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Effects of Biodiversity and Climate Variables on Fruit Fly Infestations: Implications for Nutritional Quality of Kinnow and Guava in Punjab, India

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Abstract

In India, fruit flies are among the most critical agricultural pests, due to their ability to feed on various plants (polyphagous) and the substantial economic losses they inflict on fruit and vegetable crops, with damage ranging from 2.5% - 100% depending on the crop and region. Research was undertaken in 2022 and 2023 at Lovely Professional University, Phagwara, Punjab, to investigate the impact of weather parameters on population fruit flies in kinnow and guava fruit crops across two agro-ecological zones in Northwest India. Throughout this fruiting season, methyl eugenol (ME) based pheromone and fruit fly traps were used to monitor fruit fly populations in fruit orchards. The highest fruit fly incidence in the guava ecosystem was recorded between the 35th and 39th standard weeks. In the kinnow ecosystem, the peak incidence occurred between the 39th and 42nd standard weeks in both years. The most dominant species was *Bactrocera zonata*, while *Bactrocera dorsalis* was the next most prevalent. *Zeugodacus cucurbitae* ranked third in species composition, while *Bactrocera correcta* occupied the fourth position. In both 2022 and 2023, the Shannon diversity index was highest in the kinnow ecosystem, followed by the guava ecosystem in 2022. Kinnow 2022 also exhibited greater species richness and evenness. These findings are crucial for guiding the development of precise pest management strategies tailored to specific zones.

Keywords

Biodiversity, Fruit fly, Guava, Kinnow, Population dynamics

Introduction

India is a significant producer of a variety of tropical, subtropical, and temperate fruits. The country contributes 11.38% to global fruit production and 11.78% to global vegetable production [1]. The total area dedicated to horticulture in India is 27.23 million hectares, with a corresponding production of 331 million tons. Guava (*Psidium guajava* Linn.), a key fruit crop in the Myrtaceae family, is also known as the "poor man's apple" [2].

The origin of guava was Central America, and in the seventeenth century, it was introduced to India through the Portuguese [3]. Despite its significance, India exhibits lower guava productivity compared to other countries, primarily due to significant insect pest issues [4, 5]. Citrus species are infested by numerous insect pests, including *Diaphorina citri*, *Phyllocnistis citrella*, *Bactrocera* spp., and *Planococcus citri*. Among these, fruit flies are recognized as the most significant pests and are deemed among the most detrimental crop pests globally [6].

Fruit flies, also called peacock flies or true flies, are members of the order Diptera and belong to the extensive and diverse family Tephritidae. Among the approximately 4,500 species described within this family, around 200 are recog-

nized as pests on a global scale. Of these, approximately 70 species are of significant agricultural concern and are classified as major pests worldwide [7-10]. Approximately 5% of all tephritidae species are economically significant [11]. In the Indian subcontinent, there are 325 identified species of fruit flies, with 243 species occurring in India across 79 genera [8, 11]. Key fruit fly species causing significant damage to fruit crops in India include *B. zonata* (Peach fruit fly), *B. correcta* (Guava fruit fly), *Z. cucurbitae* (Melon fly), *B. dorsalis* (Oriental fruit fly or mango fruit fly), and *Carpomyia vesuviana* (Beer fruit fly). These pests affect a range of plant species, including fruits (e.g., mangoes, apples, and citrus) and vegetables (e.g., cucumber, gourd family crops, and tomatoes) [7, 12]. In Punjab, the oriental fruit fly (*B. dorsalis* Hendel) and the peach fruit fly (*B. zonata* Saunders) are major pests of citrus fruits [13]. The adult female fruit fly uses its needle-like ovipositor to puncture fruit and lay eggs inside. Once the eggs hatch, the maggots feed on the pulp, which can lead to fruit damage ranging from 30% - 100% [14-16]. *B. dorsalis* and *B. zonata* have been observed causing damage to kinnow between August and October [17]. These fruit flies are also known to severely infest nearly all fruit crops, including peach, pear, mango, guava, and citrus, during the rainy season in Jammu and Kashmir and Punjab. The highest activity period for fruit flies is from August to November, aligning with the key growing seasons for many fruit crops [18, 19].

The management of fruit flies poses significant challenges due to the oviposition of eggs within the fruit, followed by maggot feeding inside. Upon maturation, the maggot exits the fruit to pupate in the soil, thereby evading contact with insecticides and reducing the efficacy of chemical control measures [20]. Understanding the biodiversity of fruit flies within conservation units provides crucial insights for developing effective management techniques. Additionally, it offers valuable data on fauna that may potentially impact fruit crops [12]. This study aimed to evaluate the diversity and species richness of Tephritidae fruit flies in various fruit orchards, while also examining the influence of abiotic factors on their population dynamics across different agro-ecological conditions in the Northwest Plain Zone of India. This study aims to analyze how environmental factors such as temperature, humidity, and rainfall affect fruit fly populations. The findings will provide valuable insights for developing targeted, eco-friendly pest management strategies to reduce fruit damage and improve crop productivity.

Materials and Methods

Location of the experiment

The agricultural experimental farm of Lovely Professional University in Phagwara was used as a site for the experiment. Fruit fly species were collected from guava and kinnow orchards located at 31.3260° N, 75.5762° E, and 228 meters above sea level. Data collection was done by pheromone traps, which are set up in the fruit orchards.

Trapping fruit fly by using ME trap

Traps and sex attractants ME used to catch adult male fruit flies were supplied by PCI (Pest Control Private Limited). A pear-shaped yellow trap measuring 15 × 12 × 10 cm was used to catch male fruit flies in the guava and kinnow plantations. Plywood dispenser blocks with dimensions of 4 × 2.5 × 1 cm were treated with a ME formulation to improve fruit fly trapping. Four traps with sex attractant (4 replications) were installed in both fruit orchards (randomly) with a height of 1.5 meters from ground level. The trapped male flies were kept separately in zip-lock bags. Data was collected continuously with a seven-day interval; on the basis of morphological characteristics, flies were identified and separated according to the species. This record is maintained throughout the fruiting season of the crops, and the lures were replaced after two months.

Identification and accessing the diversity indices for fruit fly mango and guava ecosystem

The sample fruit flies were observed under a stereo zoom light microscope at 40× to 60× magnification for species-level identification, utilizing the dichotomous key developed by David and Ramani [8]. The diversity indices were calculated using several methods. Relative density (%) was determined by equation 1

$$Relative\ density\ (\%) = \frac{Number\ of\ individual\ of\ one\ species}{Number\ of\ individual\ of\ all\ species} \times 100 \quad (1)$$

Simpson's diversity index (SDI)

The alpha diversity quantified using Shannon-Wiener index (H') [21], SDI [22], Margalef Richness Index (Mg) [23], Pielou's Evenness Index (EI) [24], and dominance index (D) were calculated by using the following equation 2

$$SDI = \frac{\sum n(n-1)}{N(N-1)} \quad (2)$$

Where, n represents the total number of organisms of a specific species, and N denotes the total number of organisms across all species.

H'

$$H' = -\sum Pi \ln(Pi) \quad (3)$$

Where, $Pi = \frac{S}{N}$, S represents the number of individuals of a specific species, N denotes the total number of individuals in the sample, and ln stands for the natural logarithm (logarithm to the base e).

EI

$$EI = \frac{H'}{\ln(S)} \quad (4)$$

Where, S is the total number of species in the sample.

Mg

$$Mg = \frac{(S-1)}{\ln N} \quad (5)$$

Where, S is the total number of species recorded, and N is the total number of individuals summed overall S species.

D was calculated by using the formula

$$D = \sum\left(\frac{n}{N}\right) \text{ or } D = \frac{\left(\sum n(n-1)\right)}{N(N-1)} \quad (6)$$

Where, n represents the total number of individuals of a particular species, and N denotes the total number of individuals across all species.

Data analysis

Weather data, including maximum and minimum temperatures, rainfall, relative humidity, and wind speed, were gathered from the meteorological laboratory at Lovely Professional University (LPU), Phagwara, during the experimental period. Weekly averages of the recorded weather data were computed and correlated with the weekly trapped fruit flies using Spearman's rank correlation to evaluate the impact of various abiotic factors on the diversity and population dynamics of fruit flies. R Studio software (version 4.3.3) with the vegan package was used for diverse index calculations. Additionally, multiple regression analysis was performed to gain a more comprehensive understanding of the relationship between fruit fly populations and environmental parameters.

Results and Discussion

Population dynamics of fruit fly

The species identified in the study were all classified within the tephritidae family, specifically under the genera *Bactrocera* and *Zeugodacus*. The findings of the present study are corroborated by Nage et al. [25] and Madhura and Viraktamath [26], where five types of fruit flies were found to be attracted to ME. However, in our study, four species were identified. These were *B. zonata, B. correcta, Bactrocera affinis, Bactrocera verbascifoliae,* and *B. dorsalis*. Kawashita et al. [27] reported the occurrence of *B. correcta, B. dorsalis*, and *B. zonata* in Sri Lanka. Similarly, in a guava orchard ecosystem within the coastal zone, Satarkar et al. [28] observed that ME effectively attracted four species of fruit flies, namely *B. caryeae*, *B. zonata*, *B. affinis*, and *B. correcta*. Ukey et al. [29], who worked in the Ahmednagar region of Maharashtra and recorded *B. dorsalis* as the most prevalent species in the guava ecosystems, corroborate the findings of the present study. The fruit fly population in the guava and kinnow orchard was mixed and heterogenous. Figure 1 represents the average weekly captures of fruit flies in both the orchard in 2022 and 2023. In kinnow 2022, the initial weekly capture of fruit flies was low, averaging 38 fruit flies per four traps during the 28th standard meteorological week (SMW). The numbers gradually increased to 128 fruit flies per four traps by the 29th SMW. The catches of adult flies exhibited a significant rise starting from the 31st SMW, with an average of 77 fruit flies per trap, reaching a peak of 157 fruit flies per four traps by the 38th SMW. However, by the 44th SMW, the adult population began to decline gradually, with an average of 92 fruit flies per trap in the initial weeks, decreasing to 49 fruit flies per trap in the final week (Figure 1A). This decline is likely associated with the natural reduction in fruit availability observed toward the end of the season.

Likewise, at guava 2022, the same trend line was recorded with a low initial fruit fly density of 28 SMW but gradually found to increase with the start from 29 SMW. Subsequently, the population began to start increasing at 36 SMW and reached a peak of 38 SMW with a mean of 62 fruit flies per

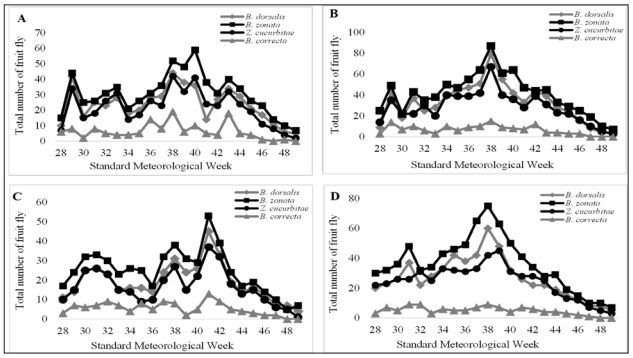


Figure 1: Weekly population fluctuations of male fruit flies in kinnow and guava orchards: **(A)** Kinnow 2022, **(B)** Guava 2022, **(C)** Kinnow 2023, and **(D)** Guava 2023.

four traps and a decline towards 43 SMW (Figure 1B). Similarly, at kinnow 2023, where the population begins at the 28 SMW and reached at 41 SMW, with an average of 37 fruit flies per four traps (Figure 1C), the population at guava 2023 started from the 28 SMW and attained its peak at 38 SMW, with an average of 46.50 fruit flies per four traps (Figure 1D). During the seasons of 2022 and 2023, the dominant fruit fly species was *B. zonata*, followed by *B. dorsalis* in the kinnow and guava orchards (Figure 1). Differences in reproductive potential, tolerance to environmental conditions, and competitive interactions may have also contributed to the higher population of *B. zonata*. These findings are consistent with those of Khan et al. [30], who documented the highest infestation of *B. zonata* in guava during August and September in Pakistan. Bansode [31] reported the year-round presence of fruit flies, with peak activity aligning with the fruiting and harvesting periods of guava. Dale and Patel [32], who reported that the *Bactrocera* spp. population peaked in September and reached its lowest levels in May within guava orchards. The variation in activity and dominance of fruit fly species can be attributed to differences in agro-climatic conditions, crop phenology, and their synchronization with the fruiting period and fruit maturity stages.

Numerous studies in literature have firmly established the significant influence of abiotic factors, such as temperature and rainfall, on the distribution of fruit flies [33] and population dynamics [34]. Stonehouse et al. [35], they conclude that the different abiotic factors affect the variation in population of *B. dorsalis*. The correlation between abiotic variables and the population dynamics of fruit fly catches of all orchards in both seasons (Figure 2). The seasonal trap captures from kinnow 2022 of male fruit flies of *Z. cucurbitae*, *B. zonata*, *B. dorsalis, and B. correcta* showed a moderately significant positive correlation with maximum temperature, minimum temperature, and rainfall. However, there was a non-significant positive correlation with relative humidity and a significantly negative correlation with *Z. cucurbtiae*, *B. zonata, and B. dorsalis,* where *B. correcta* showed a negatively non-significant relationship between the abiotic factors and fruit fly population at a significant level of $p \leq 0.05$ (Figure 2A).

In guava 2022, the seasonal trap captures of male fruit flies of *Z. cucurbtiae*, *B. zonata*, *B. dorsalis,* and *B. correcta* showed a moderately and highly significant positive correla-

tion with maximum temperature, minimum temperature, RH, and rainfall. However, *Z. cucurbtiae*, *B. zonata,* and *B. correcta* showed a significantly negative correlation with wind (Figure 2B). Because of a significantly negative correlation with wind

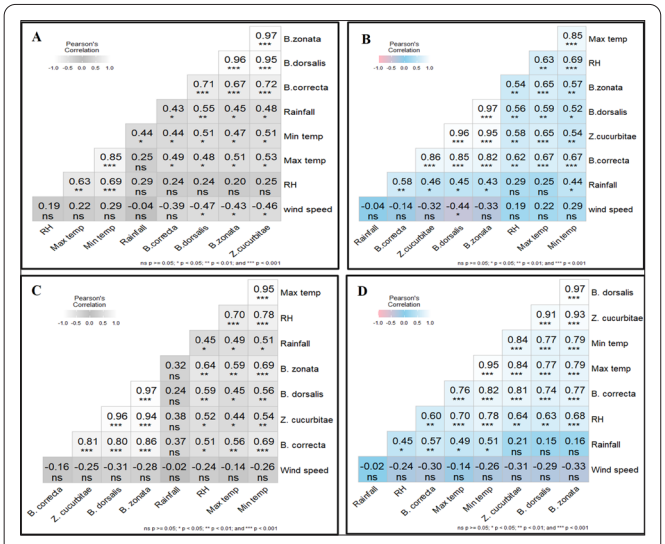


Figure 2: Pearson's correlation analysis of fruit fly populations and weather factors in kinnow and guava orchards: **(A)** Kinnow 2022, **(B)** Guava 2022, **(C)** Kinnow 2023, and **(D)** Guava 2023.

effect on fruit fly flight activity and trap efficiency and reduced the dispersal ability of fruit flies. In kinnow 2023, the result showed a significantly positive correlation between all species and maximum temperature, minimum temperature, and relative humidity, where rainfall showed a positively nonsignificant correlation between all the species. However, wind speed showed a negatively non-significant correlation between all the species (Figure 2C).

In guava 2023, the same trend was followed as per guava 2022, where wind speed showed a negatively non-significant correlation between all the species and rainfall showed a positively non-significant correlation between *Z. cucurbitae*, *B. zonata,* and *B. dorsalis,* while *B. correcta* showed a highly significant positive correlation (Figure 2D). The coefficient values of multiple regression analysis are presented in table 1. The coefficient of multiple determination (R^2) depicted that all the abiotic factors simultaneously affected the mean fruit fly population of kinnow and guava in 2022 and 2023 (Table 2). These results are consistent with those reported byVerghese et al. [36], Sarada et al. [37], Salazar et al. [38], Salazar-Mendoza et al. [39], and Megha et al. [40]. However, there is a there is a negative correlation between the wind speed and *Z. cucurbitae*, *B. zonata*, *B. dorsalis,* and *B. correcta* in both orchards. The rainfall, which moistens the soil and creates favourable conditions

Table 1: Diversity indices of fruit fly species recorded in two agro-ecological zones in 2022 and 2023.

Year	Host	No. of species (S)	H'	Simpson index	EI	Mg	D
2022	Kinnow	4	1.27	0.70	0.91	0.40	0.29
	Guava	4	1.24	0.69	0.90	0.38	0.30
2023	Kinnow	4	1.27	0.70	0.92	0.41	0.29
	Guava	4	1.23	0.68	0.88	0.39	0.31

Table 2: Correlation and multiple regression analysis of weather factors and fruit fly infestations in guava and kinnow orchards in 2022-2023.

Crop	Species	X1	X2	X3	X4	X5	Multiple regression equation	R^2	F. cal.
Kinnow 2022	*B. dorsalis*	0.228	0.251	-0.059	0.113	-1.972	$Y = 1.685 + 0.228_{X1} + 0.251_{X2} - 0.059_{X3} + 0.113_{X4} - 1.927_{X5}$	0.783	11.592
	B. zonata	0.461	0.187	-0.081	0.106	-2.082	$Y = -1.300 + 0.461_{X1} + 0.187_{X2} - 0.081_{X3} + 0.106_{X4} - 2.082_{X5}$	0.691	7.169
	B. correcta	0.196	0.032	-0.019	0.046	-0.726	$Y = -2.602 + 0.196_{X1} + 0.032_{X2} - 0.019_{X3} + 0.046_{X4} - 0.726_{X5}$	0.581	4.441
	Z. cucurbitae	0.365	0.195	-0.060	0.095	-1.943	$Y = -1944 + 0.365_{X1} + 0.195_{X2} - 0.060_{X3} + 0.095_{X4} - 1.943_{X5}$	0.766	10.482
Kinnow 2023	*B. dorsalis*	-0.293	0.250	0.163	-0.055	-0.255	$Y = -2.829 - 0.293_{X1} + 0.250_{X2} + 0.163_{X3} - 0.055_{X4} - 0.255_{X5}$	0.420	2.326
	B. zonata	-0.326	0.299	0.125	0.090	-0.024	$Y = -0.530 - 0.326_{X1} + 0.299_{X2} + 0.125_{X3} + 0.090_{X4} - 0.024_{X5}$	0.492	3.105
	B. correcta	-0.554	0.361	0.067	0.224	0.133	$Y = 5.295 - 0.554_{X1} + 0.361_{X2} + 0.067_{X3} + 0.224_{X4} + 0.133_{X5}$	0.619	5.218
	Z. cucurbitae	-0.439	0.323	0.101	0.084	-0.059	$Y = 3.132 - 0.439_{X1} + 0.323_{X2} + 0.101_{X3} + 0.084_{X4} - 0.059_{X5}$	0.380	1.966
Guava 2022	*B. dorsalis*	1.031	0.089	-0.461	0.004	-2.616	$Y = 6.094 + 1.031_{X1} + 0.089_{X2} - 0.461_{X3} + 0.004_{X4} - 2.616_{X5}$	0.600	4.800
	B. zonata	1.125	0.132	-0.467	-0.027	-2.488	$Y = 3.787 + 1.125_{X1} + 0.132_{X2} - 0.467_{X3} - 0.027_{X4} - 2.488_{X5}$	0.593	4.672
	B. correcta	0.318	0.006	-0.200	-0.001	-0.548	$Y = 4.304 + 0.318_{X1} + 0.006_{X2} - 0.200_{X3} - 0.001_{X4} - 0.548_{X5}$	0.616	5.143
	Z. cucurbitae	0.924	0.121	-0.536	-0.048	-2.205	$Y = 11.132 + 0.924_{X1} + 0.121_{X2} - 0.536_{X3} - 0.048_{X4} - 2.205_{X5}$	0.605	4.912
Guava 2023	*B. dorsalis*	0.500	0.098	0.145	-0.367	-0.482	$Y = -19.316 + 0.500_{X1} + 0.0981_{X2} + 0.145_{X3} - 0.367_{X4} - 0.482_{X5}$	0.703	7.583
	B. zonata	0.795	0.017	0.294	-0.487	-0.834	$Y = -33.866 + 0.795_{X1} + 0.017_{X2} + 0.294_{X3} - 0.487_{X4} - 0.834_{X5}$	0.760	10.184
	B. correcta	-0.0023	0.083	-0.022	0.050	-0.073	$Y = 2.028 - 0.0023_{X1} + 0.083_{X2} - 0.022_{X3} + 0.050_{X4} - 0.073_{X5}$	0.721	8.303
	Z. cucurbitae	0.498	0.072	0.049	-0.254	-0.449	$Y = -12.299 + 0.498_{X1} + 0.072_{X2} + 0.049_{X3} - 0.254_{X4} - 0.449_{X5}$	0.803	13.116

for adult emergence, may facilitate the pupation of fruit flies in the soil [41, 42]. The various parameters utilized for prediction of population of *B. dorsalis* give a 55.55% coefficient of determination due to temperature, relative humidity, rainfall, wind velocity and bright sunshine hours [11].

Abundance of fruit fly

Throughout the study period, a total of 7,667 fruit fly specimens were gathered from the two agro-ecosystems. These specimens were categorized into the genera *Zeugodacus* and *Bactrocera*. Among them, *B. zonata* emerged as the most prevalent, making up 37.98% of the total specimens collected from kinnow and guava orchards in 2022 and 2023. *B. dorsalis* ranked second (29.33%). The abundance of *Z. cucurbitae* ranked third (26.11%) and *B. correcta* was very low (6.57%) (Figure 3).

In both seasons, there was an observed highest population of *B. zonata*, followed by *B. dorsalis* (Figure 4). shows the morphological descriptions of the four species that have been recognized. The species complex was as follows, listed in decreasing order of abundance: *B. zonata* (2,912 fruit flies) > *B. dorsalis* (2,249 fruit flies) > *Z. cucurbitae* (2,002 fruit flies) > *B. correcta* (504 fruit flies) table 3.

Diversity of fruit fly

Fruit fly species richness and diversity indices were calculated for each agro-ecological zone and for both the years (2022 - 2023). Shannon's diversity index varies according to the ecological zone and year. The highest Shannon diversity index was found in kinnow 2022 and 2023 (1.27) followed by guava 2022 (1.24) and the lowest in guava 2023 (1.23) (Table 1). The present results align with the observations of Octavia et al. [43] and Gizachew [44], who found that an index value ranging from 1 to 3 signifies moderate diversity, with each species showing a balanced distribution. The higher the Simpson's index was recorded in kinnow 2022 and 2023 (0.70), which indicates the lower diversity of fruit flies, where the lower Simpson's index was recorded in guava 2023, followed by guava 2022 (Table 1). The Simpson index provides higher weight to prevalent species; therefore, the Simpson index is a measure of dominance. Shannon's EI showed a variation between season and year, with the highest value in kinnow 2023 (0.92) and the lowest in guava 2023 (0.88) (Table 1). Species EI and richness index of fruit flies in kinnow 2023, followed by kinnow 2022, were higher than the other season. Octavia et al. [43] and Gizachew [44] suggest that an index value ranging from 0.75 to 1.00 indicates a high degree of species evenness, when the index value is between 0.5 and 0.75, there are middle dominant species in the community. Several factors, such as host diversity, seasonal variations, environmental conditions, spatial distribution, and competition, contribute to variations in fruit fly diversity [45]. Habitats with a wider range of suitable host species generally exhibit higher fruit fly species diversity [46]. In multiple studies, *Z. cucurbitae* has been identified as utilizing a broad array of plant hosts across several families, including Anacardiaceae, Oxalidaceae, Solanaceae, and Rutaceae. Notable host plants include carambola and various *Citrus* species [47].

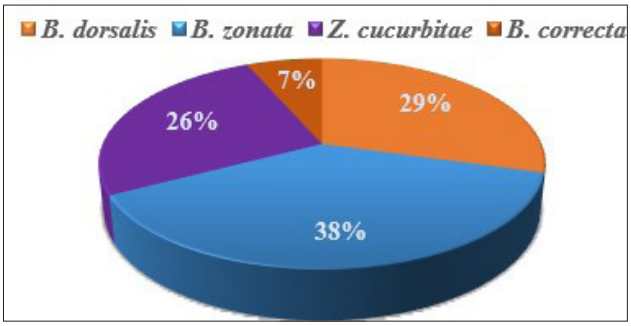


Figure 3: The relative abundance (%) of fruit fly species was observed in kinnow and guava orchard (2022 - 2023).

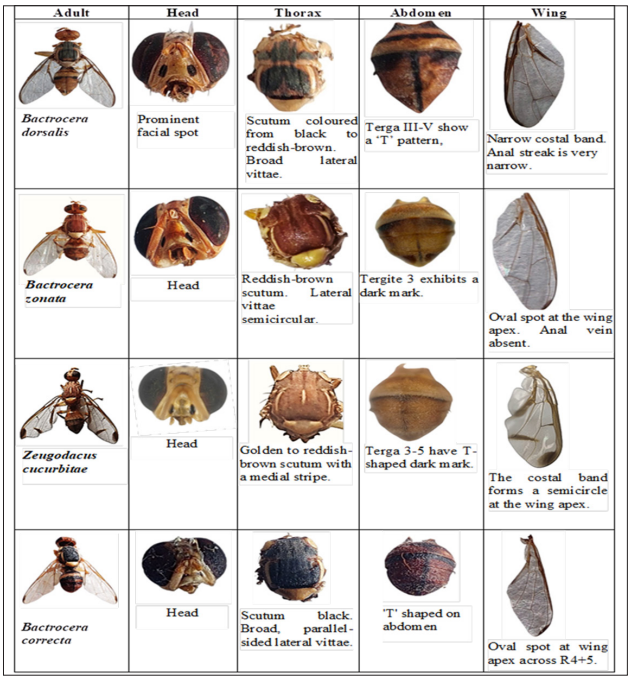


Figure 4: Morphological identification of different fruit fly species recorded from kinnow and guava orchard in Punjab, India.

Table 3: Fruit fly abundance was documented in kinnow and guava orchard (2022-2023).

Orchard	*B. dorsalis*	*B. zonata*	*Z. cucurbitae*	*B. correcta*	Total
Kinnow 2022	521	672	473	137	1803
Guava 2022	717	899	623	143	2382
Kinnow 2023	423	545	368	118	1454
Guava 2023	588	796	538	106	2028
Total	2249	2912	2002	504	7667

Conclusion

The study highlights the significant role of weather parameters in influencing fruit fly populations in kinnow and guava orchards across two agro-ecological zones of Northwest India. Pheromone trap monitoring during the fruiting seasons of 2022 and 2023 revealed peak incidences of fruit flies at distinct times for both crops, which coincided with the fruiting and maturity period of the kinnow and guava fruit. *B. zonata*

was the dominant species (37%), followed by *B. dorsalis* (29%), with *Z. cucurbitae* (26%) and *B. correcta* (7%) also present. The kinnow ecosystem showed higher species diversity, richness, and evenness, particularly in 2022. These findings provide critical insights for the development of zone-specific, targeted pest management strategies to minimize fruit fly damage and improve crop yields in affected regions. Incorporating pest management practices during population peaks could help reduce yield losses and improve overall crop productivity.

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None.

Conflict of Interest

None.

References

1. Sah S, Johar V, Karthi JS. 2022. Status and marketing of fruits and vegetables in India: a review. *Asian J Agric Ext Econ Sociol* 40(7): 1-11. https://doi.org/10.9734/ajaees/2022/v40i730911
2. Sharma S, Borah A. 2021. Bioactive compounds present in different parts of guava and their significance: a review. *Pharm Innov* 10(5): 163-171. https://doi.org/10.22271/tpi.2021.v10.i5c.6193
3. Rajan S, Hudedamani U. 2019. Genetic Resources of Guava: Importance, uses and Prospects. In Conservation and Utilization of Horticultural Genetic Resources. Springer, pp 363-383.
4. Gundappa B, Balaji Rajkumar M, Singh S, Rajan S. 2018. Pests of Guava. In Pests and Their Management. Springer, pp 491-516.
5. Gundappa B, Mani M. 2022. Pests and their Management in Guava. In Trends in Horticultural Entomology. Springer, pp 605-623.
6. Abd-Elgawad MM. 2021. The mediterranean fruit fly (Diptera: Tephritidae), a key pest of citrus in Egypt. *J Integr Pest Manag* 12(1): 1-10. https://doi.org/10.1093/jipm/pmab025
7. Clarke AR, Armstrong KF, Carmichael AE, Milne JR, Raghu S, et al. 2005. Invasive phytophagous pests arising through a recent tropical evolutionary radiation: the *Bactrocera dorsalis* complex of fruit flies. *Annu Rev Entomol* 50(1): 293-319. https://doi.org/10.1146/annurev.ento.50.071803.130428
8. David K, Ramani S. 2011. An illustrated key to fruit flies (Diptera: Tephritidae) from Peninsular India and the Andaman and Nicobar Islands. *Zootaxa* 3021(1): 1-31. https://doi.org/10.11646/zootaxa.3021.1.1
9. Schutze MK, Krosch MN, Armstrong KF, Chapman TA, Englezou A, et al. 2012. Population structure of *Bactrocera dorsalis*, *B. papayae* and *B. philippinensis* (Diptera: Tephritidae) in southeast Asia: evidence for a single species hypothesis using mitochondrial DNA and wing-shape data. *BMC Evol Biol* 12: 1-15. https://doi.org/10.1186/1471-2148-12-130
10. Konyak WS, Devi HS, Sahu AK, Singh YS, Devi HM, et al. 2023. Diversity and population dynamics of fruit fly in bottle gourd and its correlation with abiotic factors in Nagaland. *Biol Forum Int J* 15(3): 379-385.
11. Jena MK, Patel SR, Patel ZK. 2022. Population dynamics of fruit fly, *B. dorsalis* (hendle) on mango and correlation with weather parameters. *Int J Environ Clim Chang* 12(12): 1630-1638. https://doi.org/10.9734/ijecc/2022/v12i121605
12. de Almeida LBM, Coelho JB, Uchoa MA, Gisloti LJ. 2019. Diversity of fruit flies (Diptera: Tephritoidea) and their host plants in a conservation unit from midwestern Brazil. *Fla Entomol* 102(3): 562-570. https://doi.org/10.1653/024.102.0333
13. Sandeep Singh SS, Desraj Sharma DS. 2016. Integrated Pest Management for *Bactrocera dorsalis* (Hendel) and *Bactrocera zonata* (Saunders) on Kinnow Mandarin in the Indian Punjab. In Beatriz Sabater-Munoz, Vera T, Pereira R, Orankanok W (eds) Proceedings of the 9th International Symposium on Fruit Flies of Economic Importance. Bangkok, Thailand, pp 172-183.
14. Dhillon MK, Singh R, Naresh JS, Sharma HC. 2005. The melon fruit fly, *Bactrocera cucurbitae*: a review of its biology and management. *J Insect Sci* 5(1): 40. https://doi.org/10.1093/jis/5.1.40
15. Chakraborty A, Nath D, Shil S, Dey D, Das R, et al. 2019. Assessment of certain strategies to manage fruit fly *Bactrocera cucurbitae* (Coquillett) in bitter gourd of Tripura. *Int J Curr Microbiol App Sci* 8(7): 2386-2392. https://doi.org/10.20546/ijcmas.2019.807.292
16. Mohanpuria P, Govindaswamy M, Sidhu GS, Singh S, Kaur S, et al. 2021. Ingestion of bacteria expressing dsRNA to maggots produces severe mortality and deformities in fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). *Egypt J Biol Pest* Co 31: 1-11. https://doi.org/10.1186/s41938-020-00345-7
17. Singh ND, Criscoe DR, Skolfield S, Kohl KP, Keebaugh ES, et al. 2015. Fruit flies diversify their offspring in response to parasite infection. *Science* 349(6249): 747-750. https://doi.org/10.1126/science.aab1768
18. Khomane KB. 2023. Seasonal incidence and management of guava fruit fly, *Bactrocera dorsalis* (Hendel). (Doctoral dissertation)
19. Giddi TD, Emmanuel N. 2023. Seasonal incidence of fruit fly in guava cv. Taiwan white. *Eco Env Cons* 29(3): 218-221. http://doi.org/10.53550/EEC.2023.v29i03.031
20. Heve WK, El-Borai FE, Johnson EG, Carrillo D, Crow WT, et al. 2016. Responses of *Anastrepha suspensa, Diachasmimorpha longicaudata*, and sensitivity of guava production to *Heterorhabditis bacteriophora* in fruit fly integrated pest management. *J Nematol* 50(3): 261-272. https://doi.org/10.21307/jofnem-2018-039
21. Shannon CE, Weaver WA.1949. Mathematical Model of Communication. University of Illinois Press.
22. Simpson EH. 1949. Measurement of diversity. *Nature* 163(4148): 688. https://doi.org/10.1038/163688a0
23. Margalef R. 1973. Information theory in ecology.
24. Pielou EC. 1966. The measurement of diversity in different types of biological collections. *J Theor Biol* 13: 131-144. https://doi.org/10.1016/0022-5193(66)90013-0
25. Nage S, Kulkarni US, Undirwade DB, Meshram NM, Sant S. 2023. The species composition, richness and diversity studies of fruit flies captured from the orchard of Nagpur mandarin. *Sci Rep* 13(1): 21872. https://doi.org/10.1038/s41598-023-47299-y
26. Madhura HS, Viraktamath CA. 2003. Efficacy of different traps in attracting fruit flies (Diptera: Tephritidae). *Pest Manag Hortic Ecosyst* 9(2): 153–154.
27. Kawashita T, Rajapakase G, Tsuruta K. 2004. Population survey of *Bactrocera* fruit flies by lure trap in Sri Lanka. *Res Bull Plant Prot Serv Jpn* 40: 83–87.
28. Satarkar VR, Krishnamurthy SV, Falerio JR, Verghese A, Stonehouse JM. 2006. An assessment of methyl eugenol dispensers and fruit fly species complex in orchard agro-ecosystems of Goa, India. *Pest Manag Hortic Ecosyst* 12(2): 161–163.
29. Ukey NS, Chandele AG, Wagh SS, Jadhav RS. 2013. Species composition of fruit flies, *Bactrocera* spp. (Diptera: Tephritidae) in guava orchard of Ahmednagar district (Maharashtra), India. *Ecol Environ Conserv* 20(1): 313-315.
30. Khan MA, Muhammad A, Waessem A, Lee JJ. 2005. Management of fruit flies (Diptera: Tephritidae) of the most perishable fruit. *Entomol Res* 35(2): 79-84. https://doi.org/10.1111/j.1748-5967.2005.tb00140.x
31. Bansode GM. 2009. Studies on Comparative Biology, Population Dynamics, and Management of Orchard Fly (*Bactrocera* spp.). Ph. D. Thesis (Unpublished), Navasari Agricultural University, Navasari, Gujarat.
32. Dale NS, Patel RK. 2010. Population dynamics of fruit flies (*Bactrocera* spp) on guava and its correlation with weather parameters. *Current Biotica* 4(2): 245-248.

33. Duyck PF, David P, Quilici S. 2006. Climatic niche partitioning following successive invasions by fruit flies in La Réunion. *J Anim Ecol* 75(2): 518-526. https://doi.org/10.1111/j.1365-2656.2006.01072.x

34. Jayanthi PK, Verghese A. 2011. Host-plant phenology and weather-based forecasting models for population prediction of the oriental fruit fly, *Bactrocera dorsalis* hendel. *Crop Prot* 30(12): 1557-1562. https://doi.org/10.1016/j.cropro.2011.09.002

35. Stonehouse J, Mahmood R, Poswal A, Mumford J, Baloch KN, et al. 2002. Farm field assessments of fruit flies (Diptera: Tephritidae) in Pakistan: distribution, damage, and control. *Crop Prot* 21(8): 661-669. https://doi.org/10.1016/S0261-2194(02)00018-2

36. Verghese A, Knagaraju D, Madhura HS, Kamala Jayanth PD, Sreedevi K. 2006. Wind speed as an independent variable to forecast the trap catch of the fruit fly (*Bactrocera dorsalis*). *Indian J Agric Sci* 76(3): 172–175.

37. Sarada G, Maheswari TU, Purushotham K. 2001. Seasonal incidence and population fluctuation of fruit flies in mango and guava. *Indian J Entomol* (3): 272-376.

38. Salazar JF, Korie S, Ayegnon D. 2009. Correlation of fruit fly (Diptera Tephritidae) infestation of major mango cultivars in Borgou (Benin) with abiotic and biotic factors and assessment of damage. *Crop Prot* 28(6): 477-488. https://doi.org/10.1016/j.cropro.2009.01.010

39. Salazar-Mendoza P, Peralta-Aragón I, Romero-Rivas L, Salamanca J, Rodriguez-Saona C. 2021. The abundance and diversity of fruit flies and their parasitoids change with elevation in guava orchards in a tropical Andean Forest of Peru, independent of seasonality. *Plos One* 16(4): e0250731. https://doi.org/10.1371/journal.pone.0250731

40. Megha R, Singh SK, Srivastav M, Kalia V, Sharma N, et al. 2023. Population dynamics of fruit flies and correlation matrix with weather and host variables in mango (*Mangifera indica*) orchards. *Indian J Agric Sci* 93(10): 1132-1138. https://doi.org/10.56093/ijas.v93i10.138967

41. Kamala Jayanthi P, Verghese A. 2000. Mango fruit fly, *Bactrocera dorsalis* (Hendel) prefers moist soil for pupation. *Insect Environ* 6(3): 99.

42. Tarno H, Septia ED, Aini LQ. 2016. Microbial community associated with ambrosia beetle, *Euplatypus parallelus* on sonokembang, *Pterocarpus indicus* in Malang. *Agrivita* 38(3): 312-320. https://doi.org/10.17503/agrivita.v38i3.628

43. Octavia E, Tarno H, Himawan T, Setiawan Y. 2021. Abundance and diversity of fruit flies species (Diptera: Tephritidae) in Bogor and Depok District. *Res J Life Sci* 8(3): 173-180. https://doi.org/10.21776/ub.rjls.2021.008.03.7

44. Gizachew G. 2022. Spatial-temporal and factors influencing the distribution of biodiversity: a review. *J Sci Eng* 2(3): 273-284. https://doi.org/10.22034/srls.2021.247920

45. Linda L, Witjaksono W, Suputa S. 2018. Species composition of fruit flies (Diptera: Tephritidae) in Sorong and Raja Ampat, West Papua. *J Perlindungan Tanaman Indonesia* 22(2): 193-200. https://doi.org/10.22146/jpti.25280

46. De Meyer M, Delatte H, Mwatawala M, Quilici S, Vayssières JF, et al. 2015. A review of the current knowledge on *Zeugodacus cucurbitae* (Coquillett)(Diptera, Tephritidae) in Africa, with a list of species included in Zeugodacus. *Zookeys* 540: 539-557. https://doi.org/10.3897/zookeys.540.9672

47. Follett PA, Asmus G, Hamilton LJ. 2022. Poor host status of Australian finger lime, *Citrus australasica,* to *Ceratitis capitata*, *Zeugodacus cucurbitae*, and *Bactrocera dorsalis* (Diptera: Tephritidae) in Hawai'i. *Insects* 13(2): 177. https://doi.org/10.3390/insects13020177