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Unravelling Fruit Fly Attraction to Tulsi (*Ocimum tenuiflorum* L.): Insights into Self-Perfuming in Insect Ecology

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Fruit flies are important insect pests of mango, particularly during fruit development and ripening. An interesting field observation in mango orchards is the aggregation of fruit flies around Tulsi (*Ocimum tenuiflorum* L.) plants growing along orchard bunds, while comparatively fewer flies may be observed on nearby mango fruits. This behaviour is associated with plant volatiles, particularly methyl eugenol, which acts as a strong attractant for male fruit flies such as *Bactrocera dorsalis*. The response is not simply related to the fragrance of the plant, but involves a specific chemical and olfactory interaction between the plant volatile and the insect. After feeding on methyl eugenol, male fruit flies metabolise the compound into related aromatic compounds that become associated with their reproductive chemical signalling. This phenomenon, commonly described as pharmacophagy or self-perfuming, provides an interesting example of plant–insect chemical ecology. The present article discusses the possible basis of fruit fly attraction to *O. tenuiflorum*, the role of methyl eugenol, and its potential application in integrated fruit fly management in mango and guava orchards.

Keywords: *Ocimum tenuiflorum*; methyl eugenol; *Bactrocera dorsalis*; self-perfuming; chemical ecology; fruit fly management.

Introduction

Fruit flies are among the important insect pests affecting mango production, particularly during fruit development and ripening. During field visits to mango orchards, an interesting observation can sometimes be noticed: Tulsi (*Ocimum tenuiflorum* L., synonym *O. sanctum*) growing along the orchard bund or field boundary may have several fruit flies around it, whereas nearby mango fruits may show comparatively less activity. This observation raises an important question: why do fruit flies gather around Tulsi plants? The response cannot be explained simply by the general fragrance of the plant. Tulsi contains several volatile compounds, and certain chemotypes are particularly rich in methyl eugenol, a compound known for its strong attraction to male fruit flies. Understanding this plant-insect interaction provides an interesting example of chemical ecology and also indicates a possible role for Tulsi as a low-cost component of fruit fly management.

The Chemistry Behind the Attraction

The attraction of fruit flies to Tulsi is mainly associated with **methyl eugenol**, rather than eugenol itself. Eugenol is an aromatic compound commonly associated with clove oil and is also present in Tulsi. However, methyl eugenol has a much stronger behavioural effect on several fruit fly species. Chemically, methyl eugenol differs from eugenol by methylation of the free hydroxyl group. Eugenol is 4-allyl-2-methoxyphenol, whereas methyl eugenol is 4-

allyl-1,2-dimethoxybenzene. Although this appears to be a small chemical difference, it has a major effect on the way the insect detects and responds to the compound.

The concentration of methyl eugenol is not uniform among all Tulsi plants. Different chemotypes can produce different quantities and proportions of essential-oil constituents. The DOS-1 elite germplasm developed at the CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), for example, has been reported to contain a high proportion of methyl eugenol in its essential oil. Saran *et al.* (2021) reported approximately 920 g kg^{-1} methyl eugenol in the essential oil under full-sun conditions, while eugenol was present at a much lower level of approximately 28 g kg^{-1}. Therefore, it should not be assumed that every Tulsi plant growing around a farm will have the same fruit fly-attracting ability Fig.1. The chemical composition depends on the genotype or chemotype and growing conditions. This distinction is important when considering Tulsi for deliberate use as a trap crop.

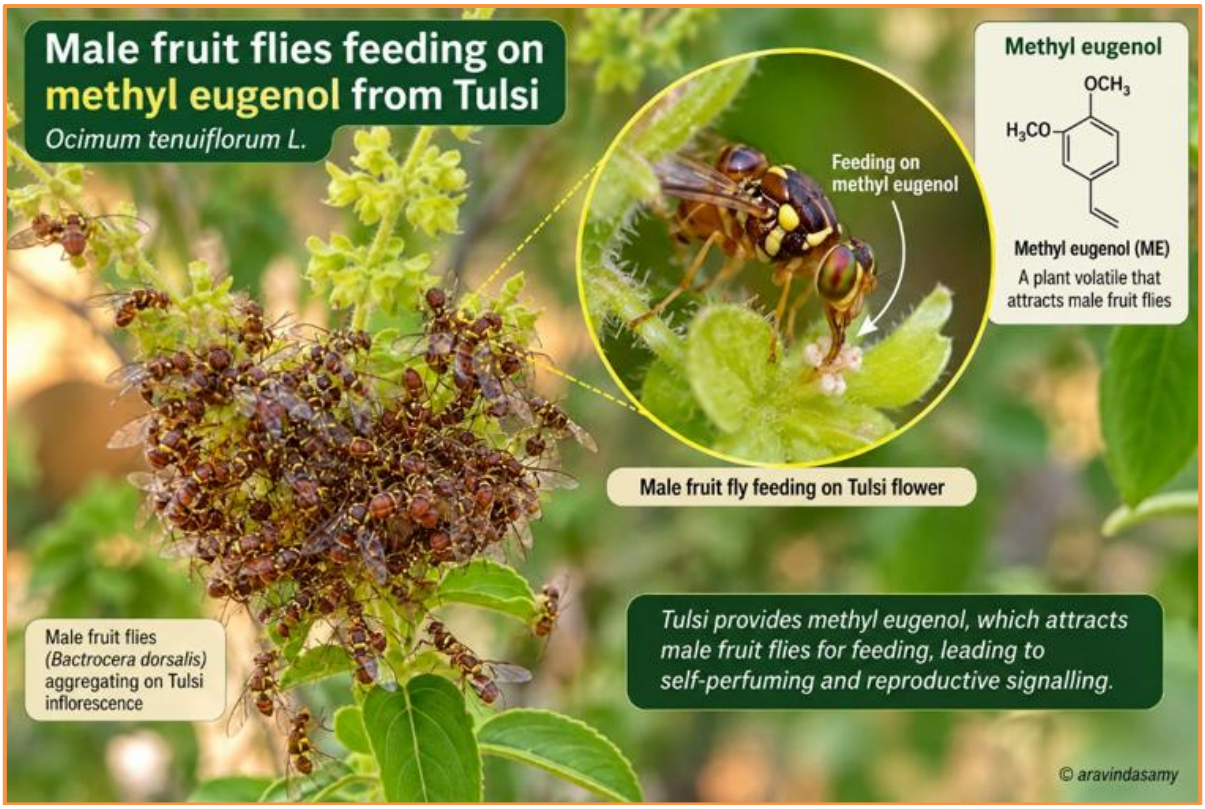

Figure 1: Tulsi–Fruit Fly Interaction: The Role of Methyl Eugenol in Male Attraction

Why the Response is Mainly in Male Fruit Flies

One of the important features of methyl eugenol attraction is its strong sex-specific response. Male oriental fruit flies, *Bactrocera dorsalis*, possess olfactory mechanisms that enable them to detect methyl eugenol efficiently. The receptor **BdorOR94b1** has been identified as an important methyl-eugenol-responsive olfactory receptor in male *B. dorsalis*. The receptor is associated with sensory neurons in the male antennae and plays an important role in the detection and behavioural response to methyl eugenol.

This explains why large numbers of male fruit flies may be observed around a methyl-eugenol source. The attraction is therefore not simply a response to a pleasant plant odour but is linked to a specific chemical signal detected through the insect's olfactory system. It is important to distinguish this male-specific attraction from the subsequent reproductive effect of methyl eugenol. Methyl eugenol should not be represented as a direct attractant for female fruit flies in the same manner as it is for males.

From Feeding to Self-Perfuming

The interaction between methyl eugenol and male fruit flies becomes more interesting after ingestion. When a male fruit fly feeds on methyl eugenol, the compound is metabolised within the insect into several related aromatic compounds, including **(E)-coniferyl alcohol**.

These metabolites accumulate in the male rectal gland and become associated with the chemical signalling involved in reproduction. Studies have shown that females can show a preference for males that have previously fed on methyl eugenol compared with males that have not.

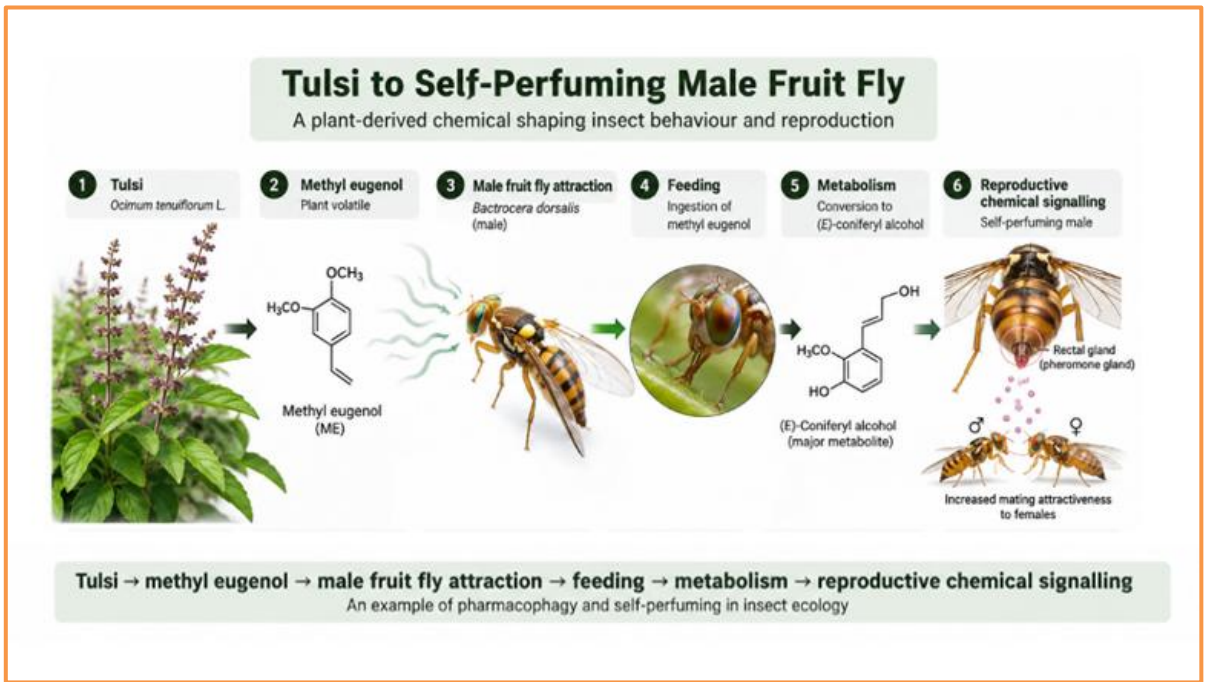

Figure 2: Mechanism of Methyl Eugenol-Mediated Attraction in Male Fruit Flies

This phenomenon is referred to as **pharmacophagy**, where an insect deliberately obtains a plant-derived chemical for a purpose other than basic nutrition. In this case, the plant chemical becomes part of the male's reproductive chemical signalling system. The term **self-perfuming** is therefore used for describing this process. The male fruit fly obtains a chemical precursor from the plant and subsequently converts it into compounds associated with its own mating-related chemical communication. Thus, the interaction can be understood as a sequence in Fig.2. This provides a fascinating example of how a plant-derived compound can influence both insect behaviour and reproduction.

Evidence for Tulsi as a Potential Trap Crop

The association between Tulsi and fruit flies is not a recent observation. Earlier work by Shah and Patel documented the role of Tulsi in relation to mango fruit fly, *Dacus correctus*. Subsequently, the identification and development of methyl-eugenol-rich Tulsi chemotypes provided a more systematic basis for exploring its use as a trap crop. Singh *et al.* (2020) evaluated different parts of basil/Tulsi, including leaves, stems, inflorescences and roots, and compared their attractiveness with synthetic methyl eugenol lures in mango and guava ecosystems. Among the plant parts tested, leaf extracts recorded the highest attraction among the plant-derived extracts. However, synthetic methyl eugenol traps recorded considerably higher catches under comparable conditions.

These observations indicate that Tulsi has potential as an economical source of methyl eugenol, but it should not be considered equivalent to purified synthetic methyl eugenol in terms of trapping efficiency. The practical importance of Tulsi therefore lies in its potential to supplement an integrated fruit fly management programme, particularly where locally available plant material and low-cost management options are important.

Chemistry at a Glance

Property	Eugenol	Methyl eugenol
Chemical structure	4-allyl-2-methoxyphenol	4-allyl-1,2-dimethoxybenzene

Property	Eugenol	Methyl eugenol
Major source	Clove oil; also present in *Ocimum* spp.	High in selected Tulsi chemotypes such as DOS-1
Behavioural response	Limited response compared with methyl eugenol	Strong attraction in male fruit flies
Olfactory significance	Does not produce the same strong response	Detected through methyl-eugenol-responsive olfactory mechanisms
Fate after ingestion	Not considered the major basis of self-perfuming	Metabolised into related compounds including (E)-coniferyl alcohol
Significance	General aromatic compound	Important chemical cue in fruit fly behaviour and trapping

Bringing the Concept to the Orchard

Based on the available evidence, Tulsi can be considered in two ways in orchard management: as a **border plant** and as a **source for plant-based attractant traps**.

Border planting

A verified methyl-eugenol-rich Tulsi chemotype, such as DOS-1, can be planted along the orchard boundary will provide source of methyl eugenol that can attract male fruit flies and concentrate them in locations where they can be monitored or trapped.

Tulsi extract-based traps

Plant-derived extracts can also be used as attractant sources in simple trapping systems. Earlier field studies have investigated Tulsi leaf extracts as an alternative source of methyl eugenol. A simple trap can consist of a plastic container with openings through which the attracted flies enter. The plant extract can be absorbed onto a sponge and placed inside the trap. The attractant source needs to be replaced periodically because volatile compounds gradually dissipate. Where an insecticidal killing agent is used, its use should follow the locally approved label, crop recommendations and applicable regulations. In organic production systems, a compatible non-chemical killing mechanism may be considered.

Tulsi in Integrated Fruit Fly Management

Tulsi-based trapping should not be considered a standalone solution for fruit fly management. Fruit fly control is more effective when several compatible practices are combined.

Important components include:

- ✓ fruit bagging
- ✓ regular collection and destruction of fallen and infested fruits;
- ✓ use of suitable methyl eugenol traps for monitoring and mass trapping;
- ✓ bait applications where recommended;
- ✓ maintenance of orchard sanitation;
- ✓ regular monitoring of fruit fly activity.

Since methyl eugenol primarily targets male fruit flies, trapping alone does not directly eliminate females that are already present in the orchard or larvae developing inside infested fruits. Therefore, Tulsi-based attraction should be incorporated into a broader integrated pest management programme.

Practical Considerations

The performance of Tulsi depends strongly on its chemical composition. The results obtained with a selected high-methyl-eugenol chemotype such as DOS-1 can be preferable for trapping male fruit flies. Plant-derived Tulsi extracts have generally shown lower trapping efficiency than synthetic methyl eugenol in comparative studies. Therefore, Tulsi should be considered as an economical supplementary option rather than a complete replacement for synthetic lures where high trapping efficiency is required. Field validation under local mango and guava production conditions is therefore necessary before recommending a standard protocol.

Scope for Mango Orchards in India

Mango-growing regions of India provide considerable scope for exploring locally available and low-cost approaches to fruit fly management. Tulsi is already commonly grown around homesteads and field boundaries, making it a readily accessible plant resource. The deliberate use of high-methyl-eugenol Tulsi planting material, combined with suitable trapping methods and orchard sanitation, may provide an additional component of fruit fly management. However, systematic field studies are required to identify suitable chemotypes, determine their methyl eugenol content, assess seasonal variation and establish the most effectiventrapping density under Indian mango-growing conditions. Such studies can help convert an interesting field observation into a scientifically validated management practice.

Conclusion

The aggregation of fruit flies around Tulsi (*Ocimum tenuiflorum* L.) illustrates an important plant–insect chemical interaction. Methyl eugenol present in certain Tulsi chemotypes acts as a major chemical cue for attracting male *Bactrocera dorsalis*. After feeding, methyl eugenol is metabolised into related compounds associated with male reproductive signalling, demonstrating the role of plant-derived chemicals in insect behaviour and reproduction.

From an agricultural perspective, Tulsi intended for fruit-fly management should preferably be planted along the orchard boundary or field bund, where attracted males can be monitored and trapped. Unintentionally growing Tulsi plants within the interior of the mango orchard should preferably be removed, particularly when no trapping arrangement is provided, to avoid attracting fruit flies close to the fruiting canopy. Tulsi-based attraction should be used as a component of integrated fruit-fly management along with orchard sanitation, monitoring, trapping and fruit bagging.

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