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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 × 12 × 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 × 38 × 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

Table 1 Effect of temperature on insecticide toxicity to the larvae of *C. carnea*.

Population	Insecticide	Temperature (°C)	LC_{50}[b](95%FL) (μg/ml)	Slope(±SE)	χ^2	df	*P*	*n*[a]	Temperature coefficient[c]	
									8 °C	20 °C
Field (G_1)	Acetamiprid	20	2283.6 (1487.26–4984.16)	1.25 ± 0.29	4.12	3	0.24	350		
		28	1676.07 (1171.58–2867.68)	1.32 ± 0.26	1.46	3	0.68	350	1.32	
		40	1139.05 (855.51–1571.79)	1.57 ± 0.26	0.99	3	0.8	350	1.47	2.0
Field (G_1)	Lambda cyhalothrin	20	334.12 (242.03–527.42)	1.49 ± 0.28	1.60	3	0.65	350		
		28	472.11 (321.95–938.56)	1.40 ± 0.31	0.009	3	0.99	350	−1.41	
		40	720.01 (424.3–2636.66)	1.21 ± 0.32	0.006	3	0.99	350	−1.52	−2.15
Field (G_1)	Spinosad	20	690.16 (484.99–1121.17)	1.26 ± 0.25	1.04	3	0.79	350		
		28	877.29 (607.27–1547.13)	1.31 ± 0.27	0.71	3	0.87	350	−1.27	
		40C	1292.38 (803.01–3444.12)	1.13 ± 0.27	0.42	3	0.93	350	−1.47	−1.87
Field (G_1)	Chlorpyrifos	20	297.64 (227.08–442.33)	1.25 ± 0.22	1.86	3	0.60	350		
		28	267.64 (195.94–382.47)	1.39 ± 0.25	1.23	3	0.74	350	1.11	
		40	166.03 (125.46–211.52)	1.71 ± 0.25	5.45	3	0.14	350	1.61	1.79

[a] Number of larvae tested.
[b] Lethal concentration.
[c] Ratio of higher to lower LC50 value for 7 and 14 °C differences in temperature. A negative coefficient indicates a higher LC50 at the higher temperature.

and 40 °C respectively, when compared with the toxicity at 20 °C with an overall −2.15 temperature coefficient (Table 1).

For spinosad, the toxicity was also decreased by 1.27 and 1.47-fold at 28 and 40 °C respectively, when compared with the toxicity at 20 °C, with an overall −1.87 temperature coefficient (Table 1).

In short, toxicity of chlorpyrifos and acetamiprid indicated a direct relationship with temperature levels investigated while the opposite relationship between toxicity of lambda cyhalothrin, spinosad, and temperature was noted.

4. Discussion

There is a broad range of pests' invasion because of the variation in cropping patterns and temperature, which shows considerable variations in insecticide applications. The persistent and excessive use of pesticides has also caused more critical problems by water supply pollution (Carey, 1991) and cropland soil degradation.

C. canrea is a popular biological control agent (Pathan et al., 2010). In this research study, effect of three different temperature ranges was evaluated on toxicity of four different insecticides to this green lacewing. Mode of application, species and development stage may change the insecticide efficacy on this predator. Hazards to natural enemies due to insecticides vary in a number of ways (Taborsky et al., 1995), depending upon intrinsic toxicity of the chemical (Hassan, 1987), exposure (Kennedy, 1988), application coverage (Cilgi et al., 1988), and behaviour of chemical (Leahy, 1985). Diverse metabolic functions are highly temperature dependent in insects' body, causing degradation of insecticides and typical operation of nervous system (Litchfield and Wilcoxon, 1949).

The chlorpyrifos and acetamiprid showed temperature dependent toxicities; with chlorpyrifos being more toxic than acetamiprid at the higher temperature range (40 °C) tested (Table 1). Theoretically, organophosphate insecticides perform better at high temperatures because these have an upbeat correlation with adjacent temperatures (Glunt et al., 2013). On the other hand, biotransformation is a biological process known to reduce the toxicity of organophosphates at lower temperatures (Harwood et al., 2009). Therefore, the above insecticides may create drastic effects on this biological control agent under warmer climates.

Unlike chlorpyrifos and acetamiprid, the lambda-cyhalothrin and spinosad tested in this study demonstrated a negative temperature coefficient (Table 1). At high temperatures, pyrethroid insecticides exhibit reduced efficacy (Scott, 1995). Temperature between 15 and 20 °C enhances neuron sensitivity which causes frequent nerve firing. At some stage in the nerve impulse movement, the sodium ions are controlled by pyrethroid (Salgado et al., 1989). But reverse at high temperatures has been reported (Song and Narahashi, 1996). Reduced biotransformation and increased sodium influx (Song and Narahashi, 1996; Harwood et al., 2009) at low temperature cause more mortality.

Spinosad is an alternative to organophosphate, carbamate and pyrethroid insecticides for control of Lepidoptera, thrips and selected pests from other orders (Thompson et al., 1995). Temperature plays a critical role to control toxicity of microbial insecticides, as spinosad is a microbial insecticide (Weinzierl et al., 1998) which might be a possible cause for the reduced toxicity at greater temperatures.

These results on the toxicity of lambda-cyhalothrin and spinosad are in agreement with bioassays on *Ostrinia nubilalis* (Musser and Shelton, 2005), where an opposite association between the temperature and toxicity was witnessed.

5. Conclusion

These results may help to design valuable pest management programs by using chemicals in cropping systems where *C. carnea* is used as a biological control agent to control various insect pests. However, several other temperature related factors must be kept in mind when using these results to organize eco-friendly pest management programs. Higher temperatures reduce residual life of insecticides (Bobe et al., 1998; Arthur et al., 1992) but augment insect activity (Cagan, 1998) and reduced deposition of insecticides, especially if applied aerially (Wilkinson et al., 1999). Timely application according to perspective temperature may reduce the non-target effects of the above mentioned insecticide on *C. carnea* and other natural enemies.

Contribution

M.M.M. and AMR designed the study and analyzed data. MMM, ZA and AW performed laboratory work. MMM wrote the manuscript. MBSA and MA helped in data analysis and scientific writing. All authors read and approved the manuscript.

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References

Anon., 2013. Geography and Climate of Muzaffargarh, Pakistan. Available: <http://en.wikipedia.org/wiki/Muzaffargarh_District#Geography_and_climate> (accessed 19.10.14).

Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18, 265–267.

Arthur, F.H., Throne, J.E., Simonaitis, R.A., 1992. Degradation and biological efficacy of chlorpyrifos-methyl on wheat stored at five temperatures and three moisture contents. J. Econ. Entomol. 85, 1994–2002.

Bobe, A., Meallier, P., Cooper, J.F., Coste, C.M., 1998. Kinetics and mechanisms of abiotic degradation of fipronil (hydrolysis and photolysis). J. Agric. Food Chem. 46, 2834–2839.

Boina, D.R., Onagbola, E.O., Salyani, M., Stelinski, L.L., 2009. Influence of post treatment temperature on the toxicity of insecticides against *Diaphorina citri* (Hemiptera: Psyllidae). J. Econ. Entomol. 102, 685–691.

Cagan, L., 1998. Spring behaviour of the European corn borer, *Ostrinia nubilalis* (Lepidoptera, Pyralidae) larvae in south-western Slovakia. Biologia (Bratislava) 53, 223–230.

Carey, A.E., 1991. Agriculture, Agricultural Chemicals, and Water Quality. In Agriculture and the Environment, 78–91. USDA Yearbook of Agriculture.

Cilgi, T., Jepson, P.C., Unal, G., 1988. The short-term exposure of non-target invertebrates to pesticides in the cereal crop canopy. Proc. Brit. Crop, 759–764.

Dreyer, H., Baumagartner, J., 1996. Temperature influence on cohort parameters and demographic characteristics of the two cowpea coreids *Clavigralla tomentosicollis* and *C. shadabi*. Entomol. Exp. Appl. 78, 201–213.

Finney, D.J., 1971. Probit Analysis, third ed. Cambridge Press, New York, NY (668pp.).

Fry, F.E.J., 1947. Effect of environment on animal activity. University Toronto. Stud., Biol. Ser. No. 55, Pub. Ont. Fish. Res. Lab 68, 1–62.

Glunt, K.D., Blanford, J.I., Paaijmans, K.P., 2013. Chemicals, climate, and control: increasing the effectiveness of malaria vector control tools by considering relevant temperatures. PLOS Pathog. 9 (10), e1003602. http://dx.doi.org/10.1371/journal.-ppat.1003602.

Harwood, A.D., You, J., Lydy, M.J., 2009. Temperature as a toxicity identification evaluation tool for pyrethroid insecticides: toxicokinetic confirmation. Environ. Toxicol. Chem. 28, 1051–1058.

Hassan, S.A., 1987. Standard methods, to test side effects of pesticides on natural enemies of insects and mites developed by the IOBC/EPPO. 15, 214–255.

Infante, F., 2000. Development and population growth rates of *Prorops nasuta* (Hym., Bethylidae) at constant temperatures. J. Appl. Entomol. 124, 343–348.

Kennedy, P.J., 1988. The use of polythene barriers to study the long term effects of pesticide on ground beetles (Coleoptera: Carabidae) in small scale field experiments. In: Greaves, B.D., Smith, B.D., Smith, P.W.G. (Eds.), Field Methods for the Study of Environmental Effects of Pesticides. BCPC Publications, Thornton Health, pp. 335–340.

Litchfield, J.T., Wilcoxon, F., 1949. A simplified method of evaluating dose effect experiments. J. Pharmacol. Exp. Ther. 99, 99–103.

Lingren, P.D., Ridgway, R.L., Jones, S.L., 1968. Consumption by several common arthropod predators of eggs and larvae of two Heliothis species that attack cotton. Ann. Entomol. Soc. Am. 61, 613–617.

Leahy, J.P., 1985. Metabolism and environmental degradation. In: Leahy, J.P. (Ed.), The Pyrethroid Insecticides. Taylor and Francis, London, pp. 263–342.

Mohyuddin, A.I., Jillani, G., Khan, A.G., Hamza, A., Ahmad, I., Mahmood, Z., 1997. Integrated pest management of major cotton pests by conservation, redistribution and augmentation of natural enemies in Pakistan. Pak. J. Zool. 29, 293–298.

Muturi, E.J., Lampman, R., Costanzo, K., Alto, B.W., 2011. Effect of temperature and insecticide stress on life-history traits of *Culex restuans* and *Aedes albopictus* (Diptera: Culicidae). J. Med. Entomol. 48, 243–250.

Musser, F.R., Shelton, A.M., 2005. The influence of post-exposure temperature on the toxicity of insecticides to *Ostrinia nubilalis* (Lepidoptera: Crambidae). Pest. Manag. Sci. 61, 508–510.

Pathan, A.K., Sayyed, A.H., Aslam, M., Liu, T.X., Razzaq, M., Gillani, W.A., 2010. Resistance to pyrethroids and organophosphates increased fitness and predation potential of *Chrysoperla carnea* (Neuroptera: Chrysopidae). J. Econ. Entomol. 103, 823–834.

Pathan, A.K., Sayyed, A.H., Aslam, M., Razaq, M., Jilani, G., Saleem, M.A., 2008. Evidence of field-evolved resistance to organophosphates and pyrethroids in *Chrysoperla carnea* (Neuroptera: Chrysopidae). J. Econ. Entomol. 101, 1676–1684.

Pree, D.J., Archibald, D.E., Morrison, R.K., 1989. Resistance to insecticides in the common green lacewing *Chrysoperla carnea* (Neuroptera, Chrysopidae) in southern Ontario. J. Econ. Entomol. 82, 29–54.

Roush, R.T., Daly, J.C., 1990. The role of population genetics in resistance research and management. In: Roush, R.T., Tabashnik, B.E. (Eds.), Pesticide Resistance in Arthropods. Chapman and Hall, New York, pp. 97–152.

Salgado, V.L., Herman, M.D., Narahashi, T., 1989. Interactions of the pyrethroid fenvalerate with nerve membrane sodium channels: temperature dependence and mechanism of depolarization. Neurotoxicology 10, 1–14.

Sayyed, A.H., Pathan, A.K., Faheem, U., 2010. Cross-resistance, genetics and stability of resistance to deltamethrin in a population of *Chrysoperla carnea* from Multan, Pakistan. Pestic. Biochem. Physiol. 98, 325–332.

Scott, J.G., 1995. Effects of temperature on insecticide toxicity, in Reviews in pesticide toxicology. In: Roe, R.M., Kuhr, R.J. (Eds.), Toxicology Communications, vol. 3. Raleigh, NC, USA, pp. 111–135.

Song, J., Narahashi, T., 1996. Modulation of sodium channels of rat cerebellar Purkinje neurons by the pyrethroid tetramethrin. J. Pharmacol. Exp. Ther. 277, 445–453.

Tauber, M.J., Tauber, C.A., Daane, K.M., Hagen, K.S., 2000. Commercialization of predators: recent lessons from green lacewings (Neuroptera: Chrysopidae). Am. Entomol. 46, 26–38.

Taborsky, V., Hejzlar, P., Kazad, J., Hruska, J., Zohdy, G.I., 1995. The toxic effects of different pesticides on the predatory bug, *Orius majuscules* (Heteropta: Anthocoridae). Ochra.Rost., UZPI 31, 257–263.

Thompson, G.D., Busacca, J.D., Jantz, O.K., Kirst, H.A., Larson, L.L., Sparks, T.C., 1995. Spinosyns: an overview of new natural insect management systems. Proc. Beltwide Cotton Conf. 2, 1039–1043.

Wilkinson, R., Balsari, P., Oberti, R., 1999. In: Plant production engineering, Pest control equipment, vol. 3. American Society of Agricultural Engineers, St Joseph, MI, USA (277pp.).

Wu, G., Miyata, T., 2005. Susceptibilities to methamidophos and enzymatic characteristics in 18 species of pest insects and their natural enemies in crucifer vegetable crops. Pestic. Biochem. Physiol. 82, 79–93.

Wu, G., Jiang, S.R., Miyata, T., 2004. Seasonal changes of methamidophos susceptibility and biochemical properties in *Plutella xylostella* (Lepidoptera: Yponomeutidae) and its parasitoid *Cotesia plutellae* (Hymenoptera: Braconidae). J. Econ. Entomol. 97, 1689–1698.

Weinzierl, R., Henn, T., Koehler, P.G., 1998. Microbial insecticides. ENY-275 (Online). <http://edis.ifas.uX.edu/IN081> (accessed 15.01.13).

Yang, P.J., Carey, J.R., Dowell, R.V., 1994. Temperature influence on the development and demography of *Bactrocera dorsalis* (Diptera: Tephritidae) in China. Environ. Entomol. 23, 971–974.

Zheng, F.S., Du, Y.Z., Wang, Z.J., Xu, J.J., 2008. Effect of temperature on the demography of *Galerucella birmanica* (Coleoptera:Chrysomelidae). Insect Sci. 15, 375–380.