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# Temporal distribution and morphological differentiation of dominant Tephritid fruit flies

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**Abstract**
The diversity, abundance, and morphometric variability of citrus fruit flies (Diptera: Tephritidae) in mandarin orchards were assessed, identifying *Bactrocera dorsalis*, *B. zonata*, and *B. correcta* as the dominant species. Systematic trapping with methyl eugenol-baited parapheromone traps from the 39th to 52nd meteorological weeks captured 1, 203 adults, with *B. dorsalis* comprising 53.12%, *B. zonata* 37.65%, and *B. correcta* 9.23%. Adult emergence peaked during the 41st week, highlighting a critical period for monitoring and control. Morphological and morphometric analyses revealed clear interspecific differences in body size, wing span, and diagnostic traits such as cephalic pigmentation, thoracic vittae, wing venation, and abdominal patterning, with *B. dorsalis* being the largest species. These results provide a baseline for understanding species composition, seasonal dynamics, and morphological variability in mandarin orchards. The findings support accurate species identification and the timing of targeted pest management strategies, contributing to sustainable citrus production and reduced economic losses from fruit fly infestations.

**Keywords:** Citrus fruit flies, *Bactrocera* Spp., Morphometrics, morphological variability, species diversity, Parapheromone traps, methyl eugenol, diagnostic characters

## Introduction

Citrus represents one of the world's most significant fruit crops, ranking second in global production in 2021 with 161.8 million tonnes harvested from over 10.2 million hectares (FAO, 2023) [19]. Within this group, oranges are the leading fruit, contributing 75.6 million tonnes (46.7% of total citrus production), followed by tangerines (25.9%), lemons and limes (12.9%), and grapefruits/pomelos (5.9%). The importance of citrus in agriculture and human nutrition has been emphasized for decades (Gmitter *et al.*, 1992), yet production continues to be challenged by insect pests and diseases that diminish yield, degrade fruit quality, and threaten sustainability.

India, blessed with a wide range of agroclimatic zones, ranks as the third largest citrus producer in the world. Among the commercially important species in the country, mandarins, sweet oranges, and limes occupy a central place in horticultural systems. Particularly, the Nagpur mandarin (*Citrus reticulata* Blanco), renowned for its distinctive acid-sugar balance, rich aroma, and bright orange rind, has achieved worldwide recognition for its superior quality. In 2014, this prized cultivar was conferred the Geographical Indication (GI) tag, highlighting its uniqueness and linking its identity to the Vidarbha region of Maharashtra. The districts of Nagpur and Amravati form the epicentre of Nagpur mandarin cultivation, collectively producing nearly seven lakh tonnes annually (NHB, 2022) [30]. The economic significance of this crop is immense, providing livelihood support to thousands of smallholder farmers and contributing substantially to India's fruit export sector.

Despite the promising production potential, citrus cultivation faces a range of biotic and abiotic challenges that threaten both yield and fruit quality. Among biotic stressors, insect pests are particularly notorious, with fruit flies (Diptera: Tephritidae) standing out as one of the most destructive groups. These pests pose a serious phytosanitary and economic threat by infesting more than 250 host plants across over 40 botanical families (Smith, 1989; Vargas *et al.*, 1984; Agarwal & Sueyoshi, 2005) [35, 40, 4]. In Indian citrus orchards, species such as *Bactrocera dorsalis*, *Bactrocera zonata*, and *Bactrocera correcta* have emerged as major concerns. Their polyphagous nature, high reproductive potential, and remarkable dispersal ability make management particularly challenging. Infestations by these fruit flies result in premature fruit drop, pulp destruction, and substantial yield losses, directly affecting the profitability of orchards and the livelihoods of growers (Dorji *et al.*, 2006) [12].

Moreover, the biology of these pests, characterized by rapid adaptation to diverse environmental conditions, ensures their persistence throughout the year, making continuous monitoring and management essential (Narayanan & Batra, 1960; Fletcher, 1987; Vargas *et al.*, 1996) [29, 20, 41]. The economic implications are further magnified by quarantine restrictions, as fruit fly infestations can limit domestic trade and export opportunities, particularly for markets with stringent phytosanitary standards.

Effective pest management begins with accurate identification of the insect species involved. Traditionally, fruit fly identification has relied on classical taxonomic approaches that utilize external morphological traits, such as thoracic patterning, wing venation, abdominal markings, and male genital structures (White & Elson-Harris, 1992; Drew & Romig, 2000) [42, 15]. While these features provide valuable diagnostic information, their use is often complicated by intraspecific variation, overlapping characteristics among closely related species, and environmental influences on morphology (Dujardin, 2008; Rohlf & Marcus, 1993) [16, 34]. Misidentification can therefore hinder timely and effective management interventions, resulting in increased pest pressure and crop losses.

In response to these challenges, integrated pest management (IPM) strategies have become the cornerstone of sustainable citrus cultivation. IPM emphasizes the combined use of cultural, mechanical, biological, and chemical approaches, tailored to the biology and ecology of pests, to maintain populations below economically damaging thresholds. For fruit flies, this may include strategies such as sanitation through regular removal of infested fruits, use of pheromone or food-based traps for population monitoring, augmentation of natural enemies, and judicious application of insecticides when necessary (Ekesi & Billah, 2007; Vargas *et al.*, 2015; FAO, 2019) [17, 38, 19].

Given the centrality of citrus to both nutrition and economy, and the persistent threat posed by fruit flies, there is a compelling need for continuous surveillance, accurate pest identification, and the adoption of efficient management practices. Strengthening these aspects not only safeguards yield and fruit quality but also contributes to the sustainability of citrus orchards, ensuring that the “golden fruits of the tropics” continue to thrive in India and around the world.

## Materials and Methods

### Study site and duration

The present investigation was carried out during September-December 2024 in the research orchards of Nagpur mandarin (*Citrus reticulata* Blanco) at ICAR-Central Citrus Research Institute (ICAR-CCRI), Nagpur, Maharashtra, India (21°09′N, 79°09′E; elevation ~310 m above mean sea level). The region experiences a subtropical climate with hot summers, a monsoon season extending from June to September, and mild winters from November onwards. The experimental period covered the 39th to 52nd Meteorological Weeks (MW), corresponding to the fruit development and harvesting stage of Nagpur mandarin, when fruit flies are most active.

### Trapping and collection of fruit flies

Adult fruit flies were collected using parapheromone-based male lure traps, a standard method for surveillance of *Bactrocera* species (IAEA, 2003) [23]. Eight methyl eugenol-baited traps (4 mL lure/trap) were deployed across three orchard blocks (Blocks 3, 5, and 6), with traps suspended at 1.0-1.5 m above ground within the tree canopy to maximize interception efficiency. Each trap consisted of a perforated plastic container with an absorbent cotton wick impregnated with methyl eugenol and a few drops of dichlorvos (DDVP 76% EC) to ensure rapid immobilization of attracted flies.

Traps were monitored at weekly intervals from the 39th MW (24-30 September) to the 52nd MW (24-31 December). At each inspection, captured insects were retrieved using forceps, transferred into labeled vials, and euthanized with chloroform. The lure cotton was replenished every 15 days to maintain attractancy. For each specimen, collection metadata including trap code, orchard block, date, and host crop were recorded to ensure traceability.

### Preservation of specimens

Collected specimens were preserved in two ways depending on their intended use:

1. **Morphological study:** Representative adults were pinned, air-dried, and labeled for morphological examination.
2. **Morphometric analysis:** Specimens were preserved in 95% molecular-grade ethanol to prevent shrinkage and to facilitate precise morphometric measurements.

Voucher specimens for each species were catalogued and deposited in the insect repository of ICAR-CCRI for future reference and taxonomic verification.

### Morphological identification

Initial identification of fruit flies was conducted under a Leica EZ4 stereomicroscope using standard diagnostic keys (White & Elson-Harris, 1992; David & Ramani, 2011) [42, 11]. Diagnostic traits such as head pigmentation, antennal shape, thoracic vittae, wing venation, abdominal markings, and presence or absence of pecten on the third abdominal tergite were examined. Male specimens were dissected to examine genitalia when external characters were insufficient for species separation. The abdomen was detached, cleared in 10% potassium hydroxide (KOH) solution for 8-10 minutes to remove soft tissues, rinsed in distilled water, and examined in glycerol. Male surstyli and female ovipositor tips were studied following standard protocols (Clausen, 1978) [10].

For high-resolution visualization of fine morphological traits, selected specimens were processed for scanning electron microscopy (SEM). Ethanol-preserved specimens were fixed in 2.5% glutaraldehyde, dehydrated through graded ethanol series, subjected to hexamethyldisilazane (HMDS) drying, and sputter-coated with gold-palladium. SEM imaging was carried out at the ICAR-CCRI microscopy facility, focusing on antennal morphology, wing venation geometry, setal arrangement, and ovipositor structures (Kumar *et al.*, 2011) [25].

### Morphometric analysis
Quantitative morphometric measurements were taken to supplement morphological identification. A minimum of 30 adult specimens per species (10 per orchard block) were measured to capture intra-specific variability. Observations were made using an ocular micrometer attached to a stereomicroscope, with each measurement repeated three times and averaged to minimize observational error.

The following characters were recorded, as recognized descriptors in tephritid taxonomy (Bookstein, 1991; Rohlf & Marcus, 1993) [8, 34]:

- **Body size**: total length (vertex to abdominal tip) and body width (with wings extended).
- **Wing traits**: length (base to tip of vein R4+5), width, and intervein distances.
- **Thorax**: length and width, vittae length.
- **Head**: capsule length and width, antennal length, eye diameter.
- **Abdomen**: length and width, tergite markings.
- **Legs**: lengths of fore, mid, and hind femora, tibiae, trochanters, and tarsi.

Measurements were tabulated as mean ± standard deviation (SD). Species-level differentiation was statistically tested using one-way analysis of variance (ANOVA), followed by Tukey's HSD test at $P < 0.05$ to determine significance of interspecific differences. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

### Data analysis
Trap catch data were expressed as weekly counts of individuals per species. The relative abundance of each species was calculated as a percentage of the total captures across the 39th-52nd MW. Temporal trends were plotted to identify peaks of activity. Morphometric data were analyzed as described above, and results were compared with published morphometric datasets to confirm species identity (Agarwal & Mishra, 2010; Kumar *et al.*, 2023) [5, 24].

## Results
### Documentation of citrus fruit fly species in citrus ecosystem
Understanding the population dynamics and species assemblage of fruit flies (Tephritidae: *Bactrocera spp.*) is fundamental for devising sustainable management strategies in citrus ecosystems. To address this, systematic monitoring was undertaken in Nagpur mandarin (Citrus reticulata) research orchards at ICAR-CCRI, Nagpur, during the citrus season of 2024. Male-annihilation traps baited with methyl eugenol (4 mL per trap), a kairomonal para-phenylpropanoid highly attractive to male *Bactrocera spp.*, were deployed from the 39th to 52nd Meteorological Week (MW). A total of eight traps were strategically installed at 1.0-1.5 m above ground across Blocks 3, 5, and 6 to ensure representative sampling of the orchard ecosystem. Weekly observations were recorded, and captured specimens were retrieved, sorted, and subjected to taxonomic identification using standard Tephritid morphological keys under a stereomicroscope. Preserved specimens were labeled with location, date, host, and trap code, serving as reference material for long-term surveillance and comparative studies.

The monitoring revealed a cumulative trap catch of 1, 203 fruit flies belonging to three specie (Table 1): *Bactrocera dorsalis* (639 individuals; 53.12%), *B. zonata* (453; 37.65%), and *B. correcta* (111; 9.23%). The species-specific temporal dynamics highlighted *B. dorsalis* as the predominant taxon, with its peak activity recorded during the 41st MW (08-14 October) when 100 individuals were captured, accounting for 15.65% of its seasonal abundance. This peak coincided with high catches of *B. zonata* (79 individuals; 17.44%) and *B. correcta* (26 individuals; 23.42%), suggesting synchronous activity of sympatric species during the early fruiting stage. The captures declined progressively thereafter, with minimal populations recorded by the 52nd MW (24-31 December). Such phenological patterns corroborate earlier reports by Bajaj and Singh (2020, 2021) [6, 7], who documented pronounced *B. dorsalis* dominance and seasonal peaks in Kinnow and other fruit crops, and by Adhikari *et al.* (2018) [2, 3] and Nair *et al.* (2018) [17], who demonstrated similar species responses in sweet orange and mixed fruit orchards.

The predominance of *B. dorsalis* in the present study reinforces its ecological adaptability and strong kairomonal affinity towards methyl eugenol, a trend consistently reported across agroecosystems. Umeh *et al.* (2008) [37] first established the lure-specific responsiveness of *B. dorsalis* (then recognized as *B. invadens*), while FAO/IAEA (2018) [18] further recognized this species as globally the most responsive to methyl eugenol, validating its use in surveillance and male annihilation strategies. In the Indian context, Ranabhat *et al.* (2021) [33] quantified *B. dorsalis* at 95.5% of total captures compared to *B. zonata* and *B. correcta*, while Nage *et al.* (2023) [28] reported similar dominance in Vidarbha mandarin orchards with *B. dorsalis* (45%) followed by *B. zonata* (22%) and *B. correcta* (14%). More recently, Acharya *et al.* (2024) [1] also confirmed *B. dorsalis* as the dominant taxon (63%) in mandarin ecosystems. These corroborative findings across geographical regions lend strong support to the present results and highlight the utility of methyl eugenol-baited traps as a reliable, species-specific, and cost-effective surveillance tool. The observed seasonal emergence patterns emphasize the importance of early-season monitoring to target peak *Bactrocera* activity windows, thereby strengthening integrated citrus fruit fly management strategies.

### Morphometric Analyses for Accurate Identification and Species Delineation of Citrus Fruit Flies
Three predominant species of Tephritid fruit flies were recorded infesting mandarins at the CCRI research block orchard ecosystem and were taxonomically classified under the genus *Bactrocera*, namely *B. dorsalis* (Hendel), *B. zonata* (Saunders) and *B. correcta* (Bezzi). Specimens were collected and examined for key morphological traits, which facilitated species-level identification. Diagnostic characters, particularly in male specimens, were found to be critical for differentiating among closely related taxa within the genus, as emphasized earlier by David and Ramani (2011) [11].

### 1. Genus Bactrocera
Species of the genus *Bactrocera* were distinguished by the presence of one pair each of scutellar, prescutellar and supra-alar setae. In males, the third abdominal tergite bore a distinct pecten of stout setae on its posterolateral margin, in line with descriptions provided by Musasa (2019) [27]. Wing morphology was observed to be highly species-specific: *B.*

*dorsalis* exhibited a continuous dark costal band extending to vein $R_{4+5}$, *B. zonata* showed a prominent apical brown spot, and *B. correcta* displayed infuscated vein markings. The surstylus of male genitalia varied considerably—broad in *B. dorsalis*, truncate in *B. zonata* and slender in *B. correcta*—supporting earlier observations by Kumar *et al.* (2023) [24]. The fifth abdominal sternite also displayed interspecific variation in the shape and depth of the posterior notch, serving as an additional diagnostic marker, a feature consistently highlighted by Adhikari and Joshi (2018) [2, 3].

**2. Key Morphological Traits in Fruit Fly Species Identification**

**Head**: The head capsule offered distinctive taxonomic features. *B. dorsalis* was recognizable by its bright yellow coloration and large circular black facial spots (Figure 1:(1)), confirming observations by Musasa (2019) [27]. *B. zonata* was characterized by small circular or oval spots within the antennal furrow (Figure 1 :(2)), while *B. correcta* displayed a fulvous head with a transverse black band (Figure 1:(3)). These facial traits align with the diagnostic criteria emphasized by Prabhakar *et al.* (2012) [32].

**Wings:** The wing venation and pigmentation patterns provided crucial distinguishing traits. *B. dorsalis* possessed a narrow costal band confluent with vein R2+3, with a faint anal streak (Figure 2: (1)). In contrast, *B. zonata* exhibited a reduced costal band with discontinuities and an apical fuscous spot (Figure 2). *B. correcta* had hyaline wings with a discontinuous cuesscotal band and an anal streak confined to the cell cup (Figure 2: (1)). These features were consistent with the illustrated keys of David and Ramani (2011) [11].

**Thorax:** Thoracic coloration showed marked polymorphism across species. The scutum of *B. dorsalis* varied from black to reddish-brown (Figure 3: (1)), while *B. zonata* exhibited a vibrant orange to reddish-brown scutum (Figure 3: (2)). *B. correcta* was primarily black with lateral and posterior brown mottling (Figure 3: (3)). These descriptions mirror the diagnostic thoracic traits reported by Chiluwal *et al.* (2023) [9].

**Vittae:** Longitudinal vittae provided additional discriminative features. *B. dorsalis* exhibited broad, parallel-sided vittae enclosing a row of setae (Figure 3: (1)), whereas *B. zonata* showed semi-circular vittae extending inward to contact the intra-alars (Figure 3: (2)). *B. correcta* displayed vittae similar to *B. dorsalis* (Figure 3: (3)). These patterns correspond with the descriptions of Nage *et al.* (2023) [28].

**Abdomen:** The abdomen was another important taxonomic unit. *B. dorsalis* exhibited orange-brown tergites with a faint to distinct T-pattern across tergites III-V and dark anterolateral corners on tergites IV-V (Figure 4: (1)). *B. zonata* had a more prominent T-shaped mark (Figure 4: (2)), while *B. correcta* displayed a reddish-brown abdomen with similar markings (Figure 4: (3)). These patterns are well in line with comparative descriptions by Kumar *et al.* (2023) [24].

**Pecten:** Males of *B. dorsalis* and *B. zonata* bore a distinct pecten on the third abdominal tergum (Figure 4: 1&2), whereas *B. correcta* lacked this structure, confirming earlier findings of Prabhakar *et al.* (2012) [32].

**Legs:** Leg morphologies were relatively conservative, although *B. dorsalis* exhibited characteristically dark hind tibiae (Figure 6). No distinctive leg characters were noted for *B. zonata* and *B. correcta*.

The diagnostic features described above corroborated with the illustrated keys of David and Ramani (2011) [11] and were further validated by the comparative works of Chiluwal *et al.* (2023) [9], Adhikari and Joshi (2018) [2, 3] and Prabhakar *et al.* (2012) [32].

**3. Comparative Morphometrics of Fruit Fly Species**

Morphometric characterization revealed distinct interspecific differences across major body parts (Table 2). *B. dorsalis* consistently exhibited larger body size, longer wings and greater abdominal dimensions compared to *B. zonata* and *B. correcta*. For instance, the mean body length of *B. dorsalis* (6.53±0.48 mm) exceeded that of *B. zonata* (5.39±0.57 mm) and *B. correcta* (4.80±0.24 mm). Similarly, wing length was greatest in *B. dorsalis* (6.28±0.41 mm), supporting the findings of Kumar *et al.* (2023) [24], who also reported *B. dorsalis* as morphometrically superior in body size and wing expansion.

Thorax measurements revealed B. zonata to have the longest thoracic length (2.72±0.13 mm), while *B. dorsalis* had the widest thorax (2.40±0.04 mm), indicating greater robustness. Vittae length was most pronounced in *B. zonata* (1.63±0.57 mm), corroborating earlier observations by Nage *et al.* (2023) [28]. Abdominal measurements followed a similar trend, with *B. dorsalis* exhibiting the broadest (2.66±0.08 mm) and longest abdomen (2.61±0.33 mm).

Head and antennal measurements also reflected clear interspecific variation. *B. dorsalis* exhibited the largest head capsule (1.14±0.05 mm length; 2.13±0.08 mm width) and longest antennae (0.89±0.06 mm). Eye ball diameter was greatest in *B. dorsalis* (1.19±0.15 mm), consistent with the morphometric descriptions of Manurung *et al.* (2022) [26].

Leg measurements further differentiated the species. *B. dorsalis* exhibited significantly longer femora and tibiae than *B. correcta*, while *B. zonata* occupied an intermediate position. These morphometric results were broadly concordant with earlier findings of Agarwal and Mishra (2010) [5] and Musasa (2019) [27], indicating morphological stability across geographical populations.

Taken together, the morphometric traits documented in this study strongly reinforce the diagnostic value of external morphology in Tephritid systematics. The agreement of our findings with earlier works (David and Ramani, 2011; Prabhakar *et al.*, 2012; Adhikari and Joshi, 2018; Kumar *et al.*, 2023; Chiluwal *et al.*, 2023; Nage *et al.*, 2023; Musasa, 2019; Manurung *et al.*, 2022; Agarwal and Mishra, 2010) [11, 32, 2, 3, 24, 9, 28, 27, 26, 5] highlights the robustness of morphometric approaches for accurate species delineation of *Bactrocera*.

## Discussion

The present study revealed the seasonal distribution and morphological differentiation of three dominant fruit fly species, *Bactrocera dorsalis*, *B. zonata*, and *B. correcta*, in Nagpur mandarin orchards of central India. The cumulative trap captures across the citrus season demonstrated a clear dominance of *B. dorsalis* (53.12%), followed by *B. zonata*

(37.65%) and *B. correcta* (9.23%). These results corroborate several earlier studies conducted in different agroecological contexts, where *B. dorsalis* has consistently emerged as the predominant tephritid pest in tropical and subtropical fruit ecosystems (Ranabhat *et al.*, 2021; Nage *et al.*, 2023; Acharya *et al.*, 2024) [33, 28, 1]. The strong affinity of *B. dorsalis* towards methyl eugenol, a highly attractive male lure, may partly explain its dominance in trap catches. This affinity has been widely documented and forms the basis for its use in surveillance and male annihilation techniques (Umeh *et al.*, 2008; FAO/IAEA, 2018) [37, 18].

The temporal distribution patterns observed in this study also highlight critical insights into the phenology of citrus fruit flies. The pronounced population peaks recorded during the 41st meteorological week (second week of October) coincided with the early fruiting stage of Nagpur mandarin. This suggests that fruit fly emergence is closely synchronized with host fruit availability, as has been reported for other citrus species and regions (Adhikari *et al.*, 2018; Bajaj & Singh, 2020) [2, 3, 6]. The subsequent decline in trap catches towards December may be attributed to reduced host availability and declining temperatures, factors known to influence tephritid survival and activity (Fletcher, 1987) [20]. Such phenological synchronization reinforces the importance of early-season monitoring and timely intervention, as management actions targeting the pre-peak or peak activity window are likely to be most effective.

Morphological and morphometric characterization provided additional clarity in species delineation, confirming the reliability of diagnostic characters in distinguishing closely related taxa. Distinct differences were noted in head pigmentation, thoracic vittae, wing venation, abdominal tergite patterning, and presence of pecten, which aligned with standard diagnostic keys (White & Elson-Harris, 1992; David & Ramani, 2011) [42, 11]. For example, the characteristic black costal band in *B. dorsalis*, apical fuscous spot in *B. zonata*, and infuscated vein markings in *B. correcta* were highly consistent and reliable for field-level identification. Similarly, abdominal T-patterns and surstylus morphology provided robust confirmation of species identity. Such characters are critical in contexts where species coexist sympatrically and misidentification may compromise management decisions.

The morphometric analyses further reinforced these diagnostic distinctions. *B. dorsalis* consistently exhibited the largest body size, longest wings, and broader abdominal dimensions, followed by *B. zonata* and *B. correcta*. These findings are in agreement with previous morphometric studies (Agarwal & Mishra, 2010; Kumar *et al.*, 2023) [5, 24], which reported interspecific differences in body size and appendage dimensions as reliable descriptors for tephritid systematics. Larger body size in *B. dorsalis* may confer ecological advantages such as higher dispersal potential, increased fecundity, and competitive dominance, which could explain its prevalence in citrus ecosystems. In contrast, the relatively smaller size of *B. correcta* may contribute to its lower abundance and ecological competitiveness.

An important implication of this study lies in its contribution to improving fruit fly management strategies. Accurate identification is the foundation of integrated pest management (IPM), as species-specific responses to lures, host preference, and ecological adaptability vary widely within the genus *Bactrocera*. The documented phenological window of peak activity offers a practical guideline for growers to deploy male annihilation traps and implement sanitation measures in synchrony with fruit fly population build-up. Moreover, morphometric data provide baseline references for distinguishing cryptic species or potential new invasions, which remain a challenge in tephritid taxonomy (Drew & Hancock, 1994; Dujardin, 2008) [13, 16].

In conclusion, the study underscores the ecological dominance of *B. dorsalis* in Nagpur mandarin orchards, identifies a clear phenological peak that can guide surveillance and management, and validates the diagnostic reliability of morphological and morphometric traits in species identification. Integrating these findings into IPM frameworks will enhance the precision of fruit fly monitoring and contribute to reducing crop losses in citrus ecosystems. Long-term, multi-location monitoring combined with integrative taxonomy is recommended to build on these results and develop regionally tailored management strategies.

**Table1:** Species composition of fruit flies trapped in methyl eugenol lure baited traps from CCRI Mandarin research blocks

| MW | Date & Month | Species composition (Total number and percent) of fruit flies emerged. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | *B. zonata* | | *B. dorsalis* | | *B. correcta* | | Total |
| | | No. | Percentage | No. | Percentage | No. | Percentage | |
| 39 | 24-30 Sep. 24 | 59 | (13.02%) | 65 | (10.17%) | 11 | (9.91%) | 135 |
| 40 | 01-07 Oct. 24 | 37 | (8.17%) | 52 | (8.14%) | 4 | (3.60%) | 93 |
| 41 | 08-14 Oct. 24 | 79 | (17.44%) | 100 | (15.65%) | 26 | (23.42%) | 205 |
| 42 | 15-21 Oct. 24 | 55 | (12.14%) | 50 | (7.83%) | 8 | (7.21%) | 113 |
| 43 | 22-28 Oct. 24 | 39 | (8.61%) | 70 | (10.96%) | 11 | (9.91%) | 120 |
| 44 | 29 Oct.-04 Nov. 24 | 28 | (6.18%) | 33 | (5.16%) | 5 | (4.50%) | 66 |
| 45 | 05-11 Nov. 24 | 12 | (2.65%) | 43 | (6.73%) | 7 | (6.31%) | 62 |
| 46 | 12-18 Nov. 24 | 31 | (6.85%) | 17 | (2.66%) | 6 | (5.41%) | 54 |
| 47 | 19-25 Nov. 24 | 25 | (5.52%) | 72 | (11.27%) | 12 | (10.81%) | 109 |
| 48 | 26 Nov.-02 Dec. 24 | 25 | (5.52%) | 37 | (5.79%) | 8 | (7.21%) | 70 |
| 49 | 03-09 Dec. 24 | 14 | (3.09%) | 31 | (4.85%) | 9 | (8.11%) | 54 |
| 50 | 10-16 Dec. 24 | 32 | (7.06%) | 22 | (3.44%) | 3 | (2.70%) | 57 |
| 51 | 17-23 Dec. 24 | 12 | (2.65%) | 28 | (4.38%) | - | | 40 |
| 52 | 24-31 Dec. 24 | 5 | (1.10%) | 19 | (2.97%) | 1 | (0.90%) | 25 |
| | Total | 453 | (37.65%) | 639 | (53.12%) | 111 | (9.23%) | 1203 |

**Table 2:** Comparative morphometrics of fruit fly species based on body part measurements (mm)

| SI. No. | Morphometric Characters | | Measurement of different fruit fly species (mm) Mean ± SD | | |
|---|---|---|---|---|---|
| | | | ***B. dorsalis*** | ***B. zonata*** | ***B. correcta*** |
| 1. | Body | Length | 6.53±0.48 | 5.39±0.57 | 4.80±0.24 |
| | | Width (With wing expansion) | 12.61±0.63 | 11.37±1.30 | 10.59±0.72 |
| 2. | Wing | Length | 6.28±0.41 | 5.66±0.27 | 4.58±0.72 |
| | | Width | 2.69±0.51 | 2.44±0.37 | 2.00±0.66 |
| 3. | Thorax | Length | 2.55±0.09 | 2.72±0.13 | 2.58±0.07 |
| | | Width | 2.40±0.04 | 2.11±0.03 | 1.81±0.03 |
| 4. | Vittae | Lateral | 1.34±0.34 | 1.63±0.57 | 1.28±0.25 |
| 5. | Abdomen | Length | 2.61±0.33 | 2.24±0.17 | 2.11±0.08 |
| | | Width | 2.66±0.08 | 2.62±0.04 | 2.13±0.05 |
| 6. | Head | Length | 1.14±0.05 | 1.05±0.08 | 0.89±0.15 |
| | | Width | 2.13±0.08 | 2.07±0.05 | 2.06±0.05 |
| 7. | Antennae | | 0.89±0.06 | 0.77±0.04 | 0.74±0.04 |
| 8. | Eye ball | diameter | 1.19±0.15 | 0.95±0.27 | 1.02±0.16 |
| 9. | Leg | | | | |
| i. | Femur | Fore leg | 1.54±0.05 | 1.50±0.06 | 0.86±0.0 |
| | | Mid leg | 1.93±0.05 | 1.83±0.06 | 1.37±0.02 |
| | | Hind leg | 1.94±0.05 | 1.94±0.04 | 1.44±0.05 |
| ii. | Tibia | Fore leg | 0.74±0.05 | 0.73±0.03 | 0.72±0.03 |
| | | Mid leg | 0.90±0.02 | 0.89±003 | 0.88±0.01 |
| | | Hind leg | 1.05±0.17 | 0.97±0.04 | 0.95±0.05 |
| iii. | Trochanter | Fore leg and Tarsi | 0.79±0.05 | 0.77±0.02 | 0.75±0.02 |
| | | Mid leg | 0.79±0.03 | 0.79±0.02 | 0.78±0.02 |
| | | Hind leg | 0.84±0.03 | 0.83±0.01 | 0.81±0.02 |

**Fig 1:** Head morphology 1: *Bactrocera Dorsalis;* 2: *Bactrocera zonata; 3: Bactrocera correcta*

**Fig 2:** Wing structure 1: *Bactroera dorsalis*; 2: *Bactrocera zonata*; 3: *Bactrocera correcta*

**Fig 3:** Thoracic morphology 1: *Bactrocera dorsalis*; 2: *Bactrocera zonata; 3: Bactrocera correcta*

**Fig 4:** Abdominal morphology 1: Bactrocera dorsalis; 2: *Bactrocera zonata;* 3: *Bactrocera correcta*

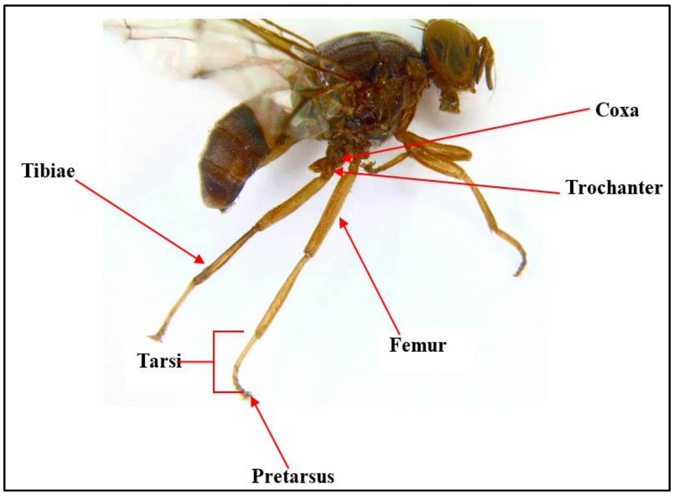


**Fig 5:** A comprehensive exploration of the diverse structural elements comprising the legs of fruit flies

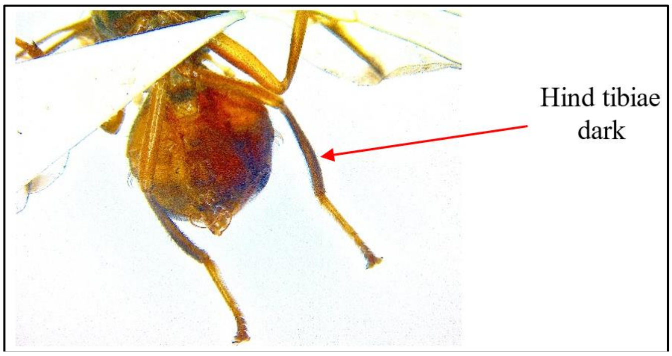


**Fig 6:** A detailed depiction of the typical black tibia on the hind legs of *Bactrocera dorsalis*, highlighting its unique structure and texture

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**Ethical approval**

This manuscript does not contain any studies with human or animal participants performed by any of the authors.

**Data availability statement**

The data supporting the conclusions of this study can be found within this manuscript and additional data can be made available upon reasonable request.

**Disclosure of potential conflicts of interest**

The authors declare there are no competing interests.

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