Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2024; 12(1): 44-49

Received: 12-12-2023
Accepted: 15-01-2024

Dil Mahjoora Majeed
School of Agricultural Sciences, Glocal University, Saharanpur, Uttar Pradesh, India

Aijaz Majeed
Hubei University of Medicine, Wuhan, China

Shafkat Jabbar Mir
School of Agricultural Sciences, Glocal University, Saharanpur, Uttar Pradesh, India

Sajjad Ahmad Khan
School of Agricultural Sciences, Glocal University, Saharanpur, Uttar Pradesh, India

Mohd Majid Jamali
School of Agricultural Sciences, Glocal University, Saharanpur, Uttar Pradesh, India

Corresponding Author:
Dil Mahjoora Majeed
School of Agricultural Sciences, Glocal University, Saharanpur, Uttar Pradesh, India

Effect of temperature, humidity and rainfall on the population of *Bactrocera spp* in mango orchards of Saharanpur district of Uttar Pradesh, India

Dil Mahjoora Majeed, Aijaz Majeed, Shafkat Jabbar Mir, Sajjad Ahmad Khan and Mohd Majid Jamali

DOI: https://doi.org/10.22271/j.ento.2024.v12.i1a.9278

Abstract
This research study was conducted in different mango orchards of Saharanpur district of Uttar Pradesh, India, aimed to analyze the impact of abiotic factors such as rainfall, temperature, and humidity on the population fluctuations of *Bactrocera spp*. The study involved the use of traps with parapheramone Methyl Eugenol, as attractant, to monitor the seasonal incidence of the fruit fly, *Bactrocera spp*, for a period of seven months Apr-Oct, over the year 2022. The results revealed that a majority of 4 fruit fly species of genus *Bactrocera* namely *Bactrocera dorsalis*, *B. zonata*, *B. correcta* and *B. tau* were identified to be present throughout the season in the region but were most active during a peak season of Jul-Sep. The species *B. dorsalis* was found to be most prevalent species among all followed by *B. zonata* and others. The study provides valuable insights into the population dynamics of *Bactrocera spp* in mango orchards in relation to abiotic factors, which is crucial for the development of effective pest management strategies. The population fluctuation of *Bactrocera spp* varied with temperature variations, relative humidity and average rainfall in the Saharanpur region of Uttar Pradesh, India. The study conducted showed that the catches of *Bactrocera spp* started at different times in relation to temperature. The peak average population of the fruit fly was also observed to be significantly affected by minimum temperature changes, with peak average populations recorded at specific times in the season in relation to temperature, relative humidity and average rainfall fluctuations. A total catch of 1348 of the different species of genus *Bactrocera* was recorded out of which 658, 394, 213 and 83 comprised of *B. dorsalis*, *B. zonata*, *B. correcta* and *B. tau* respectively. Statistical analysis of the data was carried to see the effect of abiotic factors *viz* minimum and maximum temperature, morning and evening relative humidity and average rainfall on the seasonal incidence of the different species of genus *Bactrocera*. From the correlation and regression analysis we see that there is a positive correlation between minimum temperature, relative humidity and average rainfall and the occurrence of *Bactrocera spp*.

Keywords: *Bactrocera*, abiotic factors, seasonal incidence, temperature, humidity, rainfall

Introduction
Mango (*Mangifera indica* L.), often referred to as the "King of Fruits," stands as a tropical delight cherished for its exquisite taste, vibrant aroma, and diverse culinary applications. Belonging to the Anacardiaceae family, this evergreen tree has played a pivotal role in the cultural, economic, and nutritional tapestry of regions where it thrives. The mango tree, native to South Asia, has successfully traversed geographical boundaries, making its mark as a global fruit commodity. With its succulent taste, vibrant colors, and diverse varieties, the mango has become synonymous with the tropical bounty of India. The cultivation of mango is of significant economic importance in India, with the country being one of the leading producers of this tropical fruit. As of 2021, India produced around 43% of the world's total mangoes contributing significantly to the country's agricultural economy [1, 2]. With a 21% market share, Uttar Pradesh leads India in mango production. The diverse agro-climatic conditions in Uttar Pradesh provide a favorable environment for cultivating various varieties of mangoes. However, mango production faces a considerable threat from various insect pests, among which the *Bactrocera spp*, commonly known as fruit flies, pose a substantial challenge to mango cultivation [3, 4]. The population dynamics of *Bactrocera* species are influenced by a myriad of abiotic factors, with rainfall, temperature, and humidity being among the most crucial determinants.

These factors play a pivotal role in shaping the life cycle, behavior, and population fluctuations of these fruit flies [5]. Understanding the relationship between these abiotic factors and the population dynamics of *Bactrocera spp* is imperative for devising effective pest management strategies in mango orchards [6].

Despite the significance of this relationship, there is a dearth of comprehensive studies focusing on the impact of rainfall, temperature, and humidity on the population dynamics of *Bactrocera spp* in mango orchards, particularly in the Saharanpur district of Uttar Pradesh. Therefore, this study aimed to address this knowledge gap by investigating the influence of these abiotic factors on the population fluctuation of *Bactrocera spp* in mango orchards of Saharanpur region. By elucidating these relationships, this research seeks to contribute valuable insights that can facilitate the development of sustainable pest management practices, ultimately enhancing the productivity and profitability of mango cultivation in the region. In particular, the Saharanpur district of Uttar Pradesh, India, is renowned for its mango orchards, making it a critical area for studying the dynamics of *Bactrocera spp* and their impact on mango production.

Materials and Methods

Field studies were conducted in orchards situated in different places namely Behat, Nakur and Sadholi Kadeem of Saharanpur district of Uttar Pradesh with access provided by School of Agricultural Sciences, Glocal University, Saharanpur Uttar Pradesh India. These locations were chosen due to the fact that they encompass the majority of the district's planted mango fruit hosts and were often fruit fly infested. In order to keep track of the occurrence and spread of different *Bactrocera spp*, this research used a total of 50 traps purchased from local vendor out of which 4 fruit fly traps were installed at each collection site, lured with a combination of methyl eugenol (ME), a specific parapheramone, and malathion, an aggressive agent [7]. These traps measured 14 cm in height and 8 cm in diameter. These traps were hung at a height of around one and a half meters from ground and scattered throughout the orchards to offer adult fruit flies food, shelter, and safety. Strong winds, direct sunshine, and dust is kept away from entering these traps. They were also being inspected after every week, and the dispenser was changed and refilled. The trapped flies were removed from the different traps and killed using chloroform placed safely in air-tight containers then transported to the laboratory for identification with high resolution microscope and taxonomic keys [8]. A typical view of the purchased fruit fly trap and some trapped fruit flies can be seen from Figure 2.1.

A B

Fig 1: (a) shows a typical view of fruit fly trap. (b) shows group of *Bactrocera spp* infesting a mango.

The data for different meteorological factors *viz* minimum and maximum temperature, morning and evening relative humidity and average rainfall of Saharanpur district for the months Apr-Oct was obtained from Indian Meteorological Department from their official website [9]. Based on the date of collections, weekly means were created from the daily data of each meteorological element. The data analysis package was employed to conduct a multiple-regression analysis in order to ascertain the correlation between the weekly trapped number of attracted flies and the weekly mean values of maximum, minimum temperature and relative humidity [10]. The Karl Pearson correlation was done to determine the individual influence of each item [11].

Results and Discussions

Species diversity and seasonal incidence

The presence of four species of genus *Bactrocera* was discovered through studies on the species complex under mango environments in various orchards of district Saharanpur that used methyl eugenol as an attractant. As an overall seasonal sum up a total catch of 1348 flies were captured during the 7-month fruity season of the year 2022. Out of the total *B. dorsalis* was found to be most abundant species with number 658 followed but *B. zonata*, *B. correcta* and *B. tau* with numbers 394, 213 and 83 respectively. Figure 3.2 shows the spread of different species recorded for 30 standard weeks. Most of numbers were recorded in the months of Jul-Aug. Figure 3.1 shows the percentage distribution of each species that were trapped throughout the research period. Meteorological parameters *viz* minimum and maximum temperature, morning and evening relative humidity and average rainfall were recorded from the data obtained from the Indian Meteorological Department website for district Saharanpur of Uttar Pradesh and is compiled in Table 3.1. Table 3.2 shows monthly catch of fruit flies for the duration of 7 months. The data was recorded weekly for 30 standard weeks (SW) starting from 14th standard week of the year 2022. From the data recorded we observe a maximum temperature of 46 degree Celsius and a minimum temperature of 17 degree Celsius thrives in the region of Saharanpur for months Apr-Oct. A total of 768.26 mm of rainfall was recorded during these 7 months with Jul and August being most precipitated.

Table 1: Shows the collection of different species and different meteorological parameters for the year 2022.

SW	Date and Month		Number of individuals trapped in all traps					Climatic parameters				
	Start	End	*B. dorsalis*	*B. zonata*	*B. correcta*	*B. tau*	Total	Temperature (ºC)		Rel. Humidity (%)		Av. Rainfall (mm)
								Max	Min	Morning	Evening	
14	Apr 4	Apr 10	7	5	0	0	12	40	21	46	21	0.0758
15	Apr 11	Apr 17	6	4	1	0	11	41	23	65	33	0.8950
16	Apr 18	Apr 24	9	2	0	0	11	42	22	54	21	1.0689
17	Apr 25	May 1	11	6	1	0	18	43	23	37	13	1.5192
18	May 2	May 8	8	7	3	0	18	42	23	63	55	3.9626
19	May 9	May 15	18	11	4	3	36	46	25	62	15	2.9766
20	May 16	May 22	17	7	3	0	27	44	26	55	57	3.9464
21	May 23	May 29	20	11	8	5	44	41	23	85	61	26.4435
22	May 30	Jun 5	25	14	7	4	50	44	27	70	46	0.1647
23	Jun 6	Jun 12	28	22	14	3	67	45	29	34	26	0.8009
24	Jun 13	Jun 19	25	17	11	9	62	44	24	71	66	19.0973
25	Jun 20	Jun 26	32	22	10	8	72	42	26	83	61	0.9315
26	Jun 27	Jul 3	28	12	8	2	50	40	26	85	69	96.4990
27	Jul 4	Jul 10	26	16	6	3	51	40	26	93	88	56.5276
28	Jul 11	Jul 17	31	22	9	7	69	39	27	93	86	49.6796
29	Jul 18	Jul 24	28	24	12	6	70	40	25	93	89	66.3965
30	Jul 25	Jul 31	35	16	11	8	70	34	24	97	93	28.1152
31	Aug 1	Aug 7	34	18	9	7	68	34	24	96	89	120.9214
32	Aug 8	Aug 14	28	16	11	2	57	35	24	91	84	28.7960
33	Aug 15	Aug 21	31	14	8	5	58	33	24	88	80	26.8412
34	Aug 22	Aug 28	22	11	9	4	46	35	25	91	83	5.7787
35	Aug 29	Sep 4	19	16	11	1	47	33	24	92	90	5.2715
36	Sep 5	Sep 11	23	15	6	0	44	34	25	86	73	9.3661
37	Sep 12	Sep 18	27	12	8	3	50	33	22	96	94	32.2217
38	Sep 19	Sep 25	25	16	7	0	48	32	21	95	79	136.6273
39	Sep 26	Oct 2	18	11	6	0	35	30	21	94	82	6.2754
40	Oct 3	Oct 9	21	8	5	3	37	31	20	93	78	20.1556
41	Oct 10	Oct 16	26	12	11	0	49	27	19	96	83	16.9024
42	Oct 17	Oct 23	14	16	8	0	38	27	18	87	80	0.0039
43	Oct 24	Oct 30	16	11	6	0	33	27	17	94	76	0.0000

We found our results in corroboration with Vayssières JF, *et al*. [12] and Dil Mahjoora Majeed *et al*. [13]. The former have reported *Bactrocera dorsalis* as most abundant species infesting mango and cashew orchards in the Borgou Department, Benin, whileas the latter have reported *B. dorsalis* as most prevalent species in guava orchards of Saharanpur Uttar Pradesh. Muhammad Hamayoon Khan (2021) [14], have reported *B. zonata* and *B. dorsalis* as most serios insect pests of guava and mango fruit.

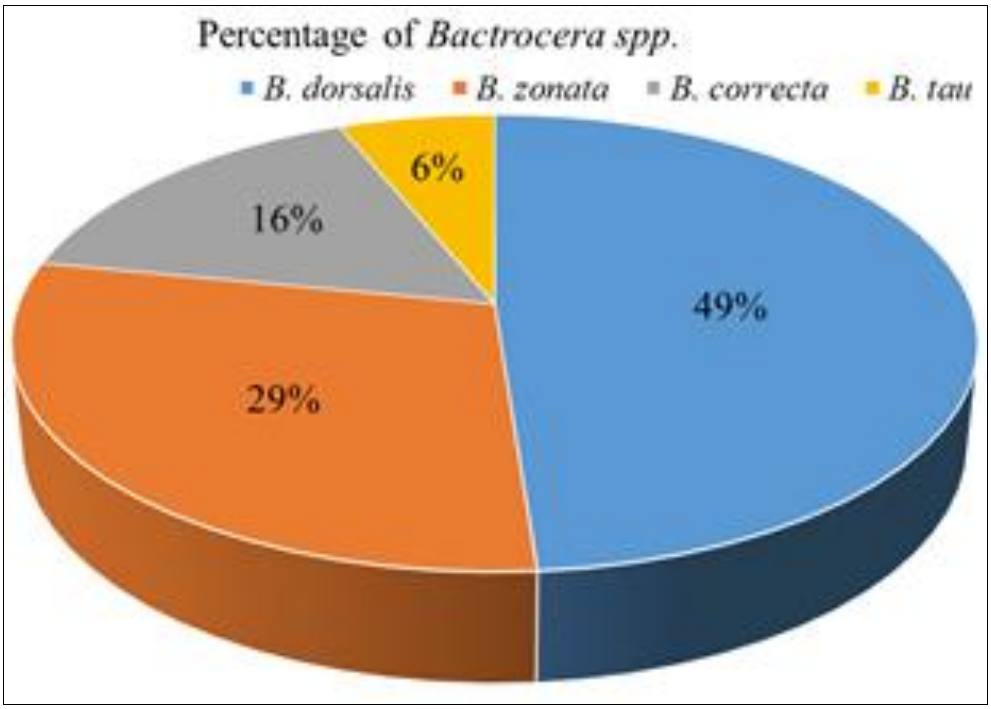

Fig 2: Shows percentage of different species out of total collection.

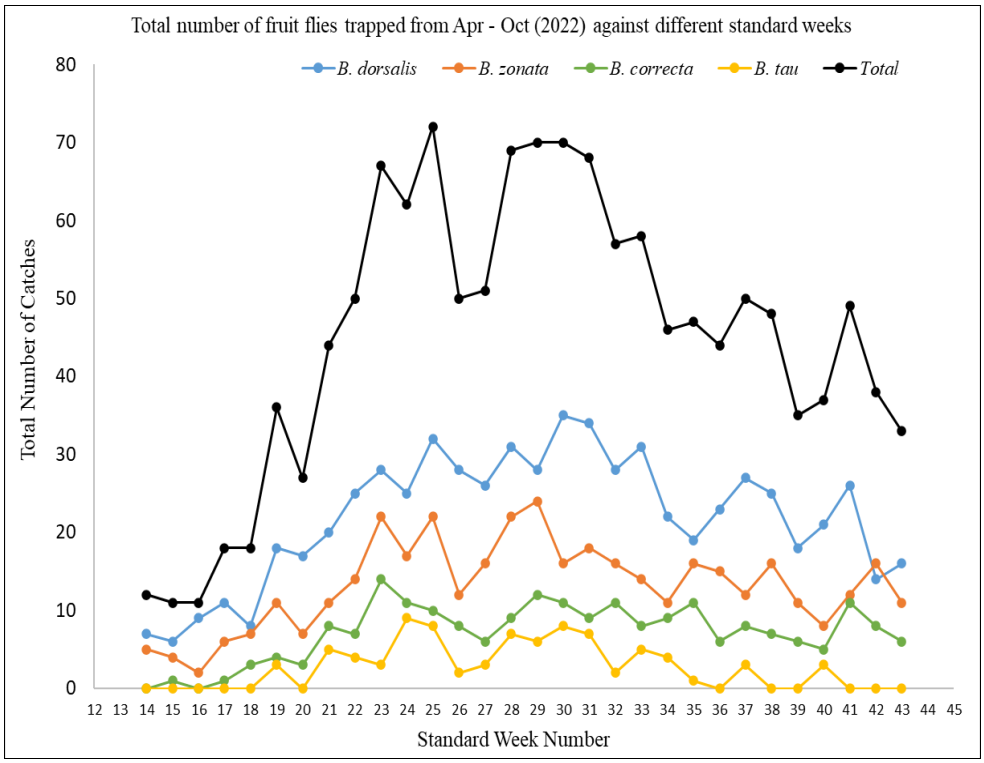

Fig 3: Shows the spread of different species of genus *Bactrocera* corresponding to 30 standard weeks.

Statistical data analysis (Correlation and regression): Table 3.3 presents the data on the correlation between fruit fly population and meteorological characteristics. According to the findings, there was a substantial positive association between the minimum temperature and the species catch. The most abundant species *B. dorsalis* was recorded with a maximum positive correlation coefficient of 0.604 and 0.510 corresponding to the evening relative humidity and average rainfall respectively. However, maximum temperature was observed to be negatively correlated and the degree of correlation is weak while minimum temperature is also recorded to be positively correlated with coefficient 0.427. For all the species except *B. tau* the maximum temperature is negatively correlated but the degree of correlation is weak or we can say that the species population is unaffected by the maximum temperature.

Table 2: Shows total population collected in different months of the fruity season.

Month/Species	*B. dorsalis*	*B. zonata*	*B. correcta*	*B. tau*	Total
Apr	33	17	2	0	52
May	63	36	18	8	125
Jun	110	75	42	24	251
Jul	148	90	46	26	310
Aug	115	59	37	18	229
Sep	94	59	32	4	189
Oct	95	58	36	3	192

Table 3: Shows correlation coefficients of different species of *Bactrocera* against different abiotic factors.

Species/Correlation coefficient	Temp (Max)	Temp (Min)	RH (Morning)	RH (Evening)	Rainfall
B. dorsalis	-0.144	0.427	0.427	0.604	0.510
B. zonata	-0.067	0.419	0.408	0.502	0.370
B. correcta	-0.229	0.283	0.482	0.598	0.260
B. tau	0.236	0.463	0.301	0.301	0.244
Total	-0.092	0.445	0.506	0.585	0.428

The nature of the correlation between the fruit fly population and various abiotic factors was evaluated with the multiple regression analysis and the recorded data is shown in Table 3.4. The equation of regression is Y = Constant term + AX_1 + BX_2 + CX_3 + DX_4 + EX_5, where Y represents total number of flies, X_1, X_2, X_3, X_4 and X_5 represents maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and average rainfall respectively with A, B, C, D and E being their respective coefficients of regression. The regression was done at a confidence of %. The terms in the parenthesis are the predictive values. Figure 3.3 shows the line fit plots of observed data and the predicted values according to the equation of regression. The value of R square for *B. dorsalis* is recorded to be maximum 0.707 providing the best predicting the most approximate values of population corresponding to different weeks.

Table 4: Shows the multiple regression coefficients of different species corresponding to different abiotic factors. All the coefficients are calculated over a significance level of 5%. The numbers within the parenthesis denote the predictive values.

Species/Regression coefficients	Constant term	A (Temp Max)	B (Temp Min)	C (RH Mor)	D (RH Eve)	E (Rainfall)	R Square	Adjusted R Square
B. dorsalis	-25.284 (0.075)	-0.529 (0.182)	2.271 (0.001)	0.133 (0.323)	0.029 (0.780)	0.046 (0.125)	0.707	0.646
B. zonata	-14.626 (0.232)	-0.218 (0.525)	1.266 (0.024)	0.003 (0.978)	0.084 (0.363)	0.016 (0.531)	0.513	0.412
B. correcta	-6.618 (0.411)	-0.205 (0.368)	0.759 (0.040)	-0.027 (0.727)	0.089 (0.152)	-0.005 (0.786)	0.518	0.418
B. tau	-24.511 (0.001)	0.397 (0.040)	0.124 (0.669)	0.090 (0.162)	0.038 (0.440)	-0.005 (0.742)	0.487	0.380
Total	-71.040 (0.046)	-0.554 (0.566)	4.419 (0.007)	0.199 (0.548)	0.240 (0.357)	0.053 (0.468)	0.649	0.576

Vayssières, Jean-François *et al*. (2009) [5], have reported significant positive correlation between population of *Bactrocera spp* with average rainfall. N. N. Yin *et al*. (2018) [15], have reported population fluctuation of male fruit flies positively correlated with temperature and rainfall, and negatively correlated with the duration of sunshine, in mango orchard farms of Department of Agricultural Research in Yezin, Myanmar. Amandeep Kaur *et al*. (2020) [16] have reported trap catches of guava ecosystem being positively correlated with all the weather parameters, while under citrus ecosystem minimum temperature and rainfall showed negative correlation, but relative humidity was positively correlated in different guava and citrus fruits crops in two agro ecological zones of North West India. Rajesh Kumar (2021) [17] reported significant positive correlations between average temperature and rainfall with the population of fruit flies, whereas average relative humidity and population of fruit flies revealed the presence of statistically insignificant negative correlations.

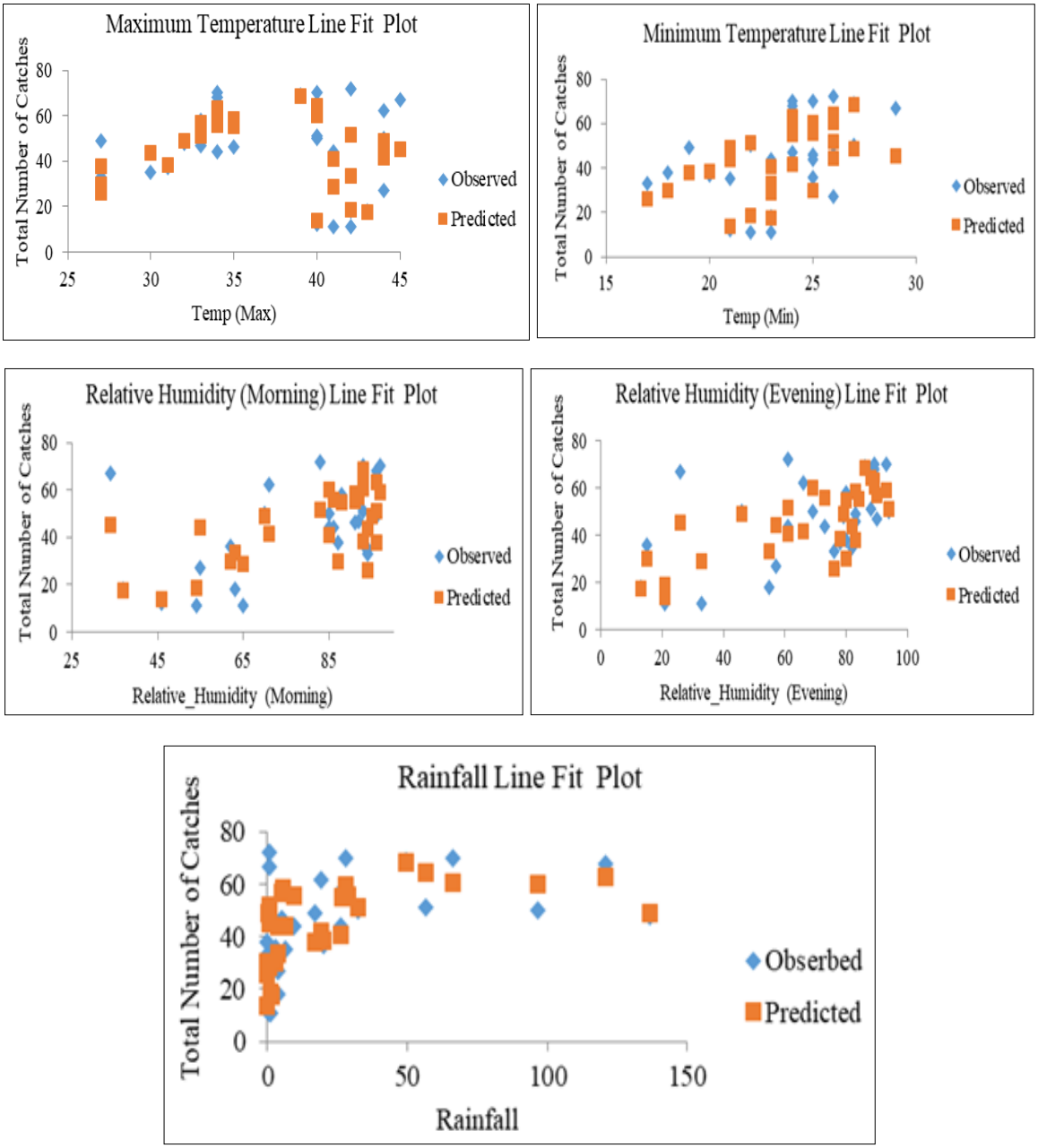

Fig 4: Shows the observed data and the fitted data with regression for each abiotic factor.

Conclusion

Understanding the challenges and opportunities for devising effective strategies to enhance productivity, reduce losses, and ensure sustainable growth this research was aimed at addressing the existing challenges by getting insights into the seasonal abundance of fruit fly species in mango orchard ecosystems in presence of abiotic factors. The species that emerged as most prevalent fruit fly species complex during research survey in the mango farms of Saharanpur district of Uttar Pradesh was recorded to be *B. dorsalis and B. zonata*. Research conducted on the frequency of mango fruit flies showed that they were present in the orchard all the season round. July and August recorded the highest population density. It was discovered that *B. dorsalis* dominated the mango environment. The population of *B. dorsalis* and others showed a significant correlation with the seasonal average rainfall and evening humidity.

Authors contribution

The field collection was done by Dil Mahjoora Majeed and the statistical analysis was done by Aijaz Majeed while as all the authors equally contributed in the writeup process. The research was supervised by Dr. Mohd Majid Jamali.

Conflict statement

The authors declare that they have no conflict of interest.

Acknowledgement

The authors would like to thank School of Agricultural Sciences, Glocal University Saharanpur India for providing access to various mango orchards of local nearby areas. Also, the authors extend their gratitude towards the farmers and workers who peacefully cooperated for the field collection.

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