Original Research Article

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

ABSTRACT

Plutellaxylostella, commonly known as the diamondback mothposes 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 *Plutellaxylostella*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 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.

Key words: Diamondback moth, Lures, Monitoring, Trap catch

Introduction

Among vegetables, the model plant family Brassicaceae, also known as Cruciferae, is of particular significance. This family is distinguished for its remarkable richness in vitamins, high fiber content, minimal fat composition, and low caloric value; besides, are also recognized for their potential as sources of compounds with medicinal and anticarcinogenic properties (Roy and Chakrabarti, 2003; Keck and Finley, 2004). 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, *Plutellaxylostella*(Lepidoptera: Plutellidae) is found to be most prevelant and highly destructive in nature and thereby results in colossal losses (Debbarma *et al.*, 2017; Sithole *et al.*, 2019; Farias *et al*., 2020). Characterized by a short life cycle, this pest demonstrates anexcellent ability to thrive in adverse weather conditions and disperse widely, additionally, its quick generation turnover further contributes to its persistence (Duarte *et al*., 2016;

Comment [R1]: Restructure the summary of the scientific article so that it follows the logic of:
Introduction and motivation
Objective/Question/Hypotheses
Methods
Results
Conclusion/Scientific implications
Reader Engagement: Aim to engage the reader further by connecting your research objectives to the broader implications or applications of your findings. This can help readers see the real-world relevance of your study from the outside.

Comment [R2]: suggestion: 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.

Huaripataand Sanchez, 2019).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*., 2009; Uthamasamy*et al*. 2011), while the control costs alone in Brassica crops, are anticipated to be US $4–5 billion globally (Shen *et al.*, 2020).

The farmers in Kashmir commonly rely on synthetic insecticides to managecruciferous pests,throughout the planting-to-harvestcycle. Nevertheless,the diamondback exhibits a tendency to develop resistance to insecticides used against it (Talekarand Shelton, 1993). 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 approachfor early pest detection, even low-density pest populations (Gurrero and Reddy, 2001).

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 *Plutellaxuloostella* (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.

Results

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

Comment [R3]: To enhance clarity, I recommend explicitly stating your main research objectives at the beginning of the introduction. This will help readers immediately grasp the purpose of your study. Concise research question that your study aims to address. This will provide a focal point for your investigation.

Comment [R4]: You mention the importance of an integrated approach to pest management, but do not specify how this will be achieved. Could you add a sentence about how sex pheromone traps fit into this strategy

Comment [R5]: Consider reading the articles: https://doi.org/10.1590/0103-8478cr20210245

https://doi.org/10.1590/0103-8478cr20220424

If applicable, emphasize what makes your study unique or novel compared to existing research on the diamondback moth and pest management in cruciferous crops. This can generate greater interest among readers.

Comment [R6]: The introduction could be more explicit about the purpose of your study. What is the main research question you are trying to answer? What is the main objective of the research? This can help orient readers to the purpose of the article.

Comment [R7]: Mention the specific months corresponding to the Kharif and Rabi seasons in 2022 to offer a precise timeframe for your study.

Comment [R8]: Include information about trap height and distances between traps, which can impact data collection.

Comment [R9]: What factors determine the replacement timing, and how does this affect the accuracy of data collection?

Comment [R10]: Consider breaking this section into subsections for clarity and ease of reference. For example, one subsection could focus on trap installation, another on data collection, and a third on data analysis.

Briefly justify the chosen methodology and why it is suitable for achieving your research objectives.

Comment [R11]: Consider adding subheadings to divide the "Results" section into subsections corresponding to different aspects of your findings, such as "Seasonal variation in moth catches," "Effectiveness of pheromone baits," etc.," This will make it easier for readers to navigate the its results.

capturingby 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).

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).

Comment [R12]: Summarize your findings and highlight any significant differences in their performance. Figures 1 and 2 can be incorporated here to visualize these differences

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).

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).

Discussion

The findingsfrom 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 (1996); the authors opined that aging of pheromone lures often leads to declined catch; though, Mayer and Mitchell (1999) 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, 2011) and subsequent reduction during 27th and 28th SW finds the support from the work of AhmadandAnsari (2010) and Hidayah *et al*. (2023). 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 aconsistent 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 (2007) 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 (2007) and Maity *et al*. (2018) is in consonance with the present findings for the decreased catch from 42nd SW at all the locations.

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.

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.

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Comment [R13]: Go beyond merely citing previous studies. Discuss how your findings relate to or expand upon existing literature. Are there any contrasting results or gaps in the current knowledge that your study addresses?

Comment [R14]: While you mention fluctuations in moth populations and attribute them to environmental factors, provide a deeper analysis of the implications. How might these fluctuations impact pest management practices or local agriculture? What are the practical applications of your research?

Clearly state the limitations of your study and offer suggestions for future research directions. Addressing these aspects demonstrates a comprehensive understanding of your research's scope

Comment [R15]: Considering the inclusion of current references: Link: https://doi.org/10.3390/insects14020149

Predicting the impacts of climate change on the biological control of *Plutella xylostella* by *Diadegma semiclausum*

https://doi.org/10.1111/afe.12548

Recent insights into pesticide resistance mechanisms in *Plutella xylostella* and possible management strategies
Link: https://doi.org/10.1007/s11356-023-29271-5

Knockout of tyramine receptor 1 results in a decrease of oviposition, mating, and sex pheromone biosynthesis in female *Plutella xylostella*
Link: https://doi.org/10.1002/ps.7571

Diamondback Moth Plutella xylostella (Linnaeus, 1758) (Lepidoptera: Plutellidae); A Real Menace To Crucifers And Its Integrated Management Tactics
Link: https://doi.org/10.24925/turjaf.v10i12.2504-2515.5231

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Table 1: Population monitoring of adult Diamondback Moth (*Plutellaxylostella*) in Cole crops at different locations during *Kharif* 2022

Standard Week (SW)	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)		Weekly adult moth catch of *Plutellaxylostella* (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 (*Plutellaxylostella*) in Cole crops at different locations during *Rabi* 2022

Standard Week (SW)	Temperature (℃)		Rainfall (mm)	Relative Humidity (%)		Weekly adult moth catch of *Plutellaxylostella* (Mean ± SE)					
						Locations					
						Shalimar		Budgam		Habbak	
						Pheromone Lures					
	Maximum	Minimum		Morning	Evening	SKUAST K Lure	*Chipku* Lure	SKUAST K 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 (*Plutellaxylostella)* 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= 15.39
Rabi	17.33	8.85	13.09	13.85	6.97	10.41	9.18	3.85	6.51	10.00	Chipku Lure= 7.39
Mean	18.92	9.42	14.17	15.16	7.34	11.25	12.10	5.42	8.76		

$CD_{(p \leq 0.05)}$

Season = 0.14

Location = 0.17

Traps = 0.14

Location*Season = 0.24

Season *Trap = 0.20

Location *Season*Trap = 0.45

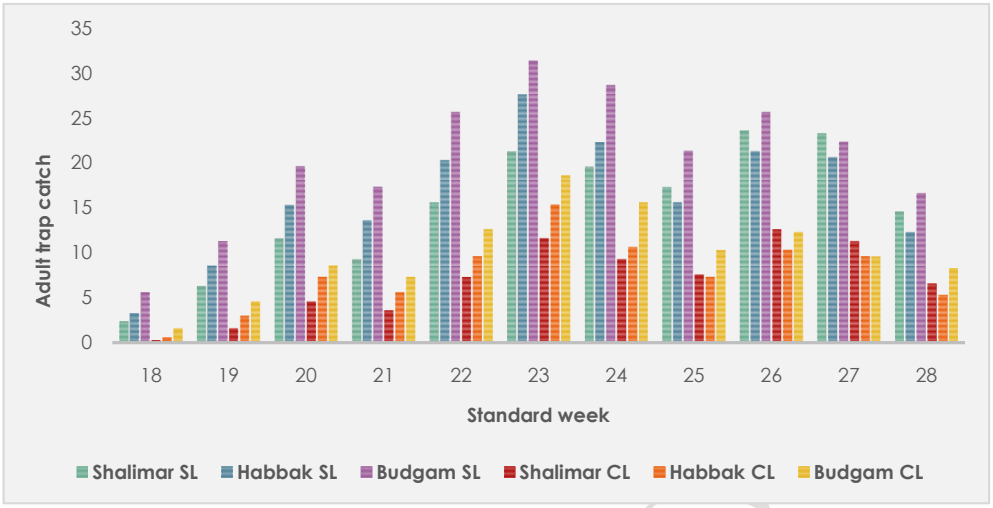

Fig.1: Adult trap catches of *Plutellaxylostella*in Cole crops at different locations using SKUAST-K and *Chipku* lure during *Kharif* 2022

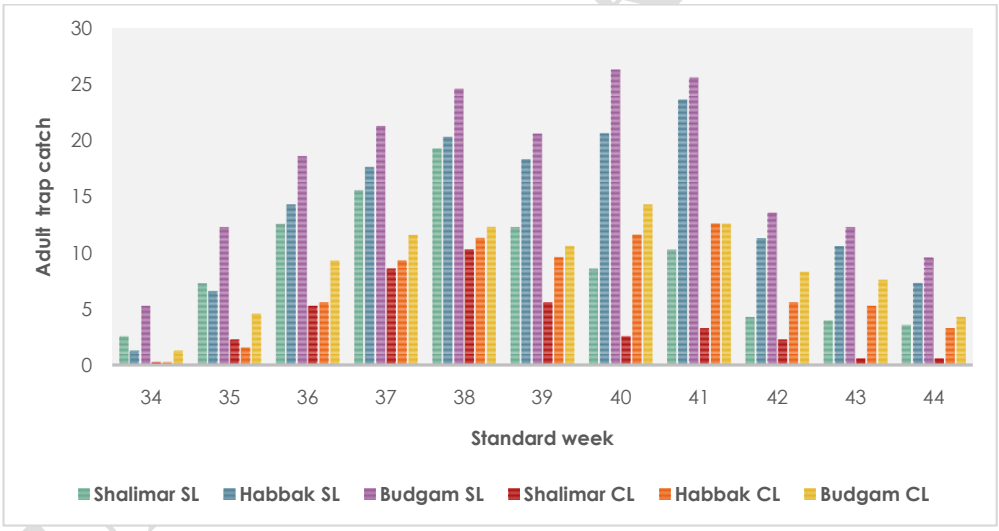

Fig. 2: Adult trap catches of *Plutellaxylostella*in Cole crops at different locations using SKUAST-K and *Chipku* lure during *Rabi*2022

Table 4: Correlation matrix between adult catch of Diamondback moth (*Plutellaxylostella*) and abiotic factors during *Kharif* 2022

Weather factors	Adult catch of *Plutellaxylostella*(*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 (*Plutellaxylostella*) and abiotic factors during *Rabi* 2022

Weather factors	Adult catch of *Plutellaxylostella*(*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**