, and distilled water with the ratio of 1:2:4. Adults were kept at 25 ± 2 °C, 60–65% RH and photoperiod of 14:10 h (l:d) in plastic rearing cages ($23 \times 38 \times 38$ cm) with ventilation holes on both sides. Black glossy paper was hung in cages for egg laying. The eggs were placed in Petri dishes and larvae were fed on eggs of *Sitotroga cerealella* (Olivier). To expose larvae to insecticide, the eggs were collected every second day by removing black paper from rearing cages. One egg was placed in a vertical cell hole (4–3 mm) of Perspex cell chamber and hatched after 2 to 3 days. Frozen eggs of *S. cereallela* were provided to the newly hatched larvae of *C. carnea* in separate holes every 48 h until pupation.

Insecticides used were spinosad (Tracer 24 SC, Dow Agro Sciences), lambda cyhalothrin (Karate 2.5 EC, Syngenta Limited, Jealot Hill, United Kingdom), chlorpyrifos (Lorsban 40 EC, Dow Agro Sciences, Hitchin, United Kingdom) and acetamiprid (Mospilan 20 SP, Arysta Life Sciences, Pakistan).

2.2. Bioassays

Four replications of each insecticide concentration were used to test toxicity at 20, 28 and 40 °C. The highest temperature level (40 °C) was selected because test population was collected from Muzaffargarh District of Punjab, Pakistan which has an arid climate with extremely hot summers and calm winters. Highest temperature witnessed in this city is just about 54 °C (Anon., 2013). At least four concentrations as serial dilutions of each insecticide were made in distilled water and tested at each temperature. Bioassays were conducted on 2–3 day-old larvae of *C. carnea* by the Insecticide-Impregnated filter method as approved by the insecticide resistance action committee (Sayyed et al., 2010). Filter papers (Whatman No. 41, 90 mm in diameter; Whatman, Maidstone, United Kingdom) were dipped in test solutions and in distilled water for controls. For one concentration, 80 larvae were used (20 larvae per replication) and 30 larvae were used for control. One larva was kept in a single Petri dish with treated filter paper to avoid cannibalism. The larvae were fed on eggs of *S. cereallela*. Treated larvae were immediately placed in growth chambers set at temperature 20, 28 and 40 °C, respectively, 60–65% RH, and photoperiod of 14:10 h (l:d).

2.3. Data analysis

Mortality data were recorded after 72 h of insecticide treatment for new chemistry insecticides and after 48 h for conventional insecticides. Mortality data were analyzed using probit analysis (Finney, 1971) corrected for control mortality at each temperature (Abbott, 1925) to find median lethal concentration (LC_{50}). Formula used to calculate the temperature coefficients of each insecticide is the ratio of higher to the lower LC_{50}. The temperature coefficient was called positive when lower LC_{50} was at a higher temperature and negative when lower LC_{50} at a lower temperature (Musser and Shelton, 2005).

3. Results

The toxicity of acetamiprid and chlorpyrifos was found to be positively correlated with the temperature ranges tested. Based on LC_{50} values, the toxicity of acetamiprid increased significantly from 1.32 to 1.47-fold at temperatures 28 and 40 °C, respectively, when compared with the toxicity at 20 °C (Table 1).

Chlorpyrifos gave similar results because toxicity was increased from 1.11 to 1.61-fold at temperatures 28 and 40 °C, respectively, when compared with the toxicity at 20 °C. Acetamiprid, and chlorpyrifos showed overall positive temperature coefficients 2.00 and 1.79-fold, respectively, for the temperature ranges tested (Table 1).

In contrast, the pyrethroid insecticide showed a negative association with temperature levels tested. The toxicity of lambda cyhalothrin decreased by 1.41 and 1.52-fold at 28