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Advancing Integrated Pest Management: Utilizing Pheromone Traps for Population Monitoring of *Plutella xylostella* in Cole Crops

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Plutella xylostella, commonly known as the diamondback moth poses significant challenges to Cole crops, impacting their growth and ultimately affecting yields. Its rapid reproduction coupled with its ability for developing pesticide resistance has elevated the diamondback moth to a critical concern for farmers and agricultural systems worldwide. The adult population of Diamondback moth was thus monitored during two cropping seasons (*Kharif* and *Rabi* season) at three locations *viz*., Vegetable Experimental Field, Faculty of Horticulture, SKUAST-K, Shalimar, Urban Technology Park, SKUAST-K, Habbak and Ichgam village in district Budgam using two different *Plutella xylostella* synthetic sex lures (SKUAST-K and *Chipku* lures). During *Kharif* season, the adult diamondback population was monitored from 18th to 28th SW with a maximum trap catch in the last

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week of June (26th SW) at Shalimar; whereas, both in Budgam and Habbak, the highest trap catch was in first week of June (23rd SW). However, in *Rabi* season, the adult population was monitored from 34th to 44th SW; the highest adult trap catch was in third week of September (38th SW) at Shalimar, though, in Budgam and Habbak, the moth catch peaked to maximum collection in first and second week of October (40th and 41st SW), respectively. During both the seasons and at all the locations, SKUAST-K lure proved more efficacious than *Chipku* lure. Besides, simple correlation analysis revealed that maximum temperature had positive and non-significant correlation with adult moth catches; conversely, the rainfall and relative humidity was negatively correlated and non-significant with *P. xylostella* adult trap catches throughout both observed seasons.

Keywords: Diamondback moth; lures; monitoring; trap catch.

1. INTRODUCTION

The Brassicaceae family, also known as Cruciferae, holds particular significance among vegetables. It is distinguished for its remarkable richness in vitamins, high fiber content, minimal fat composition, and low caloric value. Moreover, these plants are recognized for their potential as sources of compounds with medicinal and anticancer properties [1,2]. However, in India, the productivity of crucifers encounters considerable challenges, with insect pests ranking among the foremost constraints. Among various insect pests attacking these crops, the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae) is found to be most prevelant and highly destructive in nature and thereby results in colossal losses Debbarma et al. [3]; Sithole et al. [4]; Farias et al. [5]. Characterized by a short life cycle, this pest demonstrates an excellent ability to thrive in adverse weather conditions and disperse widely, additionally, its quick generation turnover further contributes to its persistence Duarte et al. [6,7]. In India, the projected yearly crop losses owing to this pest amounts to US $16 million and can cause 30-100 per cent crop losses to cole crops Ahmad et al. [8]; Uthamasamy et al. [9], while the control costs alone in Brassica crops, are anticipated to be US $4–5 billion globally Shen et al. [10].

The farmers in Kashmir commonly rely on synthetic insecticides to manage cruciferous pests, throughout the planting-to-harvest cycle. Nevertheless, the diamondback exhibits a tendency to develop resistance to insecticides used against it [11]. Consequently, a consensus exists that adopting an integrated approach is the most effective strategy for achieving a sustainable pest management. Thus, population monitoring *via* synthetic sex pheromone traps serves as a crucial diagnostic approach for early pest detection, even low-density pest populations [12].

2. MATERIALS AND METHODS

The population of *P. xyllostella* adult moth was monitored at three different locations *viz*; Vegetable Experimental Field, Faculty of Horticulture, SKUAST-K, Shalimar, Urban Technology Park, SKUAST-K, Habbak, and commercial Farmers Field in Budgam during both the *Kharif* and *Rabi* season of year 2022 and at each location, three polyethylene funnel traps of each synthetic sex lure (SKUAST-K and *Chipku* lures) were installed for recording the population of adult male moth.

SKUAST-K sex pheromone lures of Diamondback moth (Pheromone Laboratory, Division of Entomology, SKUAST-K, Shalimar) and commercial "*Chipku*" synthetic sex lures (Turning Point Natural Care, Pune, Maharashtra) impregnated with the sex pheromone of *Plutella xuloostella* (Z)-11-hexadecenal (Z11-16:Ald) and (Z) -11-hexadecenyl acetate (Z11-16:Ac) were placed in polyethylene funnel traps to monitor Diamondback moth adult population. The pheromone traps were installed after a month of crop transplanting till final harvest of the crop. Three traps were mounted on wooden poles in a cabbage plot at each of the three locations. Traps were adjusted to hang just above the crop canopy at all the growth stages. Lures were replaced after every fortnight or sooner, if the insect trap became clogged. Traps were monitored at weekly interval and data on the number of adult Diamondback moths caught per trap was recorded. After the count of adult moth trapped in each trap, these were removed from the polyethylene funnel trap and discarded. The mean number of Diamondback moth adults caught per trap per week was recorded for each site.Correlation analysis between important abiotic factors and adult population of Diamondback moth, as monitored through pheromone traps was computed at five per cent level of significance to work out the

effect of such abiotic factors on the population builds up of the pest.

3. RESULTS

3.1 Monitoring of Adult Diamondback Moth with SKUAST-K and *Chipku* Pheromone Lure

The first adult catch of diamondback moth lured with SKUAST-K and *Chipku* sex pheromone in polyethylene funnel traps got initiated during 18th SW. Throughout the monitoring period, three distinct peaks in moth captures were observed in 20th, 23rd, and 26th SW. The highest trap catches occurred during the 23rd SW (first week of June), with 31.3 and 27.6 adult moths captured in Budgam and Habbak, respectively, using SKUAST-K lure; in contrast, *Chipku* lure yielded 18.6 and 15.3 moth trap catch. However, at location Shalimar, the maximum adult population was observed during the 26th SW, with 23.6 and 11.6 moths capturing by SKUAST-K and *Chipku* lure respectively. Subsequently, moth trap catches declined following crop harvest (Table 1).

During *Rabi* season, the diamondback moth trap catch with both of the pheromone lures was initiated during 34th SW. At Shalimar, the highest trap catch was observed during 38th SW, with 19.3 and 10.3 moths caught with SKUAST-K and *Chipku* lure, respectively. However, in Budgam and Habbak, the maximum adult population was observed during 40th and 41st SW, with 26.3 and 23.6 moths captured using SKUAST-K lure, respectively; on the other hand, 14.3 and 12.6 moth trap catch was observed with *Chipku* lure, at their respective locations (Table 2).

3.2 Efficacy of Different Sex Lures with Respect to Locations and Seasons

Across all the locations and in both the seasons, it was consistently evident that the SKUAST-K sex pheromone lures demonstrated superior efficacy in comparison to *Chipku* lures. During *Kharif* season, the SKUAST-K lure trapped maximum adult moth catch than the *Rabi* season; moreover, the highest adult diamondback moths were monitored at location Budgam during *Kharif* season in comparison to both *Rabi* season and locations Habbak and Shalimar (Table 3).

3.3 Correlation Matrix of Abiotic Factors with Adult Population of *P. xylostella*

A simple correlation matrix between adult moth trap catch and maximum and minimum temperature was non-significant and positively correlated at Budgam and Habbak; whereas, a highly significant and positively correlated with *P. xylostella* adult moth catches was computed at Shalimar. The rainfall and relative humidity (evening) was non-significant and negatively correlated; though at Shalimar and Budgam, the trap catch was negatively correlated and non-significant with relative humidity (morning), while at Habbak, it was significant and negatively correlated (Table 4).

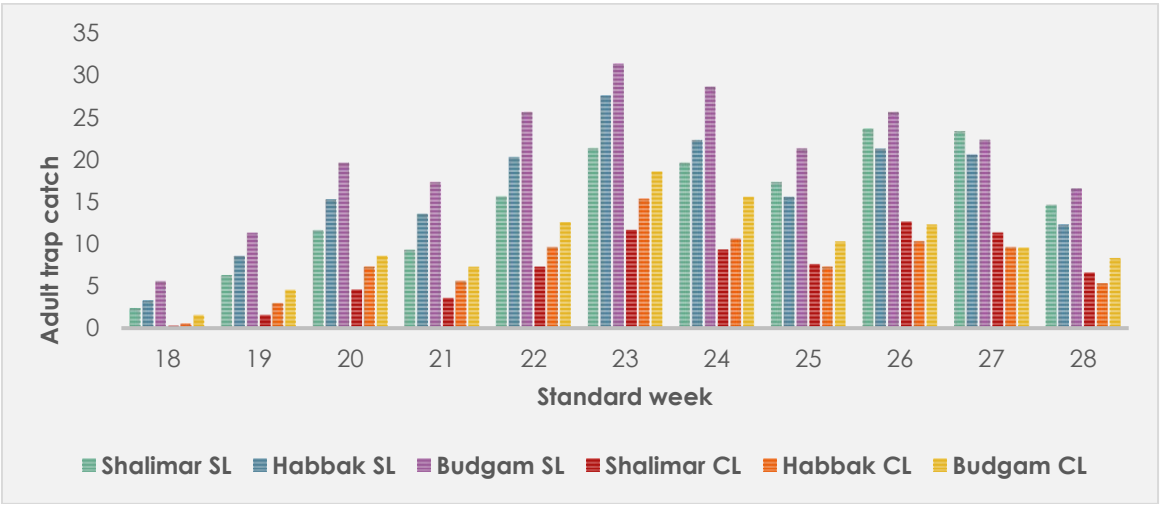

Fig. 1. Adult trap catches of *Plutella xylostella* in Cole crops at different locations using SKUAST-K and *Chipku* lure during *Kharif* 2022

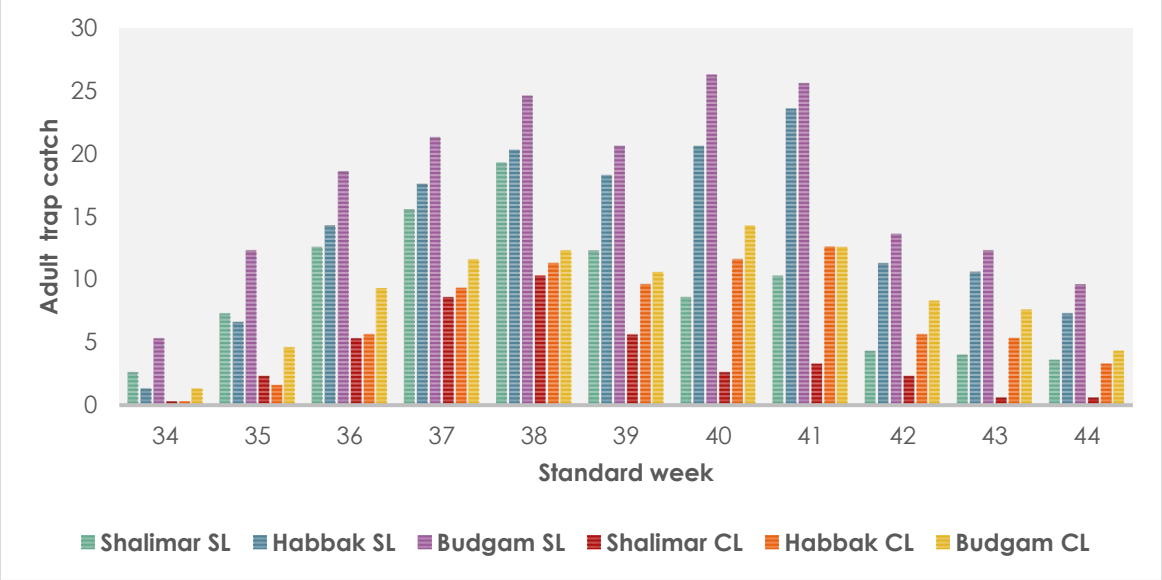

Fig. 2. Adult trap catches of *Plutella xylostella* in Cole crops at different locations using SKUAST-K and *Chipku* lure during *Rabi* 2022

During Rabi season, a positive and significant correlation was observed between adult moth trap catch and maximum temperature at location Shalimar; whereas, at Budgam and Habbak, the maximum temperature was non- significant but positively correlated with moth catches. The minimum temperature and rainfall had negative and non-significant correlation with the trap catches. The relative humidity (morning) was highly significant and negatively correlated at Shalimar, whereas, non-significant and negatively correlated with *P. xylostella* adult moth catches at Habbak. The relative humidity (evening) was highly significant and negatively correlated with the adult moth trap catches (Table 5).

4. DISCUSSION

The findings from our study on monitoring adult population of diamondback moth *via* sex pheromone lures revealed consistent fluctuations in moth trap catches. The decline in the moth population (21.3 and 15.6) during third week of June (25th SW) could be attributed to precipitation during the said period. The decreased moth catches is corroborated with the findings of Reddy and Urs [13]; the authors opined that aging of pheromone lures often leads to declined catch; though, Mayer and Mitchell [14], attributed low moth catches during rains due to reduced emission rate from the septa. The peak in moth population during 23rd and 26th SW could be attributed to the high pheromone volatility and increased emission rates driven by the elevated temperatures from 24.92 to 29.85℃ and 19.34 to 32.64℃, that can accelerate the release of the pheromone from the rubber septa Abbes and Chermiti [15] and subsequent reduction during 27th and 28th SW finds the support from the work of Ahmad and Ansari [16]; Hidayah et al. [17]. The authors too observed less moth catches due to the strong influence of the abiotic factors.

Regarding *P.xylostella* adult moth catches during *Rabi* season, our results revealed a consistent increase in moth captures in the initial crop growth phase, reaching a maximum catch during 38th SW at location Shalimar; which could be attributed to congenial climatic conditions with negligible precipitation and warmer temperatures throughout the period of observation. Similarly, the peak adult catches recorded during 40th and 41st SW in Budgam and Habbak, could be explained by the low rainfall and lower relative humidity observed during the present investigations, aligns with the findings of Hemchandra and Singh [18] who too reported higher population under conditions of meagre precipitation and less of moisture. The significant reduction in the pest density due to the lower temperature and higher relative humidity as advocated by Hemchandra and Singh [18]; Maity et al. [19] is in consonance with the present findings for the decreased catch from 42nd SW at all the locations.

Table 1. Population monitoring of adult Diamondback Moth (*Plutella xylostella*) in cole crops at different locations during *Kharif* 2022

Standard Week (SW)	Temperature (℃)		Rainfall (mm)	Relative Humidity (%)		Weekly adult moth catch of *Plutella xylostella* (Mean ± SE)					
						Locations					
						Shalimar		Budgam		Habbak	
						Pheromone Lures					
	Maximum	Minimum		Morning	Evening	SKUAST K Lure	*Chipku* Lure	SKUASTK Lure	*Chipku* Lure	SKUAST K Lure	*Chipku* Lure
18	23.28	10.21	2.05	79.00	57.28	2.38 ± 0.3	0.3± 0.3	5.6 ± 0.3	1.6± 0.3	3.3± 0.3	0.6± 0.3
19	28.64	10.22	2.34	69.71	37.57	6.3 ± 0.3	1.6 ± 0.3	11.3 ±0.3	4.6± 0.3	8.6± 0.3	3.0± 0.3
20	26.28	10.57	0.00	68.85	53.00	11.6 ±0.3	4.6 ± 0.3	19.6 ±0.3	8.6± 0.3	15.3± 0.3	7.3± 0.3
21	25.01	10.07	3.31	73.71	51.00	9.3 ± 0.3	3.6 ± 0.3	17.3± 0.3	7.3± 0.3	13.6± 0.3	5.6± 0.3
22	24.92	11.67	1.68	68.28	46.57	15.6 ± 0.3	7.3 ± 0.3	25.6± 0.3	12.6±0.3	20.3± 0.3	9.6± 0.3
23	29.85	12.05	0.57	57.57	37.57	21.3 ± 0.3	11.6±0.3	31.3± 0.3	18.6±0.3	27.6± 0.3	15.3±0.3
24	28.71	13.78	1.28	69.14	40.14	19.6 ± 0.3	9.3± 0.3	28.6± 0.3	15.6±0.3	22.3± 0.3	10.6±0.3
25	19.34	12.14	14.94	85.28	81.28	17.3 ± 0.3	7.6 ± 0.3	21.3± 0.3	10.3±0.3	15.6± 0.3	7.3± 0.3
26	32.64	17.51	0.00	75.71	44.00	23.6 ± 0.3	12.6±0.3	25.6± 0.3	12.3±0.3	21.3± 0.3	10.3±0.3
27	31.31	20.32	1.25	77.42	58.00	23.3 ± 0.3	11.3±0.3	22.3± 0.3	9.6± 0.3	20.6± 0.3	9.6± 0.3
28	26.21	17.28	13.77	88.57	67.85	14.6 ± 0.3	6.6± 0.3	16.6± 0.3	8.3± 0.3	12.3± 0.3	5.3± 0.3

Table 2. Population monitoring of adult Diamondback Moth (*Plutella xylostella*) in cole crops at different locations during *Rabi* 2022

Standard Week (SW)	Temperature (℃)		Rainfall (mm)	Relative Humidity (%)		Weekly adult moth catch of *Plutella xylostella* (Mean ± SE)					
	Maximum	Minimum		Morning	Evening	Locations					
						Shalimar		Budgam		Habbak	
						Pheromone Lures					
						SKUAST K Lure	*Chipku* Lure	SKUASTK Lure	*Chipku* Lure	SKUAST K Lure	*Chipku* Lure
34	28.07	16.98	1.542	81.85	66.57	2.6 ± 0.3	0.3± 0.3	5.3 ± 0.3	1.3± 0.3	1.3 ± 0.3	0.3 ±0.3
35	30.00	15.50	0.028	79.71	52.71	7.3 ± 0.3	2.3 ± 0.3	12.3 ±0.3	4.6± 0.3	6.6 ± 0.3	1.6± 0.3
36	30.00	15.42	1.00	78.00	46.14	12.6 ± 0.3	5.3 ± 0.3	18.6 ±0.3	9.3 ±0.3	14.3 ±0.3	5.6± 0.3
37	28.57	13.07	1.057	77.71	52.14	15.6 ± 0.3	8.6 ± 0.3	21.3± 0.3	11.6±0.3	17.6 ±0.3	9.3± 0.3
38	28.42	11.71	0.685	74.28	45.85	19.3 ± 0.3	10.3±0.3	24.6± 0.3	12.3±0.3	20.3 ±0.3	11.3±0.3
39	26.92	11.85	0.114	85.42	46.71	12.3 ± 0.3	5.6 ± 0.3	20.6± 0.3	10.6±0.3	18.3 ±0.3	9.6±0.3
40	26.57	7.92	0.00	84.85	40.57	8.6 ± 0.3	2.6 ± 0.3	26.3± 0.3	14.3±0.3	20.6 ±0.3	11.6±0.3
41	24.72	7.30	0.00	75.28	48.42	10.3 ± 0.3	3.3 ± 0.3	25.6± 0.3	12.6±0.3	23.6 ±0.3	12.6±0.3
42	20.07	4.571	5.71	92.85	53.85	4.3 ± 0.3	2.3 ± 0.3	13.6± 0.3	8.3± 0.3	11.3± 0.3	5.6± 0.3
43	19.95	2.428	0.00	91.14	70.14	4.0 ± 0.3	0.6 ± 0.3	12.3 ±0.3	7.6± 0.3	10.6± 0.3	5.3± 0.3
44	18.85	3.5	0.571	90.14	62.14	3.6 ±0.3	0.6 ± 0.3	9.6 ± 0.3	4.3± 0.3	7.3± 0.3	3.3± 0.3

Table 3. Efficacy of different sex pheromone lures in population monitoring of adult Diamondback moth (*Plutella xylostella)* at different locations and seasons during 2022

Season	Budgam			Habbak			Shalimar			Mean	Factor Mean
	SKUAST-K Lure	*Chipku* Lure	Sub-Mean	SKUAST-K Lure	*Chipku* Lure	Sub-Mean	SKUAST-K Lure	*Chipku* Lure	Sub-Mean		
Kharif	20.51	9.99	15.25	16.48	7.72	12.10	15.03	7.00	11.01	12.78	SKUAST-K Lure=
Rabi	17.33	8.85	13.09	13.85	6.97	10.41	9.18	3.85	6.51	10.00	15.39
Mean	18.92	9.42	14.17	15.16	7.34	11.25	12.10	5.42	8.76		Chipku Lure= 7.39

CD$_{(p \leq 0.05)}$

Season = 0.14
Location = 0.17
Traps = 0.14
Location*Season = 0.24
Season *Trap = 0.20
Location *Season*Trap = 0.45

Table 4. Correlation matrix between adult catch of Diamondback moth (*Plutella xylostella*) and abiotic factors during *Kharif* 2022

Weather factors	Adult catch of *Plutella xylostella* (*Kharif*)					
	Shalimar		Budgam		Habbak	
	SKUAST-K Lure	*Chipku* Lure	SKUAST-K Lure	*Chipku* Lure	SKUAST-K Lure	*Chipku* Lure
Maximum Temperature	0.51*	0.55*	0.39	0.36	0.49	0.47
Minimum Temperature	0.71*	0.69*	0.32	0.25	0.38	0.33
Rainfall	-0.03	-0.09	-0.18	-0.15	-0.26	-0.26
Morning Relative Humidity	-0.12	-0.16	-0.47	-0.51*	-0.51*	-0.54*
Evening Relative Humidity	-0.04	-0.10	-0.28	-0.32	-0.33	-0.33

**Siginificant at 5% level of siginificance*

Table 5. Correlation matrix between adult catch of Diamondback moth (*Plutella xylostella*) and abiotic factors during *Rabi* 2022

Weather factors	Adult catch of *Plutella xylostella* (*Rabi*)					
	Shalimar		Budgam		Habbak	
	SKUAST-K Lure	*Chipku* Lure	SKUAST-K Lure	*Chipku* Lure	SKUAST-K Lure	*Chipku* Lure
Maximum Temperature	0.59*	0.53*	0.31	0.16	0.16	0.10
Minimum Temperature	0.37	0.36	-0.01	-0.17	-0.14	-0.20
Rainfall	-0.25	-0.08	-0.28	-0.16	-0.24	-0.22
Morning Relative Humidity	-0.72*	-0.64*	-0.50*	-0.32	-0.41	-0.36
Evening Relative Humidity	-0.69*	-0.60*	-0.84*	-0.76*	-0.75*	-0.69*

**Siginificant at 5% level of siginificance*

Further, at all the locations and for both the seasons, SKUAST-K sex pheromone lures had highest adult captures in comparison to *Chipku* lures which possibly could be due to higher lure volatility and greater attractiveness in trapping Diamondback moths.

5. CONCLUSION

The present study has yielded several key findings on distinct seasonal variations in diamondback moth populations, with peak activity during specific periods of the year; besides also provided the valuable insights on variations in moth populations at different locations, highlighting the importance of localized pest management strategies. The research underscores the significance of sex pheromone lures as a useful tool for monitoring diamondback moth populations, providing a reliable and non-invasive means of tracking their presence. Further, these findings offer valuable information for growers and pest control practitioners, enabling them to make informed decisions regarding pest management strategies, thus contributing to the resilience of cole crop agriculture in our region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Roy SK, Chakrabarti AK. Vegetables of temperate climates-Commercial and dietary importance. Encyclopedia of food sciences and Nutrition (second edition); 2003.
2. Keck AS, Finley JW. Cruciferous vegetables: Cancer protective mechanisms of glucosinolate hydrolysis products and selenium. Integrative Cancer Therapies. 2004;3(1):5–12.
3. Debbarma A, Jayaraj J, Chandramani P, Senthil N, Ananthan M, Prabakaran K. A Survey on occurrence and diversity of insect pests of cauliflower in Dindigul and Theni Districts of Tamil Nadu, India. International Journal of Current Microbiology and Applied Sciences. 2017;6(9):2495-2505.
4. Sithole R, Nyamukondiwa C, Chinwada P, Lohr B. Population dynamics of the diamondback moth and its parasitoids in Zimbabwe. Biological Control. 2019; 133:66-74.
5. Farias ES, Santos AA, Ribeiro AV, Carmo DG, Paes JS, Picanco MC. Climate and host plants mediating seasonal dynamics and within-plant distribution of the diamondback moth (*Plutella xylostella*). Crop Protection. 2020;134: 105172.
6. Duarte RT, Gonçalves KC, Espinosa DJL, Moreira LF, De Bortoli SA, Humber RA, Polanczyk RA. Potential of entomopathogenic fungi as biological control agents of diamondback moth (Lepidoptera: Plutellidae) and compatibility with chemical insecticides. Journal of Economic Entomology. 2016;109(2): 594-601.
7. Huaripata C, Sanchez G. Life cycle of the diamondback moth *Plutella xylostella* L. (Lepidoptera: Plutellidae), in broccoli and cauliflower under laboratory conditions. Peruvian Journal of Agronomy. 2019; 3(1):1-5.
8. Ahmad T, Ansari MS, Ali H. Outbreak of diamondback moth, *Plutella xylostella* in Aligarh, India. Trends in Bioscience. 2009;2:10-12.
9. Uthamasamy S, Kannan M, Senguttuvan K, Jayaprakasg SA. Status, damage potential and management of diamondback moth, Plutella xylostella (L.) in Tamil Nadu, India. The 6th international workshop on management of the diamondback moth and other crucifer insect pests. AVRDC-The World Vegetable Center. 2011;270–279.
10. Shen J, Li Z, Li D, Wang R, Zhang S, You H, Li J. Biochemical mechanisms, cross-resistance and stability of resistance to metaflumizone in *Plutella xylostella*. Insects. 2020;11(5):311.
11. Talekar NS, Shelton AM. Biology, ecology and management of the Diamondback moth. Annual Review of Entomology. 1993; 38:275-301.
12. Gurrero A, Reddy GVP. Optimum timing of insecticide applications against diamondback moth *Plutella xylostella* in cole crops using threshold catches in sex pheromone traps. Pest Management Science. 2001;57:90–94.
13. Reddy GVP, Urs KCD. Studies on the sex pheromone of the diamondback moth *Plutella xylostella* (Lepidoptera: Yponomeutidae) in India. Bulletin of Entomological Research. 1996;86:585-590.

14. Mayer MS, Mitchell ER. Differences between attractive diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), sex pheromone lures are not determinable through analysis of emissions. Agricultural and Forest Entomology. 1999;1:229-236.
15. Abbes K, Chermiti B. Comparison of two marks of sex pheromone dispensers commercialized in Tunisia for their efficiency to monitor and to control by mass-trapping Tuta absoluta under greenhouses. Tunisian Journal of Plant Protection. 2011;6:133-148.
16. Ahmad T, Ansari MS. Studies on seasonal abundance of diamondback moth *Plutella xylostella* Lepidoptera: Yponomeutidae on cauliflower crop. Journal of Plant Protection Research. 2010;50(3):281-287.
17. Hidayah BN, Adnyana IPCP, Suparjan S, Aisah AR, Rahayu M. Moonlight and rainfall influence efficacy of sex pheromones in controlling *Spodoptera exigua* (Lepidoptera: Noctuidae) on Shallot. IOP Conference Series: Earth and Environment Science. 2023;1165 (012009).
18. Hemchandra O, Singh TK. Population dynamics of DBM, *Plutella xylostella* (L.) on cabbage agro-ecosystem in Manipur. Indian Journal of Entomology. 2007; 69:154-161.
19. Maity L, Padhi G, Samanta A. Population dynamics andmanagement of diamond back moth *Plutella xylostella* (L.) in cabbage ecosystem of West Bengal. International Journal of Chemical Studies. 2018;6(1):381-385.

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