

Influence of abiotic factors on the distribution and population of beneficial insects in rabi crops of dhod tehsil, Sikar, Rajasthan

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Abstract

The present study investigates the relationship between environmental conditions and abundance of beneficial insects associated with major Rabi crops. The research was conducted during two consecutive Rabi seasons (2021–22 and 2022–23) across multiple crop fields in Dhod tehsil to assess how variations in abiotic factors such as temperature, relative humidity and rainfall affect insect populations. The findings revealed that insect populations decreased markedly during the cold winter months (December–January), while a significant resurgence was recorded from February to March as temperatures increased and moderate humidity conditions prevailed. Episodic rainfall and cooler, humid conditions during mid-winter were found to favor pest outbreaks such as aphids, which subsequently supported higher populations of natural enemies including coccinellids and syrphid flies. Therefore, the study reinforces temperature and humidity as primary drivers of insect population behavior, while rainfall and related atmospheric factors further modulate species-specific responses.

Keywords: Beneficial insects, rabi crops, abiotic factors, natural enemies, Dhod tehsil

Introduction

Within India, Rajasthan holds a distinctive position as a predominantly agricultural state. Nearly 70% of its population resides in rural areas and depends heavily on agriculture, which contributes around 22.5% of the state's GDP. The principal crops cultivated in the area are categorized into two seasons: Kharif and Rabi. The Rabi season, especially pertinent to this subject, involves the production of wheat, mustard, gram and barley. Mustard and gram are the predominant crops owing to their adaptation to arid environments and market demand (Tripp and Pal, 1998; DoAFW, 2011).^[13] The Shekhawati region comprising the districts of Sikar, Jhunjhunu, and Churu occupies a unique place in Rajasthan's agricultural landscape. Despite being situated in the semi-arid zone of Rajasthan, characterized by water shortages and severe weather conditions, agriculture remains the primary profession for most of its rural population. The Sikar district, situated in the Shekhawati region of Rajasthan, has played a significant role in the state's agricultural production. However, despite the importance of Rabi cropping, agriculture in Shekhawati including Sikar district faces several persistent challenges such as depleting groundwater levels, erratic weather patterns and increasing pest infestations. These factors not only reduce crop yields but also elevate dependency on chemical pesticides, which may disrupt ecological balance and hinder sustainable agricultural development (Rawal, 2017).^[6]

Since the origin of agriculture nearly 10,000 years ago, crops have faced persistent threats from pests, pathogens, and weeds. Both abiotic stresses (such as drought, extreme temperatures, or nutrient imbalance) and biotic stresses (such as insect pests, fungi, and viruses) constrain productivity. Primarily animal pests (insects, mites, nematodes, rodents, slugs, snails and birds), plant pathogens (viruses, bacteria, fungi) and weeds (i.e., competitive flora),

collectively referred to as pests. These organisms may be managed using physical (cultivation, mechanical weeding, etc.), biological (appropriate cultivar, crop rotation, antagonists, predators, etc.) and chemical methods (pesticides). Decreased productivity results in quantitative losses, diminishing the output per unit area. Crop losses are both quantitative (yield reduction) and qualitative (reduced grain or seed quality, contamination, or spoilage) (Sarkar *et al.*, 2024).^[8] While certain insects are recognized as destructive agricultural pests responsible for substantial yield losses, others play equally crucial and beneficial roles in maintaining ecosystem balance and supporting agricultural productivity. Insects contribute to various ecological and economic functions such as pollination, biological pest control, decomposition, and soil aeration. Moreover, some insect species produce economically valuable products like honey, silk, wax, and lac, thereby providing direct benefits to human livelihoods and the economy. Additionally, insects that facilitate agricultural pollination hold significant importance, as they directly support crop production. Beyond pollination, many beneficial insects contribute to the biological control of pest insects and plants, helping to maintain ecological balance. They also act as soil scavengers, aiding in nutrient recycling, and have applications in medicine and scientific research. The majority of natural enemies provide a supplementary function in the pollination of food crops and blooming plants. Principal pollinators include bees (including honey bees and wild bees), butterflies, moths and flies (Rondon *et al.*, 2008).^[7] Given the significant ecological and agricultural roles of parasitoids, predators and pollinators, it becomes crucial to document and analyze their diversity, abundance and functional importance in specific agro-climatic regions. Therefore, the present study focuses on exploring the impact of abiotic factors on the biodiversity of beneficial insects associated with major Rabi crops in Dhod tehsil of Sikar district, Rajasthan.

Materials and Methods

Study Area

The present study was conducted in Dhod tehsil of Sikar district, situated in the north-eastern region of Rajasthan at 27.64°N latitude and 75.38°E longitude (Figure 1). The

study was conducted in Dhod tehsil of Sikar district, Rajasthan, covering six villages—Kudan, Dhod, Jana, Shahpura, Harsh and Kanwarpura. These sites were selected to reflect ecological variability and differences in agricultural practices.



Fig 1: Map of study area showing location of Dhod tehsil in Sikar, Rajasthan

Insect Collection Methods

To collect beneficial insects from rabi crop fields, multiple standard techniques were employed. The methods used for collection included: Wet-finger method, Hand Picking Method, Brushing, Netting, Beating, Pitfall trap method, Sticky trap method. These methods ensured minimal damage to the plants and accurate sampling across different insect groups. Sampling was carried out during two consecutive Rabi seasons (October–March 2021–22 and 2022–23). Collections were made every two weeks in the morning hours to record insect activity throughout different crop growth stages viz., vegetative, flowering, and fruiting. Each site was systematically monitored to represent the variations within the local agro-ecosystem.

Identification of collected specimen

The collected insect specimens were euthanized using ethyl acetate and then preserved either in 70% ethanol or through pinning for dry storage. Identification was carried out with the help of standard taxonomic keys (Arnett, 2000; Borror *et al.*, 1989) [1, 2] and expert consultation, with specimens classified to the family or species level whenever possible.

Effect of Abiotic Factors

Pearson’s Correlation Coefficient: The Pearson correlation between two objects with paired attributes is calculated by summing the products of their deviations from their respective means and then dividing this sum by the product of the square roots of the sums of squared deviations from those means.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2} \sqrt{\sum(y_i - \bar{y})^2}}$$

where, x_i = values of the x-variable in a sample, \bar{x} = mean of the values of the x-variable, y_i = values of the y-variable in a sample and \bar{y} = mean of the values of the y-variable.

Pair-wise Least Square Linear Regression Analysis

Pair-wise least squares linear regression is a statistical method used to examine the relationship between two variables by fitting a straight line that minimizes the sum of the squared differences between the observed values and the values predicted by the line. It is performed for each pair of variables to determine the strength and direction of their association.

Results and Discussion

The climatic data from October 2021 to April 2022 shows clear seasonal variations in temperature, relative humidity, and rainfall across the six sites studied. During October 2021, the mean temperature was around 25°C, indicating the post-monsoon transitional phase, with Site 5 (Harsh) recording the lowest temperature of 21°C. As the season progressed, a gradual decline in temperature was observed, reaching an average of about 16°C by December 2021, marking the onset of winter. The lowest temperatures were consistently recorded at Site 5 throughout the period, while Sites 1, 2, and 6 maintained slightly higher temperature averages. January 2022 remained the coldest month with mean temperatures near 15°C, after which a steady rise was noticed from February (18°C) to March (22°C) and April (28°C), reflecting the gradual shift toward summer. Relative humidity showed an inverse relationship with temperature, remaining higher during cooler months and lower during the warmer periods. In October and November 2021, mean relative humidity values hovered around 33–31%, indicating

moderate atmospheric moisture. December witnessed a slight drop to about 29%, consistent with dry winter conditions, whereas January 2022 showed an increase to nearly 32% due to higher rainfall during the month. As temperatures began to rise from February to April, humidity declined from around 34% in February to nearly 21% in April, representing the onset of a dry, pre-summer phase. Rainfall patterns during the period were minimal, showing predominantly dry conditions except for January 2022,

which received the highest mean rainfall of about 48 mm. This was particularly noticeable at Site 5, where precipitation reached 70 mm, suggesting localized rainfall or fog-drizzle accumulation. Negligible or zero rainfall was recorded in November, while December and March received only trace amounts averaging around 1 mm. February and April also witnessed light showers with mean rainfall values of 5 mm and 1 mm, respectively.

Table 1: Monthly temperature data recorded at six sites during October 2021–April 2023

Months	Data	Temperature (°C)						
		S1	S2	S3	S4	S5	S6	Mean ± SD
Oct-21	2 nd Fortnight	26.46	25.96	25.36	25.06	21	26.16	25 ± 2.03
Nov-21	1 st Fortnight	22.5	22	21.4	21.1	16.8	22.2	21 ± 2.12
	2 nd Fortnight	22.42	21.92	21.32	21.02	17.2	22.12	21 ± 1.93
Dec-21	1 st Fortnight	17.06	16.56	15.96	15.66	14	16.76	16 ± 1.11
	2 nd Fortnight	17.16	16.66	16.06	15.76	13.5	16.86	16 ± 1.33
Jan-22	1 st Fortnight	16.16	15.66	15.06	14.76	12.5	15.86	15 ± 1.33
	2 nd Fortnight	16.26	15.76	15.16	14.86	12	15.96	15 ± 1.56
Feb-22	1 st Fortnight	19.26	18.76	18.16	17.86	15	18.96	18 ± 1.56
	2 nd Fortnight	19.22	18.72	18.12	17.82	15.2	18.92	18 ± 1.47
Mar-22	1 st Fortnight	23.3	22.8	22.2	21.9	18.8	23	22 ± 1.65
	2 nd Fortnight	23.26	22.76	22.16	21.86	19	22.96	22 ± 1.56
Apr-22	1 st Fortnight	29.46	28.96	28.36	28.06	24	29.16	28 ± 2.03
Oct-22	2 nd Fortnight	27.6	27.1	26.6	26.2	22	26.5	26 ± 2.02
Nov-22	1 st Fortnight	19.6	19.1	18.6	18.2	14	18.5	18 ± 2.02
	2 nd Fortnight	19.6	19.1	18.6	18.2	14	18.5	18 ± 2.02
Dec-22	1 st Fortnight	14.6	14.1	13.6	13.2	9	13.5	13 ± 2.02
	2 nd Fortnight	14.6	14.1	13.6	13.2	9	13.5	13 ± 2.02
Jan-23	1 st Fortnight	15.6	15.1	14.6	14.2	10	14.5	14 ± 2.02
	2 nd Fortnight	15.6	15.1	14.6	14.2	10	14.5	14 ± 2.02
Feb-23	1 st Fortnight	18.6	18.1	17.6	17.2	13	17.5	17 ± 2.02
	2 nd Fortnight	18.6	18.1	17.6	17.2	13	17.5	17 ± 2.02
Mar-23	1 st Fortnight	24.6	24.1	23.6	23.2	19	23.5	23 ± 2.02
	2 nd Fortnight	24.6	24.1	23.6	23.2	19	23.5	23 ± 2.02
Apr-23	1 st Fortnight	30.6	30.1	29.6	29.2	25	29.5	29 ± 2.02

Table 2: Monthly relative humidity data recorded at six sites during October 2021–April 2023

Months	Data	Relative Humidity (%)						
		S1	S2	S3	S4	S5	S6	Mean ± SD
Oct-21	2 nd Fortnight	32.8	33.4	33.8	33.6	37.2	33.2	34 ± 1.60
Nov-21	1 st Fortnight	29.8	30.4	30.8	30.6	34.2	30.2	31 ± 1.60
	2 nd Fortnight	29.8	30.4	30.8	30.6	34.2	30.2	31 ± 1.60
Dec-21	1 st Fortnight	27.8	28.4	28.8	28.6	32.2	28.2	29 ± 1.60
	2 nd Fortnight	27.8	28.4	28.8	28.6	32.2	28.2	29 ± 1.60
Jan-22	1 st Fortnight	30.8	31.4	31.8	31.6	35.2	31.2	32 ± 1.60
	2 nd Fortnight	30.8	31.4	31.8	31.6	35.2	31.2	32 ± 1.60
Feb-22	1 st Fortnight	32.8	33.4	33.8	33.6	37.2	33.2	34 ± 1.60
	2 nd Fortnight	32.8	33.4	33.8	33.6	37.2	33.2	34 ± 1.60
Mar-22	1 st Fortnight	26.8	27.4	27.8	27.6	31.2	27.2	28 ± 1.60
	2 nd Fortnight	26.8	27.4	27.8	27.6	31.2	27.2	28 ± 1.60
Apr-22	1 st Fortnight	19.8	20.4	20.8	20.6	24.2	20.2	21 ± 1.60
Oct-22	2 nd Fortnight	35.8	36.4	36.8	36.6	40.2	36.2	37 ± 1.60
Nov-22	1 st Fortnight	28.8	29.4	29.8	29.6	33.2	29.2	30 ± 1.60
	2 nd Fortnight	28.8	29.4	29.8	29.6	33.2	29.2	30 ± 1.60
Dec-22	1 st Fortnight	26.8	27.4	27.8	27.6	31.2	27.2	28 ± 1.60
	2 nd Fortnight	26.8	27.4	27.8	27.6	31.2	27.2	28 ± 1.60
Jan-23	1 st Fortnight	34.8	35.4	35.8	35.6	39.2	35.2	36 ± 1.60
	2 nd Fortnight	34.8	35.4	35.8	35.6	39.2	35.2	36 ± 1.60
Feb-23	1 st Fortnight	29.8	30.4	30.8	30.6	34.2	30.2	31 ± 1.60
	2 nd Fortnight	29.8	30.4	30.8	30.6	34.2	30.2	31 ± 1.60
Mar-23	1 st Fortnight	27.8	28.4	28.8	28.6	32.2	28.2	29 ± 1.60
	2 nd Fortnight	27.8	28.4	28.8	28.6	32.2	28.2	29 ± 1.60
Apr-23	1 st Fortnight	21.8	22.4	22.8	22.6	26.2	22.2	23 ± 1.60

Table 3: Monthly rainfall data recorded at six sites during October 2021–April 2023

Months	Data	Rainfall (mm)						Mean ± SD
		S1	S2	S3	S4	S5	S6	
Oct-21	2 nd Fortnight	1.6	1.6	1.6	1.6	5	0.6	2 ± 1.52
Nov-21	1 st Fortnight	0	0	0	0	0	0	0 ± 0.00
	2 nd Fortnight	0	0	0	0	0	0	0 ± 0.00
Dec-21	1 st Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
	2 nd Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
Jan-22	1 st Fortnight	47.6	47.6	47.6	47.6	70	27.6	48 ± 13.42
	2 nd Fortnight	47.6	47.6	47.6	47.6	70	27.6	48 ± 13.42
Feb-22	1 st Fortnight	4.6	4.6	4.6	4.6	8	3.6	5 ± 1.52
	2 nd Fortnight	4.6	4.6	4.6	4.6	8	3.6	5 ± 1.52
Mar-22	1 st Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
	2 nd Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
Apr-22	1 st Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
Oct-22	2 nd Fortnight	93.6	93.6	93.6	93.6	120	69.6	94 ± 15.95
Nov-22	1 st Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
	2 nd Fortnight	0.6	0.6	0.6	0.6	2.5	1.1	1 ± 0.76
Dec-22	1 st Fortnight	0	0	0	0	0	0	0 ± 0.00
	2 nd Fortnight	0	0	0	0	0	0	0 ± 0.00
Jan-23	1 st Fortnight	40.6	40.6	40.6	40.6	55	28.6	41 ± 8.37
	2 nd Fortnight	40.6	40.6	40.6	40.6	55	28.6	41 ± 8.37
Feb-23	1 st Fortnight	0	0	0	0	0	0	0 ± 0.00
	2 nd Fortnight	0	0	0	0	0	0	0 ± 0.00
Mar-23	1 st Fortnight	13.6	13.6	13.6	13.6	18	11.6	14 ± 2.12
	2 nd Fortnight	13.6	13.6	13.6	13.6	18	11.6	14 ± 2.12
Apr-23	1 st Fortnight	14.6	14.6	14.6	14.6	20	11.6	15 ± 2.73

Similarly, the climatic data from October 2022 to April 2023 display a well-defined seasonal transition pattern typical of semi-arid regions, with notable variations in temperature, relative humidity, and rainfall across the six study sites. During October 2022, the mean temperature was relatively high at around 26°C, indicating the retreating monsoon phase. Site 5 consistently recorded the lowest temperature (22°C), while Sites 1, 2, and 6 maintained slightly higher values. This period also exhibited the highest humidity level, averaging 37%, reflecting residual moisture in the atmosphere after the monsoon season. Rainfall during October was exceptionally high, with a mean value of 94 mm and Site 5 receiving 120 mm, suggesting localized heavy showers that contributed significantly to soil moisture recharge and vegetation growth. As the season transitioned into November 2022, a considerable decline in temperature was recorded, with the mean dropping to about 18°C, marking the onset of winter. Relative humidity also decreased slightly to around 30%, indicating drier air conditions, while rainfall was minimal (1 mm on average), showing the beginning of the dry winter period. December 2022 registered the lowest mean temperature of about 13°C, corresponding to the peak of winter. Humidity levels during this time fell to 28%, and rainfall was absent across all sites, reflecting the typically dry and cold conditions of late winter. January 2023 maintained similar cool conditions, with an average temperature of 14°C. However, relative humidity increased to about 36%, influenced by moderate rainfall averaging 41 mm, which was highest (55 mm) at Site 5. This month marked a temporary shift from dryness, providing short-lived moisture to the environment. February 2023 showed a gradual warming trend with a mean

temperature of 17°C and a slight decline in humidity to 31%, while rainfall remained absent. This steady rise in temperature and reduction in atmospheric moisture indicated the transition from winter to pre-summer conditions. By March 2023, the mean temperature had further increased to around 23°C, with a corresponding drop in humidity to 29%. Light rainfall resumed, averaging 14 mm, again peaking at Site 5 (18 mm). These brief showers may be attributed to localized convective rain, common in early spring. Finally, in April 2023, temperatures rose sharply to an average of 29°C, marking the onset of summer. Relative humidity dropped to around 23%, indicating dry atmospheric conditions, while light rainfall of about 15 mm was recorded, which again reached its maximum at Site 5 (20 mm).

Pearson's correlation (r) between the monthly abundance of total insect fauna and abiotic factors, namely temperature, rainfall, and relative humidity, was calculated for the study period from October 2021 to March 2022 and October 2022 to March 2023. The correlation value with temperature was found to be 0.3458, indicating a positive but weak relationship, which suggests that insect abundance showed a slight increase with rising temperature. The correlation of insect abundance with temperature (r = 0.3458) was positive but weak, likely because the winter months in the study area experience cool and stable temperatures with frequent fog conditions that restricts major fluctuations in insect activity. The correlation with relative humidity was 0.4678, reflecting a moderate positive association and highlighting that higher humidity levels were more favorable for insect abundance. Similarly, rainfall showed a correlation value of 0.4170, representing a moderate positive influence on insect population trends.

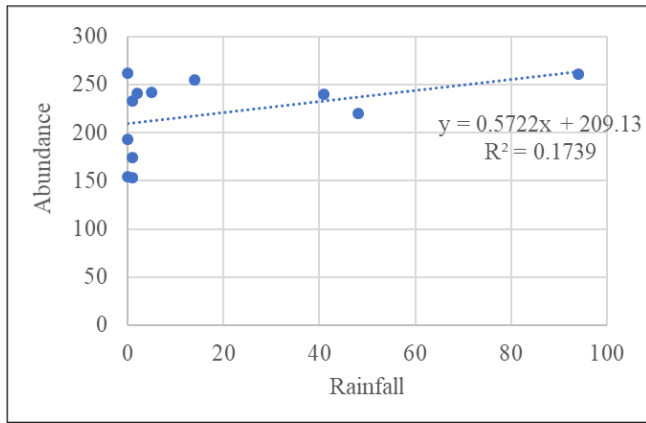


Fig 2: Pair-wise least squares linear regression analysis of total insect abundance with rainfall, observed in the study area during Oct 2021 to April 2023

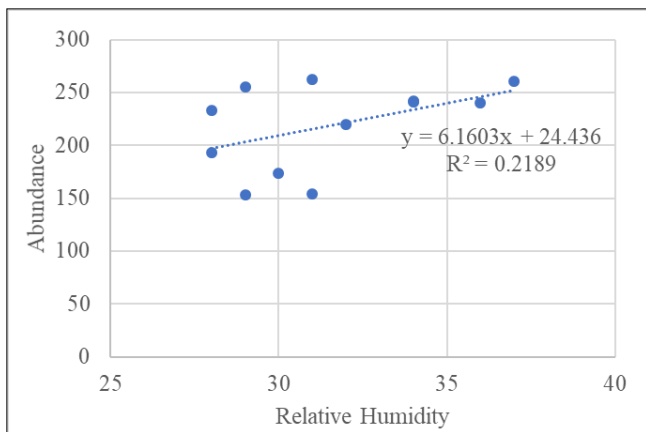


Fig 3: Pair-wise least squares linear regression analysis of total insect abundance with relative humidity observed in the study area during Oct 2021 to April 2023

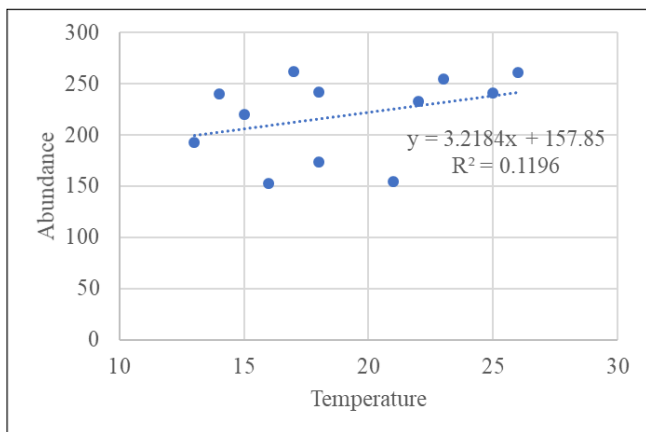


Fig 4: Pair-wise least squares linear regression analysis of total insect abundance with temperature observed in the study area during Oct 2021 to April 2023

The pair-wise least square linear regression analysis (Figure 2) revealed that rainfall had a moderate positive impact on insect abundance ($R^2 = 0.1739$); however, this relationship was found to be statistically non-significant ($p > 0.05$). Similarly, relative humidity showed a moderate positive impact on insect abundance ($R^2 = 0.2189$), but this relationship was also not statistically significant ($p > 0.05$). In the case of temperature, the impact on insect abundance was positive but weak ($R^2 = 0.1196$), and here too the

relationship was observed to be statistically non-significant ($p > 0.05$). Overall, the regression analysis indicates that while all three abiotic factors viz., temperature, relative humidity, and rainfall, exerted a positive influence on insect abundance, none of these individual relationships were strong enough to reach statistical significance, suggesting that insect populations are influenced by a combination of multiple environmental and ecological factors rather than a single abiotic variable alone.

The seasonal pattern recorded in this study, where insect abundance decreased during the cold winter months (December–January) and increased as temperatures rose in February–March, aligns well with the findings of Singh *et al.* (2025), [9] who observed a similar temperature-driven trend in the larval population of *Helicoverpa armigera* in chickpea fields. Their study reported that pest populations were negatively correlated with temperature and relative humidity but positively associated with rainfall, underscoring the influence of moderate moisture and warmth on insect development and activity. In the current study, this phenomenon was evident as the rising temperatures in late winter favored the resurgence of pollinators and natural enemies, coinciding with the flowering phase of Rabi crops.

Similarly, Thakur and Rawat (2014) [11] documented a strong positive correlation between insect populations and abiotic factors such as temperature and relative humidity in potato fields. Their findings that coccinellids, syrphids, and parasitoids responded positively to favorable weather conditions mirror the present study’s observations, where beneficial insect activity increased markedly with rising late-winter temperatures and moderate humidity levels. However, the brief decline in insect abundance during peak winter months observed in Dhod tehsil corresponds to their finding that minimum temperatures negatively affect parasitoid activity due to physiological stress. The relationship between abiotic factors and pest–natural enemy balance observed in this study also resonates with the conclusions drawn by Chouhan *et al.* (2023), [3] who reported significant correlations between temperature, vapour pressure, and the population dynamics of aphids, pod borers, and leafhoppers in field pea. Their results indicated that maximum temperature had a significant negative correlation with pest abundance, whereas moderate humidity supported pest proliferation, a trend also noted in the current study during December–January, when high humidity and low temperature favored aphid build-up and consequently attracted natural enemies like coccinellids and syrphid flies. Moreover, the observed pattern of episodic rainfall influencing insect activity in the present study is supported by Ram (2016), [5] who highlighted that irregular rainfall events in Indian agroecosystems can alter pest population intensities by 25–40%. The mid-winter rainfall recorded in January in Dhod tehsil, attributed to western disturbances, created transient conditions favorable for certain pest outbreaks, an observation consistent with Ram’s findings on rainfall-driven pest fluctuations in semi-arid regions. Comparable associations between abiotic factors and beneficial insect activity have also been documented by Singh *et al.* (2018) [10] in mustard crops, where aphid populations showed a significant negative correlation with minimum temperature and a positive correlation with relative humidity. This is consistent with the present study’s finding that aphid infestations peaked under cooler, humid

conditions, which simultaneously supported the abundance of aphid predators like *Coccinella septempunctata*.

While most studies emphasize the role of temperature and humidity, Toth *et al.* (2022)^[12] and Yadav *et al.* (2023)^[14] further showed that other abiotic factors like soil moisture, vapour pressure, and sunshine hours may also contribute to variability in insect population responses. For instance, Yadav *et al.* (2023)^[14] reported that relative humidity exhibited a significant positive correlation with several rice pests and their natural enemies, echoing the observation from the Dhod region that moderate humidity levels promote overall insect activity, especially during the reproductive phase of crops.

Conclusion

The present study on the influence of abiotic factors on the distribution and population of beneficial insects in the Rabi crops of Dhod tehsil, Sikar, Rajasthan, showed that climatic parameters such as temperature, relative humidity, and rainfall play a pivotal role in shaping insect activity and abundance. The observed trends are largely consistent with previous studies conducted across diverse agro-ecological zones in India and abroad, which collectively affirm that insect population dynamics are highly sensitive to microclimatic variations. The results of the present study corroborate earlier research demonstrating that insect populations, including both pest and beneficial, are closely linked to seasonal fluctuations in abiotic factors. The pattern of low winter activity followed by a resurgence in late winter to early spring mirrors findings across multiple cropping systems, including potato, field pea, chickpea, mustard, and rice. Collectively, these studies reinforce that temperature and humidity are the principal drivers regulating insect dynamics in agroecosystems. The current findings thus contribute to the growing body of evidence supporting the integration of weather-based monitoring and forecasting tools into pest and pollinator management programs, particularly in semi-arid regions like Dhod tehsil, where climatic variability exerts a decisive influence on agricultural productivity and ecological stability.

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