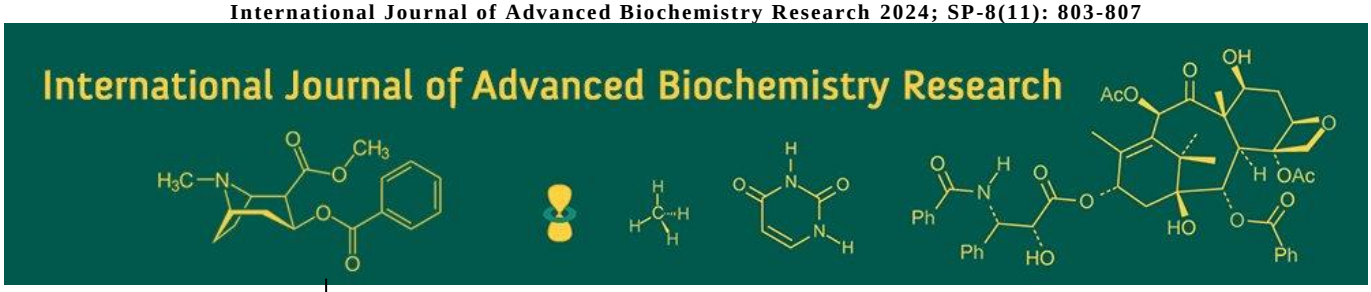

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; SP-8(11): 803-807
www.biochemjournal.com
Received: 28-08-2024
Accepted: 27-09-2024

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Comprehensive study on climatic and ecological drivers of seasonal fluctuation of guava fruit fly

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DOI: https://doi.org/10.33545/26174693.2024.v8.i11Sk.3028

Abstract
The present experiment was carried out at Fruit Research Station, Sakkar baug, College of Horticulture, Junagadh Agricultural University, Junagadh during the year 2022-23. Incidence of the guava fruit fly was recorded standard meteorological week wise throughout the course of the investigation. The fruit fly population was recorded from the 23rd standard meteorological week to the 52nd standard meteorological week. The peak incidence of fruit fly was recorded at 35th SMW which was 865.13 fruit flies per trap. In contrast, the lowest population of fruit fly (10.00 fruit flies/trap) was recorded at 52nd SMW. Furthermore, the maximum activity of fruit fly was remained throughout August month with 800.31 fruit flies per trap and the minimum activity of fruit fly was observed during the December month with 21.12 fruit flies per trap. The effects of various weather parameters on the fluctuation of the fruit fly population on guava indicated that the population of fruit fly had a highly significant positive correlation with evening humidity (r = 0.670), morning humidity (r = 0.669) and minimum temperature (r = 0.522). While, wind speed (r = 0.216) and rainfall (r = 0.293) were also found positively correlated but it was non-significant to the fruit fly population. Temperature fluctuation (r = -0.696), relative humidity fluctuation (r = -0.616), bright sunshine hours (r = -0.486) and evaporation (r = -0.483) had a highly significant negative correlation with fruit fly population. Furthermore, maximum temperature (r = -0.362) had a significant negative correlation with the fruit fly population.

Keywords: Seasonal incidence, ecological influence, climate, guava, fruit fly

Introduction
The India is one of the leading countries in fruit production with wide range of fruit crops such as mango, banana, guava, sapota, apple, pear, peach and many more. Among them guava is a major fruit crop in India due to its nutritive values and minerals contains. In India, it has gained considerable importance over the years and is now among the seven major cultivated fruit crops in the country. In India, it occupied an area of 2.87 lakh hectares with an annual production of 30.40 lakh MT (Anon., 2020). It is cultivated in Uttar Pradesh, Bihar, Madhya Pradesh, Chhattisgarh, Odisha, West Bengal, Maharashtra, Andhra Pradesh, Haryana, Gujarat and Punjab. While in Gujarat, it is cultivated on a large scale and occupies an area of 14326 ha with an annual production of 175327 MT (Anon., 2021).

Fruit flies stand out as highly destructive insects on a global scale. Their voracious appetite spans across a wide array of fruits and vegetables, making them a formidable menace. Their ability to thrive in diverse climates and their remarkable capacity for reproduction contribute to their notoriety. Across the world, tephritid fruit flies pose a substantial risk to the horticultural sector. The majority of these flies possess a polyphagous nature, leading to both immediate and consequential economic losses within the industry (Abbas *et al.*, 2021) [1]. Approximately 35% of the cataloged fruit fly species demonstrate a distinct specialization in infesting tender fruits. This group encompasses notable fruit types like guava, mango, citrus, peach, ber, in addition to a variety of cucurbitaceous vegetables, expanding the spectrum of vulnerable produce (White and Elson-Harris, 1992) [16].

The mature female fruit fly utilizes her ovipositor to puncture the fruit's surface and lay eggs in clustered patterns. These egg-laying sites manifest as dark-hued punctures. Upon hatching, the resulting larvae consume the fruit's pulp, causing the emergence of brown patches on its exterior. Subsequently, the oviposition puncture offers entry to fermenting microorganisms such as bacteria and fungi, initiating a process of fruit decay. Consequently, the mesocarp becomes soiled, culminating in the untimely premature dropping of the fruits.

Given its polyphagous nature, high reproductive capacity, wide-ranging host preferences, ability to adapt to diverse climates, and the concurrent overlapping of generations, effectively managing this pest proves to be quite a challenging task (Kumar and Agarwal, 1998) [11].

Seasonal incidence of the guava fruit fly is a preliminary survey that is carried out to investigate the sensitivity of the occurrence of the fruit fly to the different meteorological parameters. The correlation of pest population with different weather parameters provides valuable information, based on that predictive model can be developed which can be utilized in the forecasting of pest population build up. Ultimately by it, farmers can plan for plant protection strategies.

Materials and Methods

The study was conducted at Sakkar Baug Fruit Research Station, Junagadh Agricultural University, Junagadh during the year 2022-23. The research focused on investigating the seasonal incidence of the guava fruit fly, *Bactrocera dorsalis* using previously grown guava trees. The guava trees selected for the study were 15 years old and they were spaced at 6 meters apart in both rows and columns. The experimental field was maintained without the application of any pesticides, while all recommended agronomical practices were adhered to.

To capture guava fruit flies, Sawaj fruit fly traps with a capacity of 500 ml (trapezoid shape) were employed. Each trap was equipped with four openings measuring 2.5 cm each, positioned on all four sides. A soft wooden block measuring 5 x 5 x 5 cm was utilized as a bait station, loaded with a mixture of insecticide, methyl eugenol, and ethanol. The fruit fly traps were strategically positioned within the guava orchard at a height of 2 meters above the ground level. The lure within the traps, composed of methyl eugenol and ethanol, was replaced at regular intervals of 30 days. This routine maintenance ensured the consistent attractiveness of the traps to the guava fruit flies throughout the duration of the study.

Observations of trapped fruit flies were recorded on a weekly basis, starting from the onset of flowering and continuing until the fruit harvesting period. The number of trapped fruit flies in each trap was meticulously recorded during these weekly intervals. The mean number of trapped fruit flies was calculated separately for each weekly interval throughout the entire observation period. All the statistical analysis was done by using software python which developed by department of agricultural statistics, college of agriculture, Junagadh agricultural University, Junagadh.

By implementing this comprehensive experimental setup and meticulous data collection procedure, the research aimed to gain valuable insights into the seasonal patterns of guava fruit fly incidence within the specified conditions of the guava orchard. The results obtained from this study are expected to contribute significantly to the understanding of guava fruit fly dynamics and guide effective pest management strategies.

Results and Discussion

The findings presented in Table 1 and illustrated in Figure 1 unveil the fluctuations in the fruit fly population, ranging from 10.00 to 865.13 individuals per trap, spanning from the 23rd to the 52nd Standard Meteorological Weeks (SMW). Notably, the 35th SMW exhibited the pinnacle of fruit fly presence, registering a remarkable 865.13 fruit flies per trap, closely pursued by a substantial count of 839.81 fruit flies per trap during the subsequent 36th SMW. However, post the 36th SMW, a gradual descent in the fruit fly population became evident. Evidently, the nadir of this population trend was evident during the 52nd SMW, with a meager count of 10.00 fruit flies per trap, alongside a modest count of 18.20 fruit flies per trap during the 51st SMW.

Based on the findings extracted from thirty Standard Meteorological Weeks (SMW) during the year 2022, as outlined in Table 1 a comprehensive overview of the fruit fly population dynamics unfolds. The recorded data underscored a visible pattern of rise and fall in the fruit fly population, commencing from June and ending in the 30th SMW, where the population reached a peak of 498.31 fruit flies per trap. Subsequent to this, a rapid downturn was observed in the 31st SMW, with a notable decrease to 307.00 fruit flies per trap. This decline was attributed to an abrupt upsurge in both bright sunshine hours (3.4 hours) and maximum temperature (32.4 °C). However, resuming from the 32nd SMW, the fruit fly population embarked on an ascending trajectory once more, achieving its peak during the 35th SMW, totaling an impressive 865.13 fruit flies per trap. This resurgence was attributed to the mitigation of minimum temperature (23.3 °C).

Nonetheless, the subsequent weeks from the 35th SMW to the 46th SMW bore witness to a gradual and steady descent in the fruit fly population. This phenomenon was ascribed to the cumulative escalation in various factors, including bright sunshine hours, maximum temperature, temperature fluctuations, relative humidity fluctuations, alongside declining minimum temperature, morning relative humidity, evening relative humidity, and rainfall. The 47th SMW exhibited a marginal dip in the fruit fly population, reaching 19.75 fruit flies per trap, stemming from amplified bright sunshine hours and temperature fluctuations. Following this, from the 48th to the 50th SMW, a consistent fruit fly population of approximately 28.50, 28.13, and 28.13 fruit flies per trap was sustained. Subsequent to the 50th SMW, however, the fruit fly population encountered a renewed decline, plummeting to its nadir of 10.00 fruit flies per trap by the 52nd SMW. This drop was attributed to increased bright sunshine hours, temperature fluctuations, and relative humidity fluctuations.

The broader context of these findings, derived from the thirty SMW weeks in 2022 and taken in Table 1, paints a comprehensive picture of the fruit fly population dynamics. Notably, the peak population of 865.13 fruit flies per trap, witnessed during the 35th SMW in late August, aligned with the ripening and harvesting phase of guava fruits. This correlation underscores the intricate relationship between fruit maturity and fruit fly population dynamics.

A comprehensive investigation into the interplay between diverse meteorological variables and the fluctuation of the guava fruit fly population throughout the span of June to December 2022 (as presented in Table 2) unveiled noteworthy insights. The study established that the population of the fruit fly exhibited a highly significant and positive correlation with evening relative humidity, morning relative humidity, and minimum temperature, yielding correlation coefficients of r = 0.670**, r = 0.669**, and r = 0.522** respectively. Furthermore, wind speed (r = 0.216) and rainfall (r = 0.293) demonstrated a positive correlation

with the fruit fly population, albeit these relationships were not deemed statistically significant.

Intriguingly, a range of meteorological factors exhibited a highly significant and negative correlation with the fruit fly population. Notably, temperature fluctuation, relative humidity fluctuation, bright sunshine hours, and evaporation showcased correlation coefficients of r = -0.696**, r = -0.616**, r = -0.486**, and r = -0.483** respectively in relation to the fruit fly population. Likewise, maximum temperature maintained a significant negative correlation with the fruit fly population, denoted by a correlation coefficient of r = -0.362*.

This comprehensive study underscored the intricate relationships between distinct weather parameters and the dynamics of the guava fruit fly population. The observed correlations, both positive and negative, provide valuable insights into the ecological and environmental factors that shape the fluctuations in fruit fly numbers. These findings contribute to our understanding of the complex interplay between weather and insect populations, emphasizing the significance of factors

such as humidity, temperature, and sunlight in influencing the behavior and abundance of the guava fruit fly population.

The highest peak activity of fruit fly was observed during the month of August (Khomane *et al.*, 2023; Gaur and Yadav, 2022; Sharma *et al.*, 2022; Khan *et al.*, 2021; Bansode, 2009 and Sanjeevrani *et al.*, 2008) [8, 10, 4, 14]. The fruit fly infestation started in July and ended in November when all fruits were harvested and peak fruit fly population was recorded in the second week of August (Khan *et al.*, 2021; Gaur and Yadav, 2022; Sanjeevrani *et al.*, 2008; Bansode, 2009 and Sharma *et al.*, 2022) [8, 9, 14]. The activity of fruit fly was found highly significant positively correlated with minimum temperature (Patel *et al.*, 2019; Dale and Patel, 2010; Bansode, 2009; Sanjeevrani *et al.*, 2008; Verghese *et al.*, 2006 and Dale, 2002) [12, 4, 5, 13], morning and evening relative humidity (Gaur and Yadav, 2022; Patel *et al.*, 2019; Dale and Patel, 2010; Bansode, 2009; Sanjeevrani *et al.*,2008 and Dale, 2002) [8, 4, 12, 5, 13]. However, rainfall and wind speed found non-significant positive correlation with fruit fly activity (Gaur and Yadav, 2022; Patel *et al.*, 2019; Sanjeevrani *et al.*, 2008; Verghese *et al.*, 2006 and Dale, 2002) [8, 12, 5, 13, 15]. On the other hand, a highly significant correlation was observed with temperature fluctuation (Farnando, 2017 and Bansode, 2009) [4], relative humidity fluctuation (Bansode, 2009) [4], bright sunshine hours (Patel *et al.*, 2019; Bansode, 2009 and Dale, 2002) [4, 5, 12] and evaporation (Verghese *et al.*, 2006) [15]. Furthermore, the maximum temperature had found a significant negative correlation with pest population (Bansode, 2009; Verghese *et al.*, 2006 and Dale, 2002) [4, 15, 5]. Thus, the present investigation has given conformation for earlier works.

Table 1: Seasonal incidence of guava fruit fly with weather parameter (June to December 2022)

Sr. no.	SMW	Month	Mean no. of fruit fly/trap/month	Mean no. of fruit fly/trap	Temperature (°C)			Relative Humidity (%)			BSS (hr)	RF (mm)	WS (km/hr)	Evaporation (mm)
					Max	Min	Temperature Fluctuations	Morning	Evening	RH Fluctuations				
1	23	June	125.46	118.57	38.7	26.4	12.3	82.4	40.7	41.7	5.0	0.0	9.6	9.7
2	24			120.50	35.3	25.4	9.9	82.1	67.0	15.1	3.8	62.4	6.6	5.7
3	25			129.00	36.2	26.6	9.6	83.0	55.0	28.0	2.4	8.5	8.1	5.6
4	26			133.75	36.0	25.7	10.3	85.6	65.4	20.1	1.9	33.4	7.4	5.4
5	27	July	312.84	203.00	30.2	24.5	5.8	94.1	90.4	3.7	0.5	363.8	6.0	1.6
6	28			232.00	29.3	24.2	5.1	95.0	88.1	6.9	0.0	233.4	7.3	1.2
7	29			323.88	30.6	24.4	6.2	94.6	81.6	13.0	0.6	36.9	8.9	2.6
8	30			498.31	30.5	24.2	6.2	93.9	77.7	16.1	2.1	27.7	7.5	2.2
9	31			307.00	32.4	24.5	7.9	92.4	74.3	18.1	3.4	61.2	6.4	3.9
10	32	August	800.31	703.50	31.6	24.4	7.2	92.1	83.0	9.1	1.8	108.6	3.9	1.9
11	33			809.31	29.6	23.6	6.0	94.3	88.3	6.0	0.7	203.9	8.5	1.6
12	34			823.31	30.2	23.8	6.4	89.7	73.3	16.4	2.3	3.3	7.8	3.2
13	35			865.13	32.2	23.3	8.9	85.4	64.4	21.0	5.1	7.3	3.9	3.4
14	36	September	600.80	839.81	33.6	24.4	9.2	86.1	58.7	27.4	5.5	14.0	4.6	3.8
15	37			703.50	32.4	23.5	8.9	90.9	76.6	14.3	3.0	100.7	3.9	3.1
16	38			537.56	32.4	23.0	9.4	84.1	57.3	26.9	9.0	0.0	4.6	4.1
17	39			322.31	32.9	22.5	10.4	83.1	58.1	25.0	8.2	2.4	4.5	4.6
18	40	October	116.10	248.94	33.8	23.4	10.4	81.0	49.4	31.6	8.3	0.0	3.9	5.1
19	41			134.75	35.0	23.4	11.6	84.7	47.4	37.3	6.9	51.2	2.9	4.2
20	42			92.44	35.9	20.2	15.7	61.9	25.4	36.4	10.1	0.0	2.7	5.1
21	43			73.44	35.6	19.7	15.9	66.7	26.6	40.1	9.5	0.0	2.6	4.8
22	44			30.94	35.8	17.8	17.9	65.1	25.6	39.6	9.3	0.0	2.2	4.6
23	45	November	24.53	26.19	35.4	18.2	17.3	61.1	28.4	32.7	9.0	0.0	2.7	4.3
24	46			23.69	33.9	16.9	17.0	71.9	27.3	44.6	9.1	0.0	2.4	4.3
25	47			19.75	32.3	13.8	18.5	66.7	26.0	40.7	9.5	0.0	2.3	4.2
26	48			28.50	32.6	14.9	17.7	67.6	30.9	36.7	9.2	0.0	2.6	4.3
27	49	December	21.12	28.13	31.4	15.3	16.1	67.6	31.9	35.7	8.2	0.0	3.8	4.5
28	50			28.13	31.6	17.7	13.9	72.9	39.1	33.7	5.7	0.0	4.3	4.4
29	51			18.21	32.2	17.3	14.9	63.4	26.0	37.4	8.1	0.0	4.0	5.1
30	52			10.00	28.7	11.7	17.0	70.3	30.3	40.0	8.3	0.0	4.5	4.5

SMW**:** Standard Meteorological Week, Mor. RH: Morning Relative Humidity, Eve. RH: Evening Relative Humidity, BSS: Bright Sunshine hours, WS: Wind Speed and RF: Rain Fall

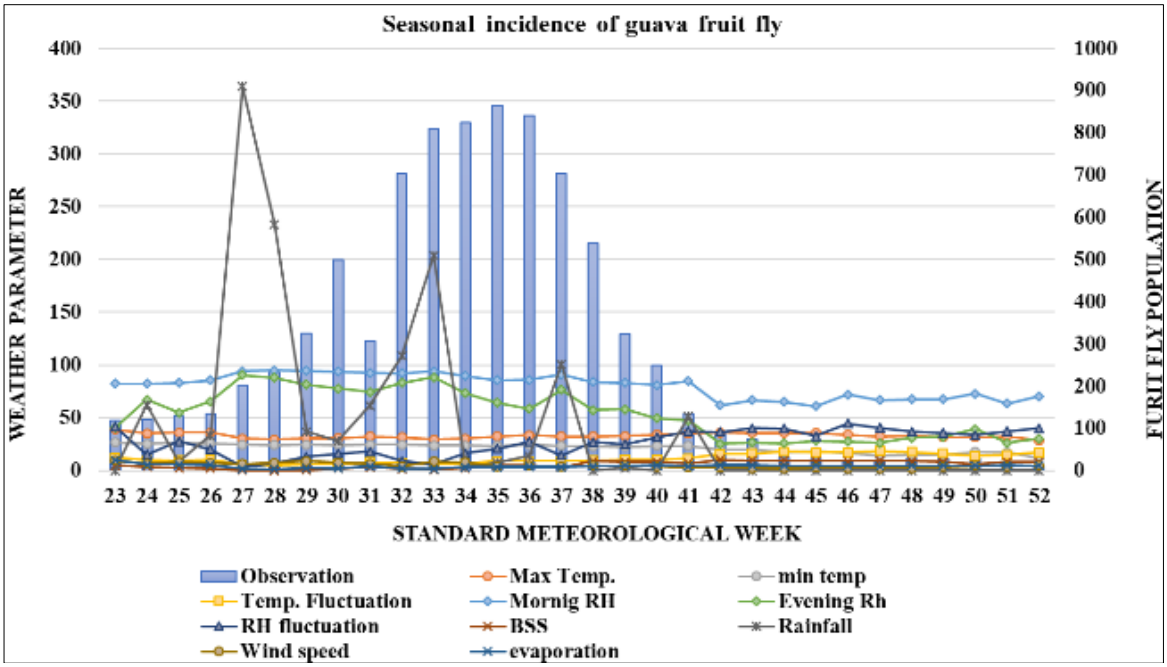

Fig 1: Seasonal incidence of guava fruit fly with weather parameter (June to December, 2022)

Table 2: Correlation coefficient (r) of weather parameters with fruit fly population (June to December 2022) (n = 30)

Sr. no.	Weather parameter	Correlation co-efficient (r)
1	Maximum Temperature (°C)	-0.362*
2	Minimum Temperature (°C)	0.522**
3	Temperature Fluctuation	-0.696**
4	Morning Relative Humidity (RH1), %	0.669**
5	Evening Relative Humidity (RH2), %	0.670**
6	Relative Humidity Fluctuation	-0.616**
7	Bright Sunshine Hors (BSS), hrs/day	-0.486**
8	Rain fall (RF), mm	0.216
9	Wind Speed, kmph	0.293
10	Evaporation, mm	-0.483**

Conclusion

The fruit fly population was found highest during the 35th SMW followed by the 36th SMW on the other hand, lowest fruit fly population was observed during 52nd SMW followed by the 51st SMW. Correlation studies observed that the fruit fly population had a highly significant positive correlation with evening relative humidity, morning relative humidity and minimum temperature. While, wind speed and rain fall were positively correlated with fruit fly population but the result was non-significant. On the contrary, temperature fluctuation, relative humidity fluctuation, bright sunshine hours and evaporation had a highly significant negative correlation with fruit fly population. While, maximum temperature had a significant negative correlation with the fruit fly population.

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