



Population fluctuations of *Bactrocera zonata* (Saunders) in connection with different weather parameters in Saharanpur, Uttar Pradesh, India

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Abstract

One of the most essential elements in developing an integrated pest management (IPM) strategy for sustainable agriculture is the regular monitoring of the population of insect pests infesting different orchards and farms, round the year. The research presented in this manuscript was conducted to investigate the population dynamics of fruit fly species *Bactrocera zonata* throughout the year 2022 (52 standard weeks) in various mango orchards of Saharanpur district of Uttar Pradesh. While considering the influence of major meteorological variables, including average monthly temperature, minimum and maximum monthly temperature, mean relative humidity and average monthly rainfall, the study aims to elucidate the impact of climatic conditions on the abundance and distribution of these insect pests. Field surveys were conducted over a specified period of 52 standard weeks and with the help of cylindrical traps associated with lure methyl eugenol a mean catch of 997.01 per trap was recorded for the year 2022. Weeks/months with relatively higher temperatures recorded larger amounts, May (150.45/trap), June(170.65/trap), August(102.03/trap), October(145.80), whileas these pests were seen active throughout the year. Since methyl eugenol attracts only male adult flies of the species *B. zonata* these traps were flooded with male flies compared to females. Statistical analysis of the collected data reveals a significant positive correlation of the fruit fly population, caught per trap for the whole year, with monthly average temperature ($r = 0.729$), monthly maximum temperature ($r = 0.649$) and monthly minimum temperature ($r = 0.637$). However, average relative humidity and average rainfall came up with negative correlations of correlation coefficients $r = -0.424$ and $r = -0.367$. These correlation results between *B. zonata* population fluctuations and specific weather parameters provide valuable insights for the development of effective pest management strategies.

Keywords: *Bactrocera zonata*, oriental fruit fly, population dynamics, weather parameters, pest management

Introduction

Mango (*Mangifera indica* L.) holds a prominent position in Indian agriculture, contributing significantly to the country's economy and global fruit trade. As per latest data record of 2022 [1], India remains the leading global producer of mangoes, accounting for a substantial share of 51% of the world's total output. Uttar Pradesh is leading the mango production in India contributing to 21% market share [2, 3, 4]. With a yield of 10 tons/hectare and a production of 259460 MT over 25946 hectares, Saharanpur is top mango producer [5]. Behat, Nakur, Sodholi Kadeem, Sarshawa Nagar, and Rampur are the primary mango clusters across the district. Various factors contribute to this success, including favorable climatic conditions, diverse agro-ecological zones, and extensive cultivation across the district. The peak mango season in the state is from June to August.

This productivity rate might have grown enormously in the past years but the mango cultivation in this area has struck badly by infestation of fruit fly species *Bactrocera zonata*, commonly known as the peach fruit fly, which is a renowned agricultural pest that inflicts substantial damage to a wide variety of fruits, leading to severe economic losses [6, 7]. *B. zonata* infestation often leads to damage in mango fruits [8,9,10]. It was observed that more than 50 cultivated and wild plant species have been found to have its infestation, primarily those with juicy fruits [11]. The larvae

of the fruit fly tunnel through the fruit, causing internal damage and affecting its quality. This results in a decline in market value and economic losses for mango farmers [12].

To combat the challenges posed by *B. zonata*, ongoing research and development efforts are essential. Understanding the factors influencing the population dynamics of this pest is crucial for the development of targeted and sustainable pest management strategies. This study recognizes the weather conditions as one of the significant factors affecting the abundance and distribution of *B. zonata*, making it imperative to investigate the relationship between weather parameters and population fluctuations. The research findings indulge in formulating various control measures and strategies including the development of effective biological control methods, and integrated pest management practices that minimize the reliance on chemical pesticides.

Materials and Methods

The research was conducted three major mango clusters of Saharanpur viz, Behat, Nakur and Sodholi Kadeem. These locations were chosen because they represented the majority of the region's planted fruit hosts and are frequently fruit fly infested. The trapping of fruit flies was accomplished using cylindrical traps (11-inch height, 7-inch diameter) purchased online from India Mart website from Farmroot Agritech Private Limited Hebbal, Bengaluru, Karnataka (100 pieces).

Methyl Eugenol, a naturally occurring chemical substance also known as allylveratrol, was used as an attractant with these traps. It is present in more than 450 species of plants, spanning 80 families, including the gymnosperm and angiosperm families, and plays a part in luring pollinators. F. M. Howlett ^[13], initially observed their propensity to attract insects in 1915, specifically genus *Bactrocera* spp. A total of 100 traps were installed, 40 traps in Behat, 30 traps in Nakur and 30 traps in Sadholi Kadeem, in different mango farms. They were hanged from mango tree at a height of one and a half meters from ground. Dispensers were employed to spray methyl eugenol at regular intervals. The traps were investigated weekly and the trapped flies were carried to laboratory for taxonomic identification.

The data for monthly average rainfall of Saharanpur for the year 2022 was collected from Indian Meteorological Department website ^[14], data for average temperature, maximum and minimum temperature and relative humidity was obtained from world weather website ^[15]. Statistical methods, including correlation analysis and regression analysis, were employed to assess the relationships between *B. zonata* populations and different weather parameters. Data were processed using IBM SPSS software to derive meaningful insights.

Results and Discussions

1. Population fluctuations with abiotic factors

The meteorological data and number of flies of species *B. zonata* corresponding to different standard weeks were categorized into monthly averages as given in Table 1. The results showed that *B. zonata* population was active round the year, but warm months captured the most number of flies as compared to cold months. Fig 1 shows the number of individuals of species *B. zonata* caught per trap corresponding to different standard weeks of year 2022 with SW1 starting from Jan 3 to Jan 9 and SW52 starting from Dec 26 to Jan 1 (2023). Initially a weekly mean of 25.24

flies per trap on matured fruits was recorded for SW16 and a remarkable increase in fly population was observed thereafter reaching 42.16 flies per trap on SW21 at maximum and minimum temperatures of 39 °C and 27 °C respectively, and 36% mean relative humidity coinciding with the fruity season of mango in Saharanpur. There is a gradual decline in population level due to the negative effects of high records of maximum temperature 47 °C, which force fertile female flies to locate other places in search of a new suitable host. From January (SW1) to early April (SW15) and mid-November (SW45) to ending December (SW52), the traps recorded lowest populations. The primary cause of this decline in fly activity and the immigration of flies towards warm zones at this time was the cold weather conditions. This drop in temperature forces the immature stages to enter a winter dormant state, which lengthens the immature stage periods and decreases the adult fly population.

The population began to increase in mid-April (SW15) and peaked at SW21 (May 23-May 29) with 42.16 flies per trap as a result of improved weather conditions that created an ideal environment for insect pest activities. The standard week number 26 and 27 of July month saw a sharp decline in the species population which was attributed to the cumulative action of maximum temperature recorded (41 °C and 40 °C respectively), mean relative humidity (80% and 78% respectively) and average rainfall (69.193 mm and 39.226 mm respectively). From late July (SW29) upto the month of August (SW30-SW34) the fly populations saw a slight increase due to the return of favorable climatic conditions. Again during month of September (SW35 to SW39) there was a decrease in fly population due to adverse effects of maximum temperature of 36 °C, relative humidity of 80% and average rainfall of 185.2 mm. From SW40 to SW44 there was a sharp incline in the fly population due to favorable climatic conditions.

Table 1: Shows number of flies of species *B. zonata* caught per trap and the monthly averages for different weather parameters for the year 2022.

Month	Number of flies/Trap	Temp (Av) °C	Temp (Max) °C	Temp (Min) °C	Humidity (%)	Av Rainfall (mm)
Jan	5.40	12.6	20	11	74	177
Feb	40.26	15.7	25	12	67	31.9
Mar	50.72*	20.9	39	13	54	0
Apr	80.81	27.2	46	25	34	0
May	150.45	30.9	47	27	36	32.7
Jun	170.65*	31.2	46	25	52	39.4
Jul	65.00	28.6	41	26	80	170.8
Aug	102.03	27.8	39	26	84	79.2
Sep	55.11*	26.6	36	24	80	185.2
Oct	145.80	23.4	32	19	66	20.6
Nov	80.55	18.8	28	18	62	0
Dec	50.23*	14.2	24	10	69	0

* Sum of five weekly observations

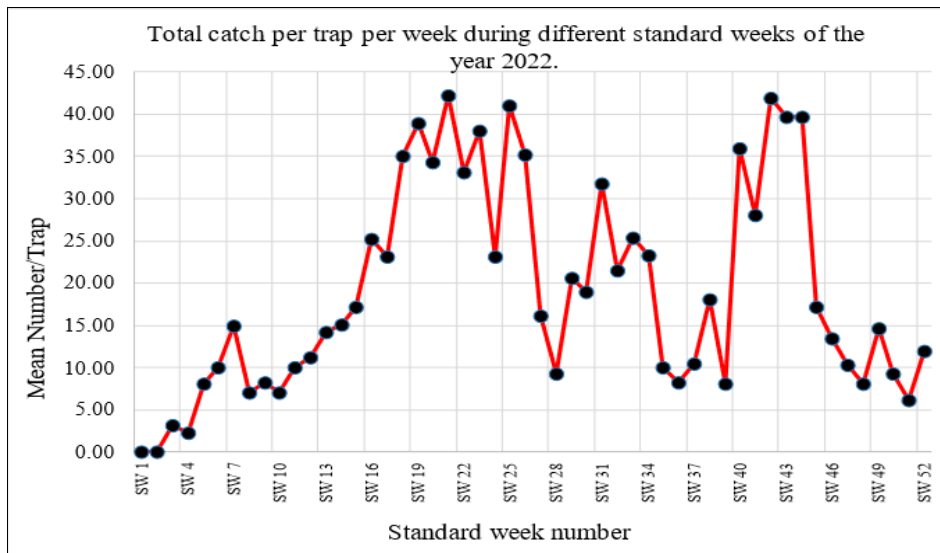


Fig 1: shows number of *B. zonata* flies caught per trap per standard week for year 2022 in different mango orchards of Behat, Nakur and Sodholi Kadeem.

From the statistical analysis of the data, done via IBM SPSS software, the fly population and monthly average, maximum and minimum temperatures revealed a highly significant positive correlation, as demonstrated in Table 2, indicating that weekly means of temperature had a substantial influence on the activities of the fly population. These results are obvious as temperature is a fundamental weather variable that profoundly influences the metabolism, behavior, and distribution of species. Species experience changes in reproductive cycles or migration patterns in response to temperature fluctuations. However, the pest population showed a negative significant correlation with the mean relative humidity and average rainfall. Humidity and rainfall play a crucial role in shaping microclimates and influencing the physiological processes of species. Species adapted to particular humidity levels may experience shifts in their habitats thus affecting population sizes. The numerical values for different weather factors are given in

Table 2 which shows a positive correlation coefficient of 'r = 0.649' for maximum temperature, 'r = 0.729' for average temperature, 'r = 0.637' for minimum temperature and a negative correlation coefficient of 'r = -0.424' and 'r = -0.367' for mean relative humidity and average rainfall respectively. Upon computing the coefficient of determination (COD), it turned out that 53.204% of the variations in *B. zonata* population were caused by monthly average temperature making it the factor with the largest impact followed by maximum and minimum temperatures bringing variations of 42.181% and 40.579% respectively in the species population. The mean relative humidity and average rainfall were least effective with variations of 17.979% and 13.495% respectively. Thus, we conclude that seasonal weather patterns introduce a temporal dimension to the analysis, as species often exhibit distinct behaviors and life stages in response to changing seasons.

Table 2: Shows the Pearson correlation analysis of species population and different weather factors influencing it.

Correlation Analysis					
	Temp (Max) °C	Temp (Av) °C	Temp (Min) °C	Humidity (%)	Av Rainfall (mm)
Pearson Correlation (r)	0.649*	0.729**	0.637*	-0.424	-0.367
Sig. (2-tailed)	0.022	0.007	0.026	0.170	0.240
COD (r ²) × 100 (%)	53.204	42.181	40.579	17.978	13.495

*. Correlation is significant at the 0.05 level (2-tailed).
 **. Correlation is significant at the 0.01 level (2-tailed).
 COD = coefficient of determination

Table 3: Shows multiple regression analysis of the *B. zonata* population with different meteorological parameters.

Multiple Linear Regression Analysis					
R	R Square		Adjusted R Square	Std. Error of the Estimate	
0.971 ^a	0.943		0.896	16.15663	
Coefficients ^b of Multiple Linear Regression					
Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	Values	Std. Error			
Constant	107.243	51.547		2.080	0.083
Temp (Av)	27.348	5.018	3.588	5.450	0.002
Temp (Max)	-11.992	2.479	-2.234	-4.837	0.003
Temp (Min)	-6.769	2.936	-0.897	-2.306	0.061
Humidity	-1.313	0.552	-0.431	-2.379	0.055
Av Rainfall	-0.305	0.095	-0.449	-3.208	0.018

a. Predictors: (Constant), Av Rainfall (mm), Temp (Av) °C, Humidity (%), Temp (Min) °C, Temp (Max) °C
 b. Dependent Variable: Total Catch

We have computed the multiple regression analysis of *B. zonata* population with different weather factors that provides a robust framework for unraveling the intricacies of ecological systems. By delving into the relationships between monthly average temperature, maximum and minimum temperature, humidity and rainfall patterns deeper understanding of how these factors collectively shape the abundance and distribution of species. Table 3 depicts the multiple regression results of *B. zonata* population and different abiotic factors. The 'R square' value of 0.943 suggests that all these weather factors work perfectly in interaction to influence the overall population of *B. zonata* species. The equation of regression was found out to be as follows:

$$Y = C + (\beta_1 \times X_1) + (\beta_2 \times X_2) + (\beta_3 \times X_3) + (\beta_4 \times X_4) + (\beta_5 \times X_5)$$

Where 'Y' is the predicted *B. zonata* population, 'C' is constant (intercept), β_1 , β_2 , β_3 , β_4 and β_5 are the multiple regression coefficients, given in Table 3, corresponding to weather variables X_1 , X_2 , X_3 , X_4 and X_5 which represent monthly average temperature, maximum and minimum temperature, mean relative humidity and average rainfall. Fig 2 depicts the deviation of predicted values of *B. zonata* population, as estimated from regression equation, from that of the actual population collected during the research period. The results show a good fit with almost all values coinciding with each other giving a straight line passing through origin with a slope of unity. All these factors are highly significant in predicting the species population.

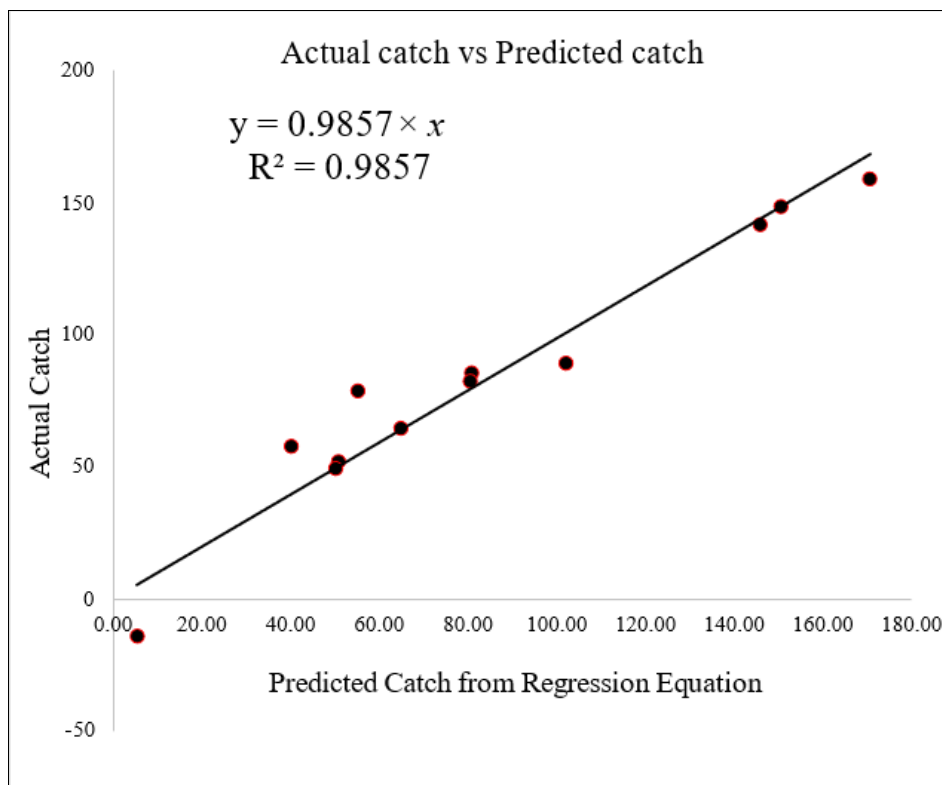


Fig 2: Shows fitness of the predicted results for *B. zonata* population as estimated from the regression equation with the actual population.

This knowledge is essential for devising conservation strategies, biodiversity management, and mitigating the impacts of climate change on ecosystems. The findings of this study suggest that weather conditions play a crucial role in shaping the population dynamics of *B. zonata*. Understanding these relationships can contribute to the development of targeted pest management strategies, taking into account the influence of climate on the fruit fly population.

Discussions

The distribution and incidence of *B. zonata* in Saharanpur district of Uttar Pradesh, particularly in the Behat, Nakur and Sodholi Kadeem, have drawn the greatest interest recently due to the rapidly rising agricultural productivity and commerce. The yearly monitoring of insect populations is one of the most important basic data sets for creating an integrated pest management (IPM) strategy for sustainable agriculture. The current study discovered that *B. zonata*

population was present all the year round, with the exception of brief intervals during the hot summer when the climate, particularly the extremes of temperature, was unfavorable for insect activity and during the harvesting stage. During the cold winter when the low temperatures force the immature stages to remain dormant, reducing the number of adults, the species population varied throughout the trial and the number of pests increased either gradually. Comparing our results with the others we found that Bagheri, Abdoolnabi, *et al* (2017) [16] also had reported that methyl eugenol baited traps were effective in capturing *B. zonata* populations in mango orchards from Iran. V. R Satarkar, *et al* (2009) [17] have also reported *B. zonata* being attracted towards methyl eugenol lured traps from Goa, India. Hossain, M. A., *et al* (2017) [18] have also reported abundance of species *B. zonata* from mango orchards of various places of Bangladesh. Khan, Muhammad Hamayoon, *et al.* (2021) [19] have reported *B. zonata* and *B. dorsalis* as most prevalent fruit fly pests infesting guava

orchards in Pakistan. Ghanim, Nabil M *et al* (2015) ^[20] has reported occurrence of *B. zonata* in various mango orchards of Egypt. Dil Mahjoora Majeed *et al* (2024) ^[21-23] also have reported abundance of two species of genus *Bactrocera* namely *B. dorsalis* and *B. zonata* in mango and guava orchards of Saharanpur district of Uttar Pradesh, India. They have also reported positive correlation of species population with climatic factors like temperature, rainfall and humidity. Rahman, K. A. Rahman (1940) ^[24] have studied effect of temperature on population of *B. zonata* as reported significant positive correlation between fly population and temperature. N. A. Ali *et al* (2011) ^[25] from Egypt have reported significant positive correlation between *B. zonata* population and minimum and maximum temperature while as negative correlation with relative humidity. I. R. El-Gendy *et al* (2012) ^[26] from Egypt also studied effect of climatic factors on *B. zonata* population in mango orchards and reported positive correlation between fly population and mean temperature and negative correlation with relative humidity. Rashid Ahmed Khan and Muhammed Naveed (2017) ^[27] from Pakistan have reported positive correlation of fruit fly with temperature and negative correlation with humidity. Jean-Francois Vayssieres *et al* (2009) ^[28] have reported minimum-maximum temperature, humidity and rainfall as major influencers of the fly population. Draz, Khalil A (2016) ^[29] also reported that negative effect of wind speed on fly trapping and positive effect of mean and maximum temperatures on fly catching.

Conclusion

In conclusion, the implementation of Integrated Pest Management (IPM) strategies for managing *B. zonata* in mango orchards requires a comprehensive understanding of the prevailing climatic factors. The success of an IPM approach is intricately linked to the dynamic interplay of temperature, humidity, and rainfall patterns. Temperature plays a pivotal role in influencing the life cycle and activity of *B. zonata*. By closely monitoring temperature variations, especially during key developmental stages, practitioners can fine-tune control measures for optimal effectiveness. Humidity, another critical climatic factor, directly impacts the population survival and reproduction. Implementing IPM practices that modify humidity levels, such as appropriate irrigation management, can disrupt the species life cycle and limit its proliferation. Furthermore, considering regional rainfall patterns is essential in devising a sustainable IPM strategy. Adequate rainfall can contribute to soil moisture management, promoting the activity of natural predators and microbial antagonists that act against *B. zonata*. In crafting an effective IPM plan for *B. zonata*, a nuanced understanding of these climatic factors becomes the cornerstone for proactive and responsive pest management. By integrating this knowledge into decision-making processes, orchard managers and researchers can foster a resilient and sustainable approach to mitigating the impact of *B. zonata* on mango orchards, ensuring the longevity and productivity of this vital agricultural ecosystem.

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