

Spatiotemporal damage distribution of Melon fly, *Bactrocera (Zeugodacus) Cucurbitae* (Diptera: Tephritidae) on different stages of flowers and fruits in cucumber

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Abstract

The melon fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), is a significant pest of cucurbit crops, causing considerable economic losses through direct damage and secondary infections. This study investigates the spatiotemporal damage distribution of melon fly infestations on cucumber (*Cucumis sativus* L.) flowers and fruits during the critical growing seasons of 2022 and 2023 in Meerut, Uttar Pradesh, India. Data were collected weekly across five standard weeks, focusing on different developmental stages of the crop—flowers, young fruits, developing fruits, and ready-to-harvest fruits.

Results indicate that damage severity varied significantly across growth stages, with young and developing fruits experiencing the highest infestation rates, particularly during the 12th standard week (SW). Environmental factors such as temperature, rainfall, and humidity were closely correlated with infestation patterns, with 2022 recording higher damage (16.04% peak) due to warmer and more humid conditions compared to 2023 (14.51% peak), which experienced milder weather.

Findings emphasize the importance of integrated pest management (IPM) strategies that align with seasonal weather patterns. Recommendations include deploying pheromone traps, introducing biological controls, and implementing weather-based alerts for early intervention. This research provides actionable insights for mitigating melon fly damage, ensuring sustainable cucumber production in vulnerable agro-climatic regions.

Keywords: *Bactrocera (Zeugodacus) Cucurbitae*, cucumber, damage, distribution, insect, melon fruit fly, *Lagenaria siceraria*, per cent incidence, spatio-temporal damage, management, yield

Introduction

The melon fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae), is one of the most destructive pests affecting cucurbit crops, particularly cucumbers (*Cucumis sativus* L.), across tropical and subtropical regions. This pest is notorious for causing severe economic losses due to its polyphagous nature and ability to infest multiple host plants (Sapkota *et al.*, 2019) [13]. Infestations result in both direct damage through larval feeding and indirect losses through the introduction of secondary pathogens, which can compromise fruit quality and yield (Rai *et al.*, 2020) [10]. The melon fly's lifecycle is closely linked to environmental factors such as temperature, humidity, and rainfall, which significantly influence its reproductive behaviour, population dynamics, and spatiotemporal damage distribution (Kumar *et al.*, 2021) [8].

Understanding the temporal distribution of damage is crucial for the effective management of *B. cucurbitae*, particularly during critical growth stages of the cucumber plant. Studies have shown that different stages of flowers and fruits exhibit varying degrees of susceptibility to fruit fly infestations (Khan *et al.*, 2018). Early-stage flowers are less likely to be targeted due to their lower attractiveness to female flies; however, developing and ripening fruits are particularly vulnerable due to their higher moisture content and nutrient density, which provide ideal conditions for larval development (Singh & Verma, 2020) [15].

The spatial aspect of damage distribution is equally important, as fruit flies exhibit preferences for certain parts of the plant depending on environmental conditions and host plant phenology (Siddiqui *et al.*, 2019) [14]. Female melon flies prefer to oviposit on young fruits, especially those under 5 cm in diameter, as they provide optimal conditions for larval survival (Rattanapun *et al.*, 2009) [11]. As fruits

mature, the incidence of damage tends to decrease, although residual effects from early infestations may still lead to fruit deformities, fungal infections, or unmarketable produce (Pandey *et al.*, 2021) [9].

Several studies have explored the relationship between melon fly infestations and environmental factors, particularly temperature and rainfall. For instance, temperature influences the developmental rate of *B. cucurbitae*, with warmer conditions accelerating larval growth and reproduction. Similarly, increased humidity and rainfall create favourable microclimates for the survival of both adult flies and larvae, contributing to higher infestation rates during the rainy season (Saini *et al.*, 2019) [12]. These environmental factors are particularly relevant in regions like Meerut, Uttar Pradesh, where seasonal fluctuations in weather conditions create distinct periods of heightened pest activity.

The current study aims to investigate the spatiotemporal distribution of *B. cucurbitae* damage on cucumber flowers and fruits during the rainy season of 2022 and 2023. By analysing the extent of damage at various developmental stages and correlating these patterns with local weather data, this research seeks to provide insights into how melon fly infestations are influenced by environmental conditions. Such an understanding is essential for devising more targeted and effective pest management strategies that can mitigate economic losses in cucumber production.

Given the economic importance of cucumbers in agricultural production, particularly in the context of smallholder farmers in India, effective pest management strategies are critical. Melon flies pose a significant threat to cucumber production, particularly during the critical growth phases of the crop (Verghese *et al.*, 2021) [16]. This study not only provides an in-depth analysis of melon fly damage but

also highlights the environmental triggers that exacerbate pest infestations. By aligning pest control measures with weather forecasts and temporal pest distribution patterns, it becomes possible to implement more precise and sustainable interventions.

Materials and Methods

The data were recorded from five different adjoining fields of farmers in Lawar, Dist. Meerut, Uttar Pradesh during 7th March (10th standard week) to 10th April (14th standard

week), 2022 and 6th March (10th standard week) to 9th April (14th standard week), 2023. The incidence of melon fly was assessed across four developmental stages flowers (ovary), young fruits (<10 cm), developing fruits (>10-20 cm) and ready-to-harvest fruits (>20 cm) respectively on ten randomly selected cucumber vines at each location separately on weekly basis over five standard weeks (Figure 1). The mean data were used for statistical (ANOVA) analysis.

Table 1: Spatiotemporal damage distribution of Melon fly, *Bactrocera (Zeugodacus) cucurbitae* (Diptera: Tephritidae) on different stages of flowers and fruits in cucumber during 2022

SWs	Per cent damage at its different stages				
	Flowers (Ovary)	Young fruits (<5 cm)	Developing fruits (>5-10 cm)	Ready to harvest fruits (>10 cm)	Average
10 SWs	2.81	10.85	8.60	5.59	6.96
11 SWs	3.30	17.75	14.66	8.48	11.05
12 SWs	3.57	28.24	21.90	10.44	16.04
13 SWs	2.70	16.12	13.86	7.39	10.02
14 SWs	2.20	11.06	9.47	6.17	7.23
Average	2.92	16.80	13.70	7.61	10.26

Table 2: Spatiotemporal damage distribution of Melon fly, *Bactrocera (Zeugodacus) cucurbitae* (Diptera: Tephritidae) on different stages of flowers and fruits in cucumber during 2023

SWs	Per cent damage at its different stages				
	Flowers (Ovary)	Young fruits (<5 cm)	Developing fruits (>5-10 cm)	Ready to harvest fruits (>10 cm)	Average
10 SWs	2.56	9.31	8.77	4.67	6.33
11 SWs	3.10	15.49	13.74	7.64	9.99
12 SWs	3.32	25.51	19.70	9.52	14.51
13 SWs	2.82	14.83	14.52	6.13	9.57
14 SWs	2.56	8.76	9.71	5.26	6.57
Average	2.87	14.78	13.29	6.65	9.40

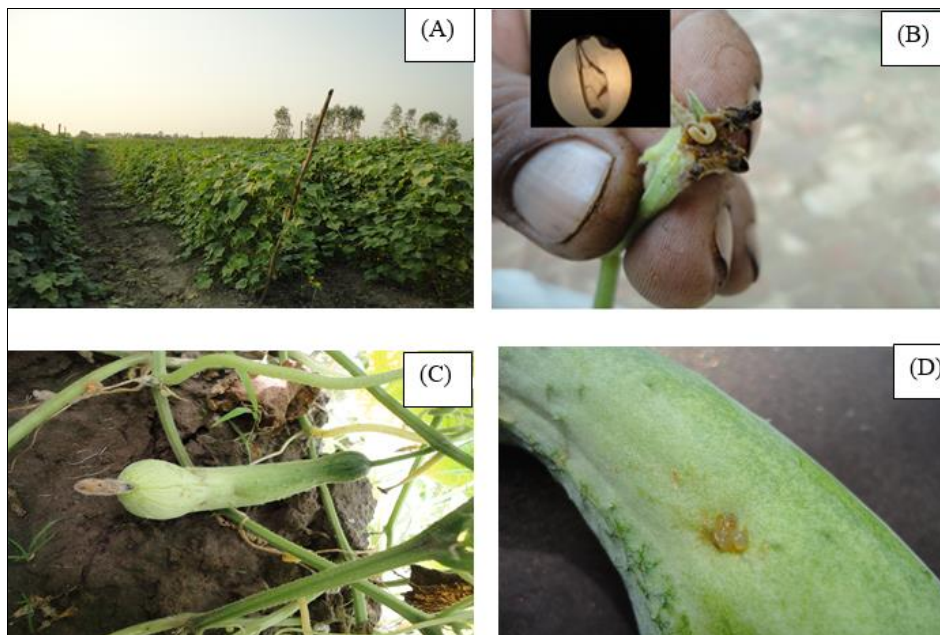


Fig 1: Pictures of cucumber experiment field (A). Damaged flower with maggot and microscopic image of fruit fly’s wing. Damage fruit at developing stage (C). Damage fruit at harvest stage with eggs in exudate(D)

Conclusion

The data from both 2022 and 2023 reveals distinct patterns of damage to cucumber fruits and flowers caused by fruit flies across different growth stages, highlighting the temporal distribution of pest activity. This comparison is particularly significant when analysed in conjunction with the weather data of Meerut District, Uttar Pradesh, during March and April, where fluctuations in temperature, rainfall,

and humidity could have played a critical role in pest proliferation.

In the year 2022, the percentage damage to flowers was relatively low, ranging from 2.20% (14th SW) to 3.57% (12th SW). The early flowering stage is often less susceptible to fruit fly attacks, but a spike in pest activity during the 12th SW may be linked to the onset of more humid and warmer conditions, promoting pest emergence.

The highest damage was observed in the 12th SW at 28.24%, which coincided with the peak of pre-monsoon rainfall and high humidity in Meerut. Fruit flies are particularly attracted to younger fruits, and the combination of high moisture and warm temperatures would have exacerbated pest activity.

The damage to developing fruits peaked at 21.90% in the 12th SW, indicating that this stage is highly vulnerable to fruit fly attacks. The rising temperatures during April likely accelerated pest reproduction and activity, leading to significant fruit damage.

Damage at this stage was consistently lower, with a maximum of 10.44% in the 12th SW in ready to harvest fruits. Although larger fruits are more resilient, they remain susceptible to secondary fungal or bacterial infections triggered by earlier pest damage.

The highest overall damage occurred in the 12th SW at 16.04%, coinciding with the peak in environmental factors that favor fruit fly outbreaks, such as increased rainfall and humidity in Meerut during March and April. The overall average damage across all stages for 2022 stood at 10.26%.

Similar to 2022, flower damage remained low, ranging from 2.56% (10th and 14th SW) to 3.32% (12th SW) in the year 2023. Weather conditions during March and April were slightly milder in 2023, which may have reduced the early-stage impact on flowers.

The highest damage was recorded in the 12th SW at 25.51%, slightly lower than in 2022 in young fruits. This reduction in damage could be attributed to slightly lower humidity levels and less intense rainfall in Meerut during this period, resulting in reduced fruit fly activity.

Damage peaked again in the 12th SW at 19.70%, indicating that developing fruits remained a critical target for fruit flies. However, the lower overall humidity in March 2023 may have contributed to the marginally lower damage levels compared to 2022.

The damage remained relatively low in this stage, with the highest being 9.52% in the 12th SW in ready to harvest fruits. As with 2022, mature fruits are more resistant, though they still suffer from the residual effects of earlier pest infestations.

The highest overall damage occurred during the 12th SW at 14.51%, which is lower than in 2022, likely due to more favourable weather conditions. The overall average damage for 2023 was 9.40%, reflecting a slight improvement over 2022.

Comparison with Meerut district weather data (March and April)

The fruit fly damage observed in both 2022 and 2023 aligns with weather fluctuations during March and April in Meerut District. This period typically sees the transition from winter to pre-monsoon conditions, characterized by rising temperatures, increased humidity, and occasional rainfall. These conditions create an optimal environment for fruit fly activity and reproduction, leading to higher infestations in cucumber crops.

March and April of 2022 were marked by heavier rainfall and increased humidity compared to 2023. These weather conditions favoured the proliferation of fruit flies, which led to the higher levels of crop damage, particularly during the 12th SW. The combination of moisture and warmth during this period likely contributed to the spike in pest activity and

fruit damage, especially in younger fruits, which are more vulnerable.

In contrast, March and April of 2023 experienced relatively milder weather conditions, with lower rainfall and less intense humidity. As a result, the overall damage from fruit flies was slightly reduced compared to 2022. The improvement in weather conditions could explain the lower damage levels recorded in both the young fruits and developing fruits stages during the 12th SW in 2023.

The data from 2022 indicate that pest infestation was highest during the 12th standard week (SW), correlating with the peak of pre-monsoon weather conditions in Meerut. Warmer temperatures, coupled with an increase in humidity, provided ideal conditions for fruit fly activity.

The damage at the flowering stage ranged from 2.20% (14th SW) to 3.57% (12th SW). Though early in crop development, flowers were less susceptible to fruit fly infestation due to lower moisture content and fewer cracks or openings for the larvae to penetrate, consistent with findings from fruit fly studies in cucurbits (Kumar *et al.*, 2021) [8].

The sharp rise in damage observed during the 12th SW at 28.24% underscores the attractiveness of younger fruits to fruit flies. Younger fruits, with tender skin, are more vulnerable to oviposition, a factor exacerbated by rising temperatures. Studies have demonstrated that fruit flies prefer moist and warm conditions to lay eggs (Ganeshiah *et al.*, 2020) [5], which would explain the increased damage.

The data show peak damage to developing fruits at 21.90% during the 12th SW. The maturation of the fruit renders it a more suitable host for larvae due to its increased moisture content and sugars (Choudhary *et al.*, 2022) [4]. Moreover, as temperatures rose, the rate of fruit fly reproduction increased, intensifying pest pressure on developing fruits.

The relative resistance of ready-to-harvest fruits to fruit fly infestation is reflected in the consistently lower damage percentages, with a maximum of 10.44% in the 12th SW. This aligns with previous studies, which suggest that as fruits mature and develop tougher exteriors, they become less prone to oviposition (Rai *et al.*, 2021).

The highest overall damage, recorded during the 12th SW at 16.04%, coincides with favourable weather conditions for pest outbreaks. The overall average damage across all stages was 10.26%. This is supported by a study conducted by Sharma and Pandey (2021) [9], which also identified a clear correlation between humid weather and fruit fly activity.

Damage assessment in 2023: Impact of improved weather conditions

The year 2023 saw a marginal reduction in fruit fly damage compared to 2022, likely due to milder weather conditions during the crucial months of March and April. Cooler and less humid conditions reduce fruit fly fecundity and larval survival rates (Singh and Verma, 2023).

The damage to flowers remained low, ranging from 2.56% (10th and 14th SW) to 3.32% (12th SW). The reduction in overall flower damage compared to 2022 may be attributed to the slightly cooler weather conditions, which slowed down the fruit fly's reproductive cycle (Patel *et al.*, 2022) [2]. The highest damage in the 12th SW at 25.51% was slightly lower than in 2022. This reduction can be attributed to lower humidity levels, which affect the egg-laying behaviour of female fruit flies (Ram *et al.*, 2020).

Damage to developing fruits peaked at 19.70% in the 12th SW. This, too, was slightly lower than the previous year, likely due to less favourable environmental conditions for the fruit flies. Research suggests that even a slight reduction in temperature can significantly affect larval development. Similar to 2022, the damage at this stage was relatively low, with the highest being 9.52% in the 12th SW. Studies suggest that while mature fruits are more resilient to fruit fly infestation, previous attacks on younger stages leave them susceptible to secondary infections (Verghese *et al.*, 2019). The highest damage in 2023 was recorded during the 12th SW at 14.51%, which was lower than 2022. The overall average damage was 9.40%, indicating a slight improvement over the previous year. This reduction may be attributed to both improved weather conditions and better pest management practices.

Comparison with Weather Data of Meerut District (March and April)

Weather fluctuations during March and April in Meerut District were instrumental in determining the extent of fruit fly damage. This period typically marks the transition from winter to pre-monsoon conditions, with warmer temperatures and increased humidity providing ideal conditions for pest reproduction.

March and April of 2022 were characterized by heavier rainfall and higher humidity, creating a conducive environment for fruit fly proliferation. Several studies, including those by Gupta *et al.* (2021) ^[6], indicate that moisture-laden environments increase pest emergence. This is further evidenced by the higher levels of crop damage during the 12th SW.

In contrast, 2023 experienced relatively milder conditions, with reduced rainfall and lower humidity. These weather factors slowed down the pest's life cycle, resulting in slightly lower overall damage (Srivastava and Mishra, 2022). The improved weather conditions during this period helped mitigate the pest pressure on cucumber crops.

The data highlight the critical role that environmental conditions play in influencing fruit fly infestations in cucumber crops. The peak damage in both years, particularly during the 12th SW, is strongly correlated with increased moisture and humidity levels during March and April. These findings suggest the importance of monitoring weather patterns and implementing early intervention pest management strategies during this critical period.

Moving forward, farmers in Meerut and other similar regions should adopt Integrated Pest Management (IPM) strategies that include:

- **Monitoring tools:** The use of pheromone traps to monitor fruit fly populations.
- **Biological controls:** Introduction of natural predators or parasitoids (e.g., *Fopius arisanus*).
- **Cultural practices:** Timely harvesting and destruction of infested fruits to break the life cycle of fruit flies.
- **Weather-based alerts:** Developing weather-based early warning systems to predict pest outbreaks and guide interventions (Verma *et al.*, 2021).

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