Journal of Agrometeorology 21 (4) : 499-503 (December 2019)

Influence of temperature on spinosad toxicity in different populations of *Plutella xylostella* (Linnaeus)

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ABSTRACT

Diamond back moth, *Plutella xylostella* (Linnaeus) is one of the major insect-pest of cole crops, causing high yield losses. In present study, larval populations of *P. xylostella*, collected from different regions of Punjab i.e. Amritsar, Kapurthala, Malerkotla and Ludhiana were exposed to different concentrations of spinosad at 15, 20, 25 and 30 °C for evaluation of LC_{50} values. The LC_{50} (Lethal concentration) increased from lower (15 °C) to higher (30 °C) temperature for all populations of *P. xylostella.* Negative correlation was observed between the temperature coefficient and toxicity of spinosad towards *P. xylostella* populations, which decreased with increase in temperature. The LC_{50} values varied among different populations of *P. xylostella* i.e. Amritsar populations with higher LC_{50} values followed by Kapurthala, Malerkotla and Ludhiana populations. The temperature and insecticide exposure history both affected the toxicity of spinosad for *P. xylostella.* The information would be helpful in developing management strategies for *P. xylostella* according to prevailing environment conditions.

Key words: *Plutella xylostella;* spinosad; $LC_{50;}$ toxicity; temperature coefficient

The diamondback moth, *Plutella xylostella* (Linnaeus) (Lepidoptera: Plutellidae) is one of the most noxious insect-pest of cruciferous crops universally distributed throughout the world. (Saeed *et al*., 2018). The damage is caused by foliage feeding leading to retardation in growth of crop and resulting in severe yield losses (Sontakke *et al*., 2014). The high reproductive potential of diamond back moth, diversity and abundance of its host crops play a major role in deciding its status as cosmopolitan pest worldwide (Legwaila *et al.,* 2014). The most commonly followed strategy for management of diamond back moth is use of synthetic insecticides. However the indiscrimate use of insecticides has led to development of resistance in this pest due to increased selection pressure (Teja *et al*., 2018). Apart from conventional insecticides newer molecules such as natural insecticides are introduced which have novel mode of action and are safer for non-target organisms and mammals (Singh *et al*., 2017).

Spinosad is a natural insecticide derived from actinomycete, *Saccharopolyspora spinosa* having neurotoxic mode of action. Spinosad affects nervous system (Nicotinic acetyl choline and Gamma amino butyric acid receptors) of insect pest resulting in inhibition of feeding and paralysis (Singh *et al.,* 2017). It has been registered for management of diamond back moth and is widely used in more than 35 countries for its control (Anonymous, 2019).

Temperature is an important climatic factor, which influences biological activities of insect pest such as metabolism, growth, development, reproduction and survival (Duraimurugan, 2018; Nebapure *et al*., 2018). There is also strong correlation between the toxicity of insecticides and temperature, thus affecting the efficacy of insecticides (Jaleel *et al*., 2019). The variation in response of efficacy and temperature can be dependent upon method of application, concentration, mode of action of insecticides and species of insects. The present study was conducted to investigate the toxicity of spinosad towards different populations of *P. xylostella* collected from different regions of Punjab as influenced by with respect to variations in temperature.

MATERIALS AND METHODS

Raising of food crop

To provide continuous supply of food for *P. xylostella,* a month old seedlings of cauliflower (*Brassica oleracea* var. *botrytis L.*) were transplanted in the field. Insecticides use was avoided on food crop and any insect-pest infestation on the plants was checked only manually.

Rearing of *P. xylostella*

The larvae of diamondback moth (DBM) were collected from the cabbage/cauliflower fields of Punjab Agricultural University, Ludhiana and were reared for 22 generations, without exposure to any insecticides for maintenance of susceptible population. The larval populations of *P. xylostella* collected from the fields of cabbage and cauliflower from Amritsar, Kapurthala, Malerkotla and Ludhiana districts of Punjab were reared upto first generation only. The culture of *P. xylostella* was maintained on the cauliflower leaves in glass jars (10 ×15 cm) placed in an environmental chamber at 27±1° C and 65 per cent relative humidity (RH) in Insect Physiology Laboratory of Department of Entomology, Punjab Agricultural University, Ludhiana. The jars were covered with *dasuti* cloth and fastened with rubber bands around its rim and food was changed daily. The leaf portions bearing pupae were transferred into other glass jars and those remaining attached to the walls of the jars were allowed to emerge into adults as such. The emerging adults were sexed and transferred into new jars for mating and oviposition on the same day. A piece of cauliflower leaf placed in each jar acted as stimulant for egg laying. A cotton swab dipped in 10 per cent honey solution was hung from top of the *dasuti* cloth covering the mouth of the jar which provided food to the adults. The leaf with eggs laid upon was removed daily and replaced with a new one to facilitate further oviposition (Chandi and Singh, 2017).

Bioassay

The study was conducted in two subsequent years i.e. 2018 and 2019. Commercial formulation of insecticide spinosad 2.5 SC (Success) was procured for toxicity. The standard 'Leaf-disc dip' method of bioassay (Mann, 2003) was employed to determine LC_{50} values of the test-insecticide i.e. spinosad 2.5 SC against third instar larvae of *P. xylostella.* Different concentrations of spinosad were prepared by serial dilutions with distilled water. Leaf-discs (4.8 cm diameter) were cut from the centre of the middle leaves of cauliflower. Each disc was dipped in a concentration of the insecticide for 20 seconds and then allowed to dry at room temperature for about one hour by hanging it with the help of a clip. The leaf-discs were then shifted to plastic petri plates (5 cm diameter). Ten test-larvae (third instar larvae) were then transferred to

Table 1: Influence of temperature variation on spinosad toxicity in *Plutella xylostella* in year 2018

Populations	Temperature (° C)	LC_{50} (%)	Fiducial Limits		Slope ± S.E	Temperature coefficient		
			Lower Limit	Upper Limit		5° C	10° C	15° C
Amritsar	15	0.0068	0.0035	0.0154	1.26±0.30	-	-	-
	20	0.0070	0.0041	0.0155	1.68±0.56	-1.03	-	-
	25	0.0072	0.0042	0.0163	2.32±0.23	-1.03	-1.05	-
	30	0.0074	0.0041	0.0167	2.55±0.16	-1.02	-1.06	-1.08
Kapurthala	15	0.0064	0.0034	0.0116	1.60±0.25	-	-	-
	20	0.0065	0.0032	0.0157	2.19±0.35	-1.01	-	-
	25	0.0067	0.0034	0.0137	2.04±0.22	-1.03	-1.04	-
	30	0.0070	0.0039	0.0148	1.52±0.61	-1.04	-1.07	-1.09
Malerkotla	15	0.0060	0.0032	0.0120	1.47±0.26	-	-	-
	20	0.0063	0.0042	0.0130	1.42±0.10	-1.05	-	-
	25	0.0065	0.0036	0.0137	1.23±0.13	-1.03	-1.08	-
	30	0.0067	0.0038	0.0144	1.56±0.42	-1.03	-1.06	-1.11
Ludhiana	15	0.0055	0.0025	0.0114	2.34±0.47	-	-	-
	20	0.0058	0.0029	0.0129	2.12±0.74	-1.05	-	-
	25	0.0060	0.0035	0.0117	1.78±0.25	-1.03	-1.09	-
	30	0.0063	0.0027	0.0125	1.50±0.16	-1.05	-1.08	-1.14
Susceptible	15	0.0045	0.0023	0.0102	1.15±0.26	-	-	-
	20	0.0055	0.0026	0.0094	1.45±0.24	-1.22	-	-
	25	0.0057	0.0022	0.0105	1.63±0.30	-1.03	-1.26	-
	30	0.0058	0.0031	0.0122	1.96±0.55	-1.01	-1.05	-1.28

Table 2: Influence of temperature variation on spinosad toxicity in *Plutella xylostella* in year 2019

Populations	Temperature (° C)	LC_{50} (%)	Fiducial Limits		Slope ± S.E	Temperature coefficient		
			Lower Limit	Upper Limit		5 ° C	10° C	15° C
Amritsar	15	0.0075	0.0042	0.0192	1.19±0.66	-	-	-
	20	0.0082	0.0031	0.0357	1.26±0.12	-1.09	-	-
	25	0.0088	0.0055	0.0213	1.45±0.34	-1.07	-1.17	-
	30	0.0092	0.0025	0.0101	1.08±0.23	-1.04	-1.12	-1.22
Kapurthala	15	0.0068	0.0035	0.0137	1.22±0.18	-	-	-
	20	0.0074	0.0037	0.0182	2.04±0.52	-1.08	-	-
	25	0.0080	0.0045	0.0190	1.70±0.42	-1.08	-1.17	-
	30	0.0084	0.0050	0.0215	2.58±0.18	-1.05	-1.13	-1.23
Malerkotla	15	0.0063	0.0024	0.0124	1.51±0.48	-	-	-
	20	0.0067	0.0033	0.0165	2.34±0.23	-1.06	-	-
	25	0.0071	0.0044	0.0185	2.62±0.26	-1.06	-1.12	-
	30	0.0076	0.0043	0.0176	1.15±0.70	-1.07	-1.13	-1.20
Ludhiana	15	0.0057	0.0020	0.0204	1.06±0.17	-	-	-
	20	0.0062	0.0028	0.0107	2.46±0.82	-1.08	-	-
	25	0.0066	0.0036	0.0135	1.18±0.25	-1.06	-1.15	-
	30	0.0071	0.0042	0.0146	1.63±0.32	-1.07	-1.14	-1.24
Susceptible	15	0.0050	0.0017	0.0122	2.13±0.55	-	-	-
	20	0.0058	0.0030	0.0102	1.88±0.65	-1.16	-	-
	25	0.0063	0.0023	0.0096	1.20±0.43	-1.08	-1.26	-
	30	0.0065	0.0018	0.0088	2.13±0.30	-1.03	-1.12	-1.30

each petri plate containing a treated leaf-disc. Preliminary bioassay was carried to determine the range of toxic levels of the test-insecticide. Based on this, at least six serial dilutions were prepared to work out LC_{50} with three replications. The larvae were allowed to feed on treated leaf-discs kept at different temperatures i.e. 15, 20, 25 and 30° C for 48 hours. Experiment was conducted with three replications and ten larvae per replication. The mortality was recorded after 48 hours of exposure of larvae to the treated leaf discs.

Data analysis

The log concentration-mortality regression was worked out by log probit technique (Finney, 1971) employing the computer programme POLO (Robertson *et al*., 1980). Temperature coefficients of insecticide (spinosad) were also calculated (Musser and Shelton, 2005).

RESULTS AND DISCUSSION

The results indicated the influence of variation in temperature on toxicity levels of spinosad with respect to different populations of *P. xylostella* collected from different regions of Punjab. Negative correlation was observed between tested temperature range and toxicity of spinosad in both years i.e. 2018 and 2019. In the year 2018 (Table1) the increase in LC_{50} values was observed from 15° C to 30°C for all populations of *P. xylostella.* In terms of LC_{50} values, the toxicity of spinosad was 1.03 and 1.08 times lower at 20°C and 30°C as compared to 15°C for populations of Amritsar region respectively. Similarly the decrease in toxicity of spinosad for Kapurthala population was recorded at 20°C and 30°C i.e. 1.01 to 1.09 folds respectively. The Malerkotla population showed 1.11 times lower spinosad toxicity at 30°C as compared to 15°C. The decrease in spinosad toxicity was observed at 30°C i.e. 1.14 times as compared to 15°C for Ludhiana population of *P. xylostella.* The spinosad toxicity for susceptible population was 1.28 times lower at 30°C as compared to 1.22 at 20°C. On comparison of regions the higher spinosad toxicity (1.28) was displayed towards susceptible population as compared to other populations i.e. Ludhiana, Malerkotla, Kapurthala and Amritsar. The spinosad toxicity was recorded low for Amritsar population followed by Malerkotla, Kapurthala and Ludhiana populations. In study period 2019 (Table 2) increase in LC_{50} values were recorded as compared to 2018 for all populations of *P. xylostella.* The trend of toxicity with respective to different temperatures was similar as of 2018 i.e. lower spinosad toxicity at 30°C. The spinosad toxicity decreased upto 1.30 times at 30°C in comparison of 1.16 at 20°C for susceptible population of *P. xylostella.* The similar pattern of toxicity decrease at 30°C was observed for other regions also i.e. Amritsar, Kapurthala, Malerkotla and Ludhiana. The toxicity of spinosad was 1.24. 1.20, 1.23, 1.22 times lower at 30°C for Ludhiana, Malerkotla, Kapurthala and Ludhiana populations, respectively as compared to 15°C.

The results of present study are in line with findings of Mansoor *et al*., (2015) who also reported decrease in toxicity of spinosad with increase in temperature range in green lacewing, *Chrysoperla carnea* (Stephens). Musser and Shelton (2005) also observed low toxicity of spinosad at high temperature in *European corn borer, Ostrinia nubilalis* (Hubner). Khan and Akram (2014) reported negative correlation between the temperature and toxicity of spinosad in house fly*, Musca domestica* (Linnaeus). Insecticides with a negative temperature coefficient become more toxic at lower temperatures (Mansoor *et al*., 2015). The phenomenon which is responsible for inverse relationship between toxicity and temperature in case of spinosad is not well understood (Khan and Akram, 2014).The negative temperature coefficient of toxicity would have important practical implications for controlling insect pests such as *P.xylostella* during cool weather conditions (Kumar and Chapman, 1983).The variation in the LC_{50} values and toxicity between various populations of *P. xylostella* (Amritsar, Kapurthala, Malerkotla, and Ludhiana) was found. It could be due to difference in insecticide exposure history of all populations of *P. xylostella*. Earlier studies by Chandi *et al*., (2016) also revealed that LC_{50} values of Amritsar population were higher as compared to Kapurthala and Ludhiana for spinosad. It is to be noted that the rate of insecticide applied for control of any pest in any area plays an important role in contribution towards pest resistance along with other physical and biological factors. In present investigation both temperature and background of *P. xylostella* in context to insecticide exposure acted as important factors for toxicity of spinosad, further investigation nevertheless required.

CONCLUSION

The temperature coefficient is negatively correlated to spinosad toxicity in respect of all populations of *P. xylostella*. The judicious application of spinosad in context to particular temperature could be helpful in generating effective results. Hence, the present study would be helpful in developing management strategies for efficient control of *P. xylostella* by spinosad in changing environmental conditions, mainly temperature variations due to climate change.

ACKNOWLEDGEMENT

We are thankful to the Head of the Department of Entomology, Punjab Agricultural University, Ludhiana (India) for providing the necessary facilities.

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Received : July 2019 ; Accepted : November 2019