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Sonika Sharma
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Hafeez Ahmad
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Devinder Sharma
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Suheel Ahmad Ganai
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Ramandeep Kour
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Nadeya Khaliq
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Thanlass Norboo
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Correspondence
Sonika Sharma
Division of Entomology, FoA, Main Campus, SKUAST-J, Chatha, Jammu, J&K, India

Studies on seasonal incidence and field efficacy of insect growth regulators against diamondback moth, *Plutella xylostella* (L.) infesting cabbage, *Brassica oleracea* var. *capitata* (L.)

Sonika Sharma, Hafeez Ahmad, Devinder Sharma, Suheel Ahmad Ganai, Ramandeep Kour, Nadeya Khaliq and Thanlass Norboo

Abstract
A field experiment was conducted on cabbage (*Brassica oleracea* var. *capitata*) at the Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, India. The infestation of *Plutella xylostella*, diamondback moth started from the 5th standard week (0.88 larvae plant^{-1}) and reached peak (18.68 larvae plant^{-1}) in 14th standard week. The maximum and minimum temperature showed significant positive correlation with larval population of diamondback moth whereas, non-significant correlation with relative humidity and rainfall. Regression studies revealed that the weather factors had 77.60 percent contribution towards larval population. Abiotic factors like temperature, relative humidity, extent and distribution of rainfall, influenced the infestation and stabilization of *P. xylostella* in cabbage. Amongst the different treatments fenvalerate showed higher efficacy against *P. xylostella* in reducing pest population. Mean population of *P. xylostella* after two sprays revealed that fenvalerate 0.004% was effective and superior. The next best were lufenuron 0.006% and novaluran 0.100% which were at par. chlorfenapyr 0.150% was found to be least effective against *P. xylostella.*

Keywords: *Brassica oleracea* var. *capitata*, *Plutella xylostella*, fenvalerate, lufenuron, novaluran, chlorfenapyr

1. Introduction
Cabbage (*Brassicae oleracea* var. *capitata* Linn.) is one of the most important cultivated vegetable crops grown in India. It is grown more or less in all the states. India is the second largest producer of cabbage in the world after China [27]. The total area under cultivation of cabbage in India is 386 thousand hectares with an annual production to the tune of 8585 thousand tonnes [1]. The total area under cultivation of cabbage in Jammu and Kashmir is 249 hectares with an annual production to the tune of 7323 tonnes [2]. China is major cabbage producing country with 47 percent of world followed by India with 12 percent of world production [26]. The crop is prone for infestation by a number of insect pests consisting sucking and defoliating insects starting from germination to harvesting stage of the crop. Cabbage production is limited by attacks of insects' pests [14]. In India, a total of 37 (thirty seven) insect pests have been reported to feed on cabbage, of which the diamond back moth, *Plutella xylostella* Linneaus are the major constraints for profitable cultivation of the crop (Younas *et al.*, 2004) and reported 50-80 percent loss in marketable yield of cabbage due to attack of *P. xylostella* [12]. Since it has attained the status of major pest, farmers are more concern to control it. It has been estimated that, globally the cost of control is about of 1 billion US $ [10]. However in India, the cost of pest control particularly DBM (*P. xylostella),* cabbage worm (*S. litura)* and aphids, was estimated around US $ 168 million [17]. The wide spread use of insecticides on cabbage and cauliflower has led to the elimination of natural enemies of DBM [24], thus paving the way to attain the status of most noxious pest of various cole crops in India [21]. In Jammu & Kashmir, no such work has been done on these aspects. Therefore, keeping in view the economic importance of the crop and the magnitude of the damage caused by the insect, the present study was proposed to study the seasonal incidence and field efficacy of insect growth regulators against diamondback moth, *Plutella xylostella.*

2. Materials and Methods

The present investigation was undertaken to study the seasonal incidence and management of diamondback moth at University Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during *Rabi*, 2014-15 & 2015-16. Cabbage variety "Pride of India" was raised with recommended agronomic practices in the plot size of 4×3 m^2 with row to row and plant to plant distance of 60 and 45 cm, respectively. For the observation on diamond back moth direct visual counting method was used and population was recorded on ten plants selected randomly from each replicate at weekly intervals during morning hours when most of the insect species are less active. These data were subjected to correlation and regression analysis with various abiotic factors of the environment and the statistical analysis were worked out. For the diamondback moth management, the experiment was laid out in randomized block design (RBD) with four replications and five treatments. Observations on the diamondback moth population from the selected plants were recorded before and after 1, 3, 7 and 15 days of spray. Data thus obtained were analysed statistically and the efficacy of the insecticides were worked out.

3. Results and Discussion

The pooled data regarding *P. xylostella* in cabbage field during two years, 2014 -15 and 2015-16 (Table 1; Fig. 1) revealed that infestation (0.88 larvae/plant) was observed right from 5th standard week, when the mean maximum, minimum temperature, mean relative humidity and rainfall were 19.40 and 5.85 ºC, 92.50 and 57.50 percent and 9.15 mm, respectively. The larval population ranged from 0.88-18.68 larvae per plant. With an increasing larval population during successive weeks larval population reached its maximum (18.68 larvae/plant) in 14th standard week, when the mean maximum and minimum temperature, relative humidity (morning) and (evening) and rainfall were 28.20 and 15.35 ºC, 79.50 and 53.50 percent and 53.70 mm, respectively. Thereafter, the larval population declined and reached to minimum of 1.26 larvae/plant during 19th standard week when the mean maximum, minimum temperature, relative humidity and rainfall were 36.70 and 20.50 °C, 58.35 and 33.90 percent and 6.55 mm, respectively. The maximum population of diamondback moth in the month of March was also reported by Devjani and Singh [8]; Kumar *et al*. [13] and Venkateswarlu *et al*. [23] which are in agreement with the present findings. On the contrary, Shukla and Kumar [20] reported that in Rajasthan, the diamondback moth appeared in the beginning of September and the population reached its peak by the end of November followed by a declined phase from the last week of December to the last week of January, but this difference may probably be due to the difference in transplanting time and the prevailing climatic conditions of the region. However, the findings of Parvathi *et al*. [16] are in conformity with the present findings as they also reported that the damage due to diamondback moth was severe in the later stages of the crop (70 days after planting). Devi and Raj [7] also observed that the peak population of diamondback moth coincides with the active vegetative and late growth stages of crops.

The results on correlation studies revealed (Table 2), that minimum temperature had positive and highly significant effect with 'r' values (r = 0.611) and the maximum temperature had positive and significant effect on larval population with 'r' values (r = 0.463). On the other hand relative humidity (morning and evening) had negative effect on larval population with r values (r = -0.274 and r = -0.280), whereas the rainfall had positive effect on larval population with 'r' value (r = 0.357). Regression studies for the effect of abiotic factors on the build-up of *P. xylostella* population revealed that it was significantly influenced by weather factors with their contribution being 77.60%. The present findings of the significant positive correlation of diamondback moth population with the maximum and minimum temperature was also reported by Venkateswarlu *et al*. [23] but the findings of the same author that significant negative relation with the relative humidity and significant positive with rainfall is in contrast with the present findings as it has been observed that the relative humidity has no significant effect has negative and non-significant relation with the population fluctuation of diamondback moth. Jat *et al*. [11]; Vanlaldiki *et al*. [22] and Meena and Sharma [15] also reported that the minimum temperature showed positive and significant relation with the larval population of diamondback moth which corroborates the present findings. Similarly the present finding of the non-significant relation of diamondback with the relative humidity is in conformity with the observations made by Bana *et al*. [3]. Similarly, Venkateswarulu *et al*. [23] and Bindu, [4] reported diamondback moth showed significant positive correlation with maximum temperature, minimum temperature, whereas significant negative correlation with morning and evening relative humidity was detected. On the other hand, rainfall was not found to influence.

The pooled data (Table 3; Fig. 2; First spray) revealed that there was no significant difference between the treatments one day before spray. The observations recorded on 1st day after spray revealed that all the treatments proved significantly superior over control. Fenvalerate 20 ES (7.13larvae/ plant) was found to be most effective treatment followed by lufenuron 5 EC (12.13 larvae/ plant), novaluron 10 EC (12.25 larvae/ plant) were statistically at par with each other whereas chlorfenapyr10 SC (12.75 larvae /plant) was found to be least effective against the *P. xylostella*. On 3rd day after spray revealed that all the treatments proved significantly superior over control. Fenvalerate 20 ES (4.75 larvae/ plant) was found to be most effective treatment followed by lufenuron 5 EC (10.63 larvae/ plant), novaluron 10 EC (10.88 larvae/ plant) were statistically at par with each other whereas chlorfenapyr10 SC (11.63 larvae /plant) was found to be least effective. The observations recorded on 7th day after spray revealed that all the treatments proved significantly superior over control. Fenvalerate 20 ES (2.00larvae/ plant) was found to be most effective treatment followed lufenuron 5 EC (5.50 larvae/ plant), novaluron 10 EC (5.88 larvae/ plant) were statistically at par with each other whereas chlorfenapyr10 SC (7.50 larvae /plant) was found to be least effective. On 15thday after spray revealed that all the treatments proved significantly superior over control. Fenvalerate 20 ES (2.75 larvae/ plant) was found to be most effective treatment in reducing the larval population. The treatments viz., lufenuron 5 EC (6.25 larvae/ plant), novaluron 10 EC (6.63 larvae/ plant) were statistically at par with each other whereas chlorfenapyr 10 SC (8.37 larvae /plant) was found to be least effective against the *P. xylostella*. Second spray (Table 3; Fig. 2) revealed that there was no significant difference between the treatments one day before spray. The observations recorded on 1st day after spray revealed that all the treatments proved significantly superior over control. Fenvalerate 20 ES (6.63 larvae/ plant) was found to be most effective treatment followed by lufenuron 5 EC (8.75 larvae/ plant), novaluron 10

EC (9.25 larvae/ plant) were statistically at par with each other whereas chlorfenapyr 10 SC (10.75 larvae /plant) was found to be least effective. The observations recorded on 3rd day after spray revealed that all the treatments proved significantly superior over control. Fenvalerate 20 ES (4.13 larvae/ plant) was found to be most effective treatment in reducing the larval population. The treatments viz., lufenuron 5 EC (7.00 larvae/ plant), novaluron 10 EC (7.13 larvae/ plant) were statistically at par with each other whereas chlorfenapyr10 SC (9.00 larvae /plant) was found to be least effective. The observations recorded on 7thday after application. Fenvalerate 20 ES (1.53 larvae/ plant) was found to be most effective treatment in reducing the larval population. The treatments viz., lufenuron 5 EC (4.63 larvae/ plant), novaluron 10 EC (5.00 larvae/ plant) were statistically at par with each other whereas chlorfenapyr10 SC (6.13 larvae /plant) was found to be least effective. On 15th day after spray all the treatments proved significantly superior over control. Fenvalerate 20 ES (2.25 larvae/ plant) was found to be most effective treatment followed by lufenuron 5 EC (5.13 larvae/ plant), novaluron 10 EC (5.75 larvae/ plant) were statistically at par with each other whereas chlorfenapyr10 SC (7.38 larvae /plant) was found to be least effective against the *P. xylostella*. Our results are in agreement with Gautam and Pareek [9] who found that fenvalerate 20 ES be most effective treatment in reducing the larval population. The results are in line with Sharma [19] who reported that lufenuron (0.006%) was the most promising insecticide. The similar results were also reported by Sangareddy *et al.* [18] who recorded novaluron at 0.5, 0.075 and 0.1% to be highly toxic and best to DBM, based on % reduction of larval population in cauliflower. Our results are in agreement with the findings of Chatterjee and Mondal [5] who reported the effectiveness of chlorfenapyr against diamondback moth on cabbage and similarly Choudhary *et al.* [6] reported that chlorfenapyr was less effective as compared to novaluron against *P. xylostella* on cabbage.

Table 1: Seasonal incidence of *P. xylostella* on Cabbage (pooled).

Standard week	*Larval population / plant	Metrological Parameters				
		Temperature (ºC)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
5	0.88	19.40	5.85	92.50	57.50	9.15
6	2.15	21.50	6.30	87.50	47.00	1.40
7	2.97	22.75	7.90	87.00	49.50	2.90
8	5.19	24.10	10.05	87.50	60.00	31.65
9	7.40	23.40	10.45	87.00	62.00	58.30
10	11.36	23.75	11.35	86.00	57.50	14.45
11	14.48	22.70	10.50	88.50	66.00	86.70
12	15.63	28.35	13.00	82.00	49.50	0.10
13	17.43	28.35	15.05	84.10	59.80	49.80
14	18.68	28.20	15.35	79.50	53.50	6.70
15	17.17	31.90	15.60	75.45	39.60	0.80
16	14.71	32.10	17.80	77.00	48.00	30.00
17	11.26	35.80	17.20	65.65	43.85	0.00
18	9.43	35.40	17.65	64.15	36.05	1.30
19	9.04	37.80	21.65	58.35	38.95	6.55
Range	0.88-18.68	19.65-36.70	12.30-41.00	58.35-93.00	33.85-66.00	0.00-86.70
Mean	10.68	27.91	25.91	79.77	50.32	22.34
S.Em(±)	6.59	6.19	4.71	9.82	9.74	46.88

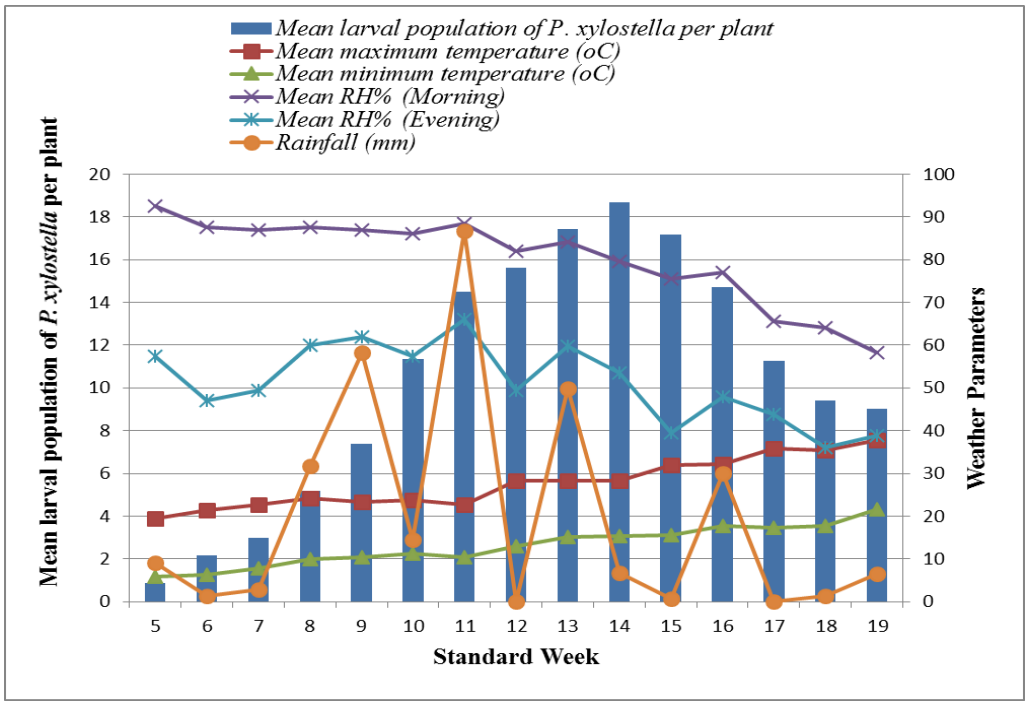

Fig 1: Seasonal incidence of larval population of *P. xylostella* on cabbage (pooled).

Table 2: Correlation coefficients and regression model between mean larval population of *P. xylostella* and abiotic factors.

Characters	'r' values
	Pooled
X_1	0.463*
X_2	0.611**
X_3	-0.274
X_4	-0.280
X_5	0.357
Regression Model	$Y= -115.33 + 1.12X_1 + 1.35X_2 + 1.12X_3 - 0.28X_4 + 0.08X_5$ ($R^2 = 0.776$)

**Correlation is significant at 0.01level

*Correlation is significant at 0.05level

Where,

Y= Mean larval population of *P. xylostella*

X_1= Maximum temperature (°C)

X_2= Minimum temperature (°C)

X_3= Mean relative humidity morning (%)

X_4= Mean relative humidity evening (%)

X_5=Rainfall (mm)

Table 3: Efficacy of insecticides against *P. xylostella*, population on cabbage (pooled).

Treatments	Concentration (%)	Larval population of *Plutella xylostella* / plant									
		First spray					Second spray				
		1DBS*	1DAS*	3DAS	7DAS	15DAS	1DBS	1DAS	3DAS	7DAS	15DAS
Novaluron 10 EC	0.10%	15.50 (0.41)	12.25 (0.43)	10.88 (0.66)	5.88 (0.47)	6.63 (0.43)	13.38 (0.24)	9.25 (0.43)	7.13 (0.32)	5.00 (0.41)	5.75 (0.32)
Lufenuron 5 EC	0.006%	15.25 (0.43)	12.13 (0.47)	10.63 (0.47)	5.50 (0.41)	6.25 (0.43)	12.75 (0.25)	8.75 (0.32)	7.00 (0.00)	4.63 (0.32)	5.13 (0.38)
Fenvalerate 20 ES	0.004%	14.75 (0.60)	7.13 (0.66)	4.75 (0.43)	2.00 (0.20)	2.75 (0.43)	12.38 (0.43)	6.63 (0.38)	4.13 (0.32)	1.53 (0.33)	2.25 (0.25)
Chlorflenapyr 10 SC	0.15%	15.38 (0.32)	12.75 (0.32)	11.63 (0.75)	7.50 (0.20)	8.37 (0.13)	13.13 (0.63)	10.75 (0.48)	9.00 (0.46)	6.13 (0.32)	7.38 (0.38)
Control	-	16.00 (0.29)	16.25 (0.72)	16.75 (0.60)	16.63 (0.32)	16.63 (0.32)	13.00 (0.71)	13.63 (0.55)	14.50 (0.41)	16.38 (0.24)	16.88 (0.66)
CD ($p \leq 0.05$)	-	NS	1.58	1.84	0.63	0.87	NS	1.45	0.99	1.09	1.38
SE(m)	-	0.40	0.51	0.59	0.20	0.28	0.53	0.47	0.32	0.35	0.44

*DBS – Days before Spray,*DAS – Days after Spray

Figures in parenthesis are square √x+0.5 transformed values

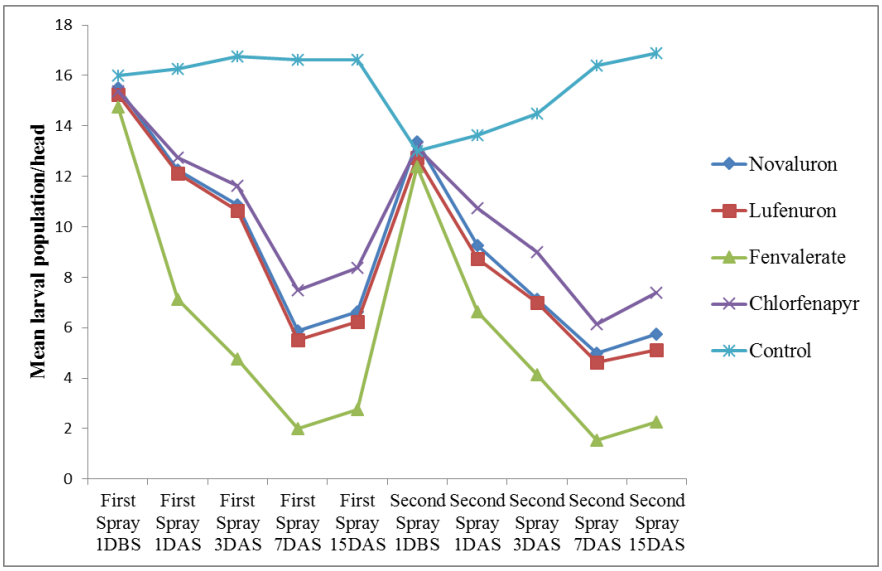

Fig 2: Efficacy of different insecticides against *P. xylostella* (pooled).

4. Conclusion

From the study, it can be concluded that the *P. xylostella* population remained active from February to May with the peak activity in 14th standard week. Fenvalerate followed by lufenuron were found to be best treatment against *P. xylostella* followed by novaluran and chlorfenapyr.

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