

**Efficacy of Hoary Basil (*Ocimum canum*) as a Trap Plant for Oriental Fruit Fly (*Bactrocera dorsalis*) in Mango Orchards Across Two Agro-Ecological Zones of The Gambia**

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**Abstract**

*Mango is The Gambia's most important export fruit, yet yields remain low partly due to heavy infestation by the Oriental fruit fly (*Bactrocera dorsalis*). This study evaluated the trapping efficiency of hoary basil (*Ocimum canum*) as a non-chemical attractant in mango orchards located within two agro-ecological zones (Sudan-Guinea and Sahel) during the 2018 and 2019 production seasons. A split-split plot design was used with four *O. canum* densities (0, 2, 4, and 8 plants per ten mango trees) as the main factor, trapping time (morning vs. afternoon) as the subplot factor, and four replications. Data were analyzed using ANOVA, with means separated by Duncan's Multiple Range Test at  $p = 0.05$ ; correlation and Student's *t*-tests were also applied to assess associations and zone differences. Results showed that the 8-plant density trapped significantly more *B. dorsalis* males (up to 20.6 flies per trap in the Sahelian zone, 2018) than all other treatments, with morning trapping consistently superior to afternoon. Fruit infestation declined from 9.7% in untreated plots to 4.1% at 8-plant density in 2018 and from 8.6% to 4.9% in 2019. Correlation analysis revealed a significant negative association between captures and infestation in 2018 ( $r = -0.59$ ,  $p < 0.05$ ), while zone comparisons showed Sudan-Guinea generally had higher catches, though infestation differences were not significant. The study concludes that planting 8 *O. canum* plants per 10 mango trees can substantially reduce fruit fly infestation and serve as an effective, low-cost, non-chemical management strategy for mango growers.*

**Keywords:** *Ocimum canum*, mango, trap cropping, *Bactrocera dorsalis*, agro-ecology

**Introduction**

Fruit flies (Diptera: Tephritidae) are among the most destructive pests of fruits and fruit-vegetables worldwide, causing both quantitative and qualitative losses. Female fruit flies oviposit beneath the skin of suitable fruits, and emerging larvae feed on the fruit pulp, resulting in premature fruit drop, internal decay, and total loss of marketability (Allwood *et al.*, 2001).

More than 4,000 species of Tephritidae have been described globally (White & Elson-Harris, 1992), with *Bactrocera*, *Ceratitis* and *Anastrepha* containing the most economically important species. The Oriental fruit fly, *Bactrocera dorsalis*, originally from South Asia, invaded Africa in the early 2000s and rapidly spread across the continent. First detected in Kenya in 2003, it became widespread in West Africa by 2004 (STDF, 2010). Mango is a major fruit crop in The Gambia and the wider West

African region (Vayssières *et al.*, 2009). Infestation by *B. dorsalis* and other native fruit fly species can cause up to 85% yield losses, depending on variety, locality, and season (STDF, 2010). Infested fruits destined for export may be intercepted or rejected, leading to substantial economic losses (Ekesi & Billah, 2006; Vayssières *et al.*, 2013). Chemical attractants and insecticides are effective but costly and often inaccessible to smallholder growers (Roberto *et al.*, 2014). Farmers therefore rely on labor-intensive methods such as fruit bagging and manual removal of infested fruits (ISFFEI, 2014). Environmentally friendly and affordable alternatives are therefore urgently needed.

Hoary basil (*Ocimum canum* Syn. *O. americanum*, family Lamiaceae) is an aromatic plant known for possessing insecticidal (David J. Weaver *et al.*, 1994) and antimicrobial properties (P. H. Zollo *et al.*, 1998; Kouadio R. Oussou *et al.*, 2004). Its essential oil contains methyl eugenol, a potent attractant for male *Bactrocera* species (Tonzibo *et al.*, 2008). Observations from fruit fly management training conducted in The Gambia in 2015 indicated that *O. canum* naturally attracts fruit flies in local orchards (National Agricultural Research Institute, 2015). Given these attributes, the present study was designed to determine the influence of *O. canum* plant density on the trapping efficiency of *Bactrocera dorsalis*, assess variations in trap performance across two distinct agro-ecological zones of The Gambia, and evaluate the fruit fly species composition associated with mango orchards as well as the corresponding levels of mango fruit infestation.

## **Materials and Methods**

### **Study sites.**

The experiment was conducted during the 2018 and 2019 mango production seasons within two major agro-ecological zones of The Gambia, namely the Sahelian and the Sudan–Guinean zones. Study sites were selected based on the availability of mango orchards at the onset of the study. The Sahelian zone is characterized by low and erratic annual rainfall of less than 600 mm, open savannah vegetation, and a relatively short growing season of approximately 79 days. Soils in this zone generally have low water-holding capacity, which limits agricultural productivity. In contrast, the Sudan–Guinean zone receives higher annual rainfall ranging from 900 to 1200 mm and has a longer growing season of approximately 120–150 days. This zone is characterized by moderately high humidity and temperatures ranging between 18°C and 36°C, creating favourable conditions for fruit and vegetable production.

Experimental orchards were located at Berending (13.2934°N, 16.2714°W) in the Sahelian zone and Pirang (13.1636°N, 16.3248°W) in the Sudan–Guinean zone. Both locations consisted of mature ‘Keitt’ mango orchards covering approximately 2.5 hectares, with an estimated 270–300 trees per orchard.

## **Propagation and establishment of *Ocimum canum***

### **Seed source and nursery setup**

Seeds were obtained from the Pest Management Programme (PMP) of NARI. Propagation occurred at NARI headquarters in Brikama (13°16'N, 16°38'W) during June–July of both seasons.

**Soil sterilization:** Topsoil was heat-treated by pouring boiling water through perforated metal containers holding the soil, repeated three times at 15-minute intervals, then left for 24 h before use.

### **Sowing and transplanting**

Seeds were broadcast into trays (48 × 35 × 6 cm) filled with sterilized soil. Watering occurred twice daily (25 mL per tray). After 7 days, seedlings were transplanted into 2-kg soil-filled polybags (7.5 × 15.3 × 15.3 cm). Four-week-old seedlings were transplanted into the field.

### **Experimental design and treatment application**

A split–split plot design within a randomized complete block structure was used for the experiment, with three replicates established in each agro-ecological zone. The main plot factor consisted of *Ocimum canum* density treatments, which included 0 plants (control), 2 plants, 4 plants, and 8 plants per ten mango trees. The subplot factor was the time of trapping, which was categorized into two periods: morning trapping conducted between 08:00 and 11:00 hours, and afternoon trapping conducted between 12:00 and 16:00 hours.

Each experimental plot measured 10 × 50 m and contained ten mango trees spaced at 10 × 10 m intervals. Treatment blocks were separated by a distance of 50 m in order to minimize interference between treatments. *Ocimum canum* seedlings were transplanted at a distance of 5 m from the mango trees with a spacing of 0.75 × 1 m between plants. Following transplanting, the seedlings were watered for two consecutive days to facilitate establishment, after which the plants were maintained under natural rainfall conditions for the remainder of the experimental period.

### **Data collection**

#### **Fruit fly trapping**

Fruit fly counts were visually recorded twice daily (morning and afternoon) for one week during peak fruiting. Sweep nets were used biweekly to collect flies, which were preserved and identified in the NARI Pest Management Laboratory using the keys of White & Elson-Harris (1992) and Ekesi & Billah (2007).

#### **Fruit infestation**

Five mature fruits per plot were harvested from randomly selected trees. Fruits were dissected, and infestation was scored according to Vayssières *et al.* (2009b);

$$\text{Infestation (\%)} = \frac{\text{Number of infested fruits}}{\text{Total harvested fruits}} \times 100$$

### Statistical analysis

Data were subjected to analysis of variance (ANOVA) using Genstat 9.2. Means were separated using Duncan's Multiple Range Test (DMRT) at  $p = 0.05$  to determine significant differences among *O. canum* densities and trapping times. Fruit fly count data were square root transformed before analysis to stabilize variance.

To assess relationships between fruit fly captures and fruit infestation, Pearson correlation analysis was performed. In addition, independent samples Student's t-tests were conducted to compare mean infestation levels between the Sudan Guinea and Sahelian agro-ecological zones.

## Results and Discussion

### Fruit fly species composition

Across both seasons and agro-ecological zones, only male *Bactrocera dorsalis* were trapped on *Ocimum canum*. The morphological characteristics of the captured flies corresponded with the diagnostic descriptions provided by Ekesi and Billah in their field identification guide for African fruit flies. The exclusive capture of male flies suggests that *O. canum* releases male-specific attractants.

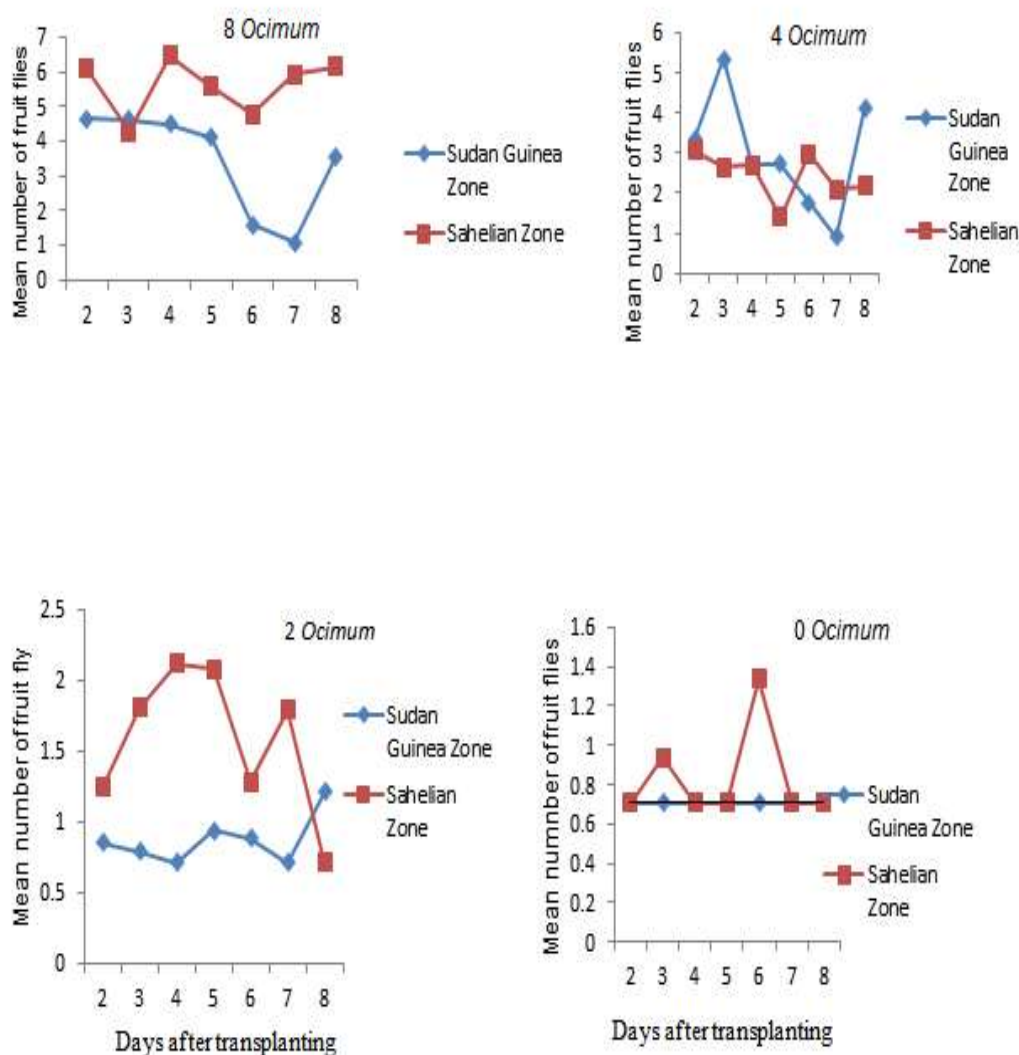
This observation is consistent with the known chemical ecology of *Bactrocera* species, which respond strongly to plant-derived compounds such as methyl eugenol. Subsequent studies conducted in Senegal and The Gambia confirmed that *O. canum* contains methyl eugenol and can serve as a natural source of this attractant for *B. dorsalis*. Methyl eugenol has long been recognised as a powerful lure for male fruit flies and plays a role in pheromone production and mating success (Howlett, 1915; Nishida et al., 1988; Tan & Nishida, 1996).

### Influence of *Ocimum canum* density and agro-ecology on fruit fly captures

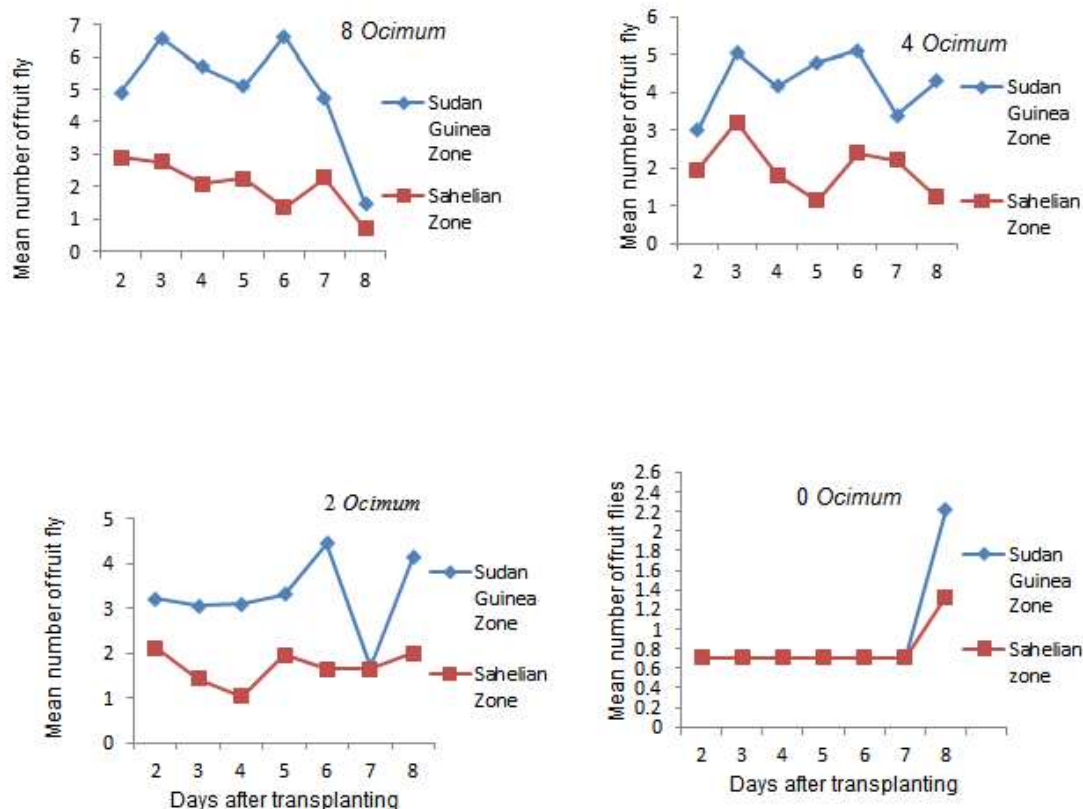
#### Population fluctuations

Figures 1 and 2 illustrate the variations in the population fluctuation of *B. dorsalis* trapped at different *O. canum* densities in the two agro-ecological zones of The Gambia during the study period. Across both agro-ecological zones and seasons, sixth-degree polynomial models best described the population trends observed during the mango fruiting period. Higher densities of *O. canum* (particularly 8 plants) consistently recorded greater numbers of flies compared to lower densities and the control (0 plants). The Sudan Guinea Zone generally exhibited higher trap catches than the Sahelian Zone, reflecting differences in fruit fly abundance between the two ecologies. The figures further highlight temporal fluctuations across days after transplanting, showing that fly populations increased progressively with time, peaking at higher *O. canum* densities before stabilizing. These fluctuations likely reflect periodic aggregation of male fruit flies responding to volatile attractants emitted by *O. canum* plants.

The attraction of male *Bactrocera* species to methyl eugenol-containing plants has been widely reported in tropical agro-ecosystems (Metcalf & Metcalf, 1992; Tan et al., 2014). Increasing densities of *O. canum* may therefore increase the release of volatile compounds, resulting in stronger attraction and higher trap captures.



**Figure 1.** Variations in the population fluctuation of *B. dorsalis* trapped at different *O. canum* densities in the two agro-ecological zones of The Gambia during the first season (2018).



**Figure 2.** Variations in the population fluctuation of *B. dorsalis* trapped at different *O. canum* densities in the two agro-ecological zones of The Gambia during the second season (2019).

### First season (2018)

The highest captures occurred at the 8-plant density, significantly greater than lower densities (Table. 1). Morning trapping consistently yielded more flies than afternoon trapping. The Sahelian zone recorded higher captures overall compared to Sudan Guinea, but the density effect was consistent across zones. Increasing *O. canum* density enhances attraction, and morning trapping maximizes efficiency. Similar density-dependent responses have been reported in fruit fly management programmes where higher concentrations of methyl eugenol result in increased attraction of male *Bactrocera* species (Metcalf & Metcalf, 1992; IAEA, 2003).

Table 1. Mean number of *B. dorsalis* captured at different trapping times and *O. canum* densities in two agro-ecological zones of The Gambia during the first season (2018). Means followed by the same letter within a column are not significantly different at  $p = 0.05$  (DMRT).

| Agro-ecological zone | <i>O. canum</i> density | Morning | Afternoon | Mean    |
|----------------------|-------------------------|---------|-----------|---------|
| Sudan Guinea         | 0                       | 0.71 c  | 2.18 b    | 1.44 c  |
|                      | 2                       | 2.21 c  | 2.35 b    | 2.24 c  |
|                      | 4                       | 11.08 b | 8.60 a    | 9.84 b  |
|                      | 8                       | 14.29 a | 8.52 a    | 11.40 a |
| Sahelian             | 0                       | 2.12 c  | 2.18 b    | 2.15 c  |
|                      | 2                       | 5.13 b  | 3.55 b    | 4.34 b  |
|                      | 4                       | 9.31 b  | 6.74 a    | 8.03 b  |
|                      | 8                       | 20.64 a | 12.28 a   | 16.46 a |

Fruit infestation levels were significantly lower in all *O. canum* treatments compared with control plots, and infestation declined progressively with increasing plant density. The **8-plant density** had the lowest infestation, significantly different from the control (Table 2). This reduction in fruit damage may be attributed to the removal of sexually mature males, which likely reduced mating success within the fruit fly population. This pattern aligns with the principle of male annihilation techniques (MAT) widely used in area-wide fruit fly control programmes, where suppression of male populations results in lower infestation levels even without directly targeting females (IAEA, 2003).

Table 2. Percentage mango fruit infestation by *B. dorsalis* in two agro-ecological zones of The Gambia during the first season (2018). Means followed by the same letter within a column are not significantly different at  $p = 0.05$  (DMRT).

| O. canum density | Sudan Guinea Zone | Sahelian Zone | Mean   |
|------------------|-------------------|---------------|--------|
| 0                | 10.02 a           | 9.42 a        | 9.72 a |
| 2                | 9.42 a            | 0.71 c        | 5.06 b |
| 4                | 7.59 b            | 6.17 b        | 6.88 b |
| 8                | 7.41 b            | 0.71 c        | 4.06 c |

### Second season (2019)

In the second season, *O. canum* density, agro-ecological zone, and trapping time all significantly affected *B. dorsalis* captures. The highest numbers of flies were again recorded at the 8-plant density treatment, particularly in the Sudan Guinea agro-ecological zone however, the density effect was evident in both zones (Table 3). Morning trapping remained significantly more effective than afternoon trapping. This observation supports earlier findings that *B. dorsalis* shows peak responsiveness to methyl eugenol during early daytime periods (Karunaratne & Karunaratne, 2012).

**Table 3. Mean number of *B. dorsalis* captured at different trapping times and *O. canum* densities in two agro-ecological zones of The Gambia during the second season (2019). Means followed by the same letter within a column are not significantly different at  $p = 0.05$  (DMRT).**

| Agro-ecological zone | <i>O. canum</i> density | Morning | Afternoon | Mean    |
|----------------------|-------------------------|---------|-----------|---------|
| Sudan Guinea         | 0                       | 2.49 c  | 1.94 c    | 2.22 c  |
|                      | 2                       | 10.09 b | 8.43 b    | 9.26 b  |
|                      | 4                       | 12.41 b | 11.03 b   | 11.72 b |
|                      | 8                       | 15.45 a | 12.77 a   | 14.11 a |
| Sahelian             | 0                       | 1.27 c  | 1.38 c    | 1.33 c  |
|                      | 2                       | 5.46 b  | 3.97 b    | 4.71 b  |
|                      | 4                       | 6.69 b  | 4.65 b    | 5.67 b  |
|                      | 8                       | 7.16 b  | 5.12 b    | 6.14 b  |

Fruit infestation in the second season followed a pattern similar to that observed in the first season (Table 4). The lowest infestation levels were recorded in the 8-plant density treatment, confirming the effectiveness of *O. canum* in reducing fruit damage in both seasons.

**Table 4. Percentage mango fruit infestation by *B. dorsalis* in two agro-ecological zones of The Gambia during the second season (2019). Means followed by the same letter within a column are not significantly different at  $p = 0.05$  (DMRT).**

| <i>O. canum</i> density | Sudan Guinea Zone | Sahelian Zone | Mean   |
|-------------------------|-------------------|---------------|--------|
| 0                       | 8.19 a            | 8.96 a        | 8.58 a |
| 2                       | 5.82 b            | 5.94 b        | 5.88 b |
| 4                       | 8.18 a            | 6.08 b        | 7.13 b |
| 8                       | 7.13 b            | 2.40 c        | 4.89 c |

Across both seasons, *O. canum* density significantly influenced fruit fly captures and mango fruit infestation. Higher densities, particularly 8 plants per 10 mango trees, consistently yielded the highest captures and the lowest infestation levels, with means separated by Duncan's Multiple Range Test at  $p = 0.05$ . Morning trapping was significantly more effective than afternoon trapping. Although the Sudan Guinea zone generally recorded higher infestation levels than the Sahelian zone, differences between zones were not statistically significant. These results demonstrate that increasing *O. canum* density enhances male annihilation effects, leading to reduced fruit damage in mango orchards.

#### **Correlation between captures and infestation**

Correlation analysis revealed a significant negative association between fruit fly captures and fruit infestation levels in 2018 ( $r = -0.59$ ,  $p < 0.05$ ), indicating that increased trapping of male flies was linked to reduced infestation. In the second season (2019), the relationship was a negative one ( $r = -0.08$ ,  $p > 0.05$ ) but not significant (Table 5).

**Table 5. Pearson correlation coefficients (r) between fruit fly captures and mango fruit infestation levels in two agro-ecological zones of The Gambia during the first (2018) and second (2019) seasons.**

| Season | Correlation (r) | Significance |
|--------|-----------------|--------------|
| 2018   | -0.59           | *            |
| 2019   | -0.08           | ns           |

- = Significant at 0.05; ns = Not significant at 0.05

#### Zone differences in infestation (Student's t-test)

Student's t-test analysis comparing infestation between zones showed that although Sudan Guinea consistently recorded higher mean infestation levels than the Sahelian zone, the differences were not statistically significant in either season (2018:  $t = 1.94$ ,  $p = 0.133$ ; 2019:  $t = 1.02$ ,  $p = 0.365$ ). This outcome is noteworthy because plant chemical composition is often influenced by location, which can affect bio-efficacy when tested across different agro-ecological zones (Pitan *et al.*, 2009). The findings therefore suggest that while ecological zone effects may contribute to variation in infestation levels, other seasonal or environmental factors likely moderated these differences, resulting in non-significant contrasts between zones.

**Table 6. Student's t-test comparing mean mango fruit infestation between Sudan Guinea and Sahelian zones during the first (2018) and second (2019) seasons.**

| Season | Sudan Guinea Mean (%) | Sahelian Mean (%) | t-value | p-value | Significance |
|--------|-----------------------|-------------------|---------|---------|--------------|
| 2018   | 8.61                  | 4.25              | 1.94    | 0.133   | ns           |
| 2019   | 7.33                  | 5.85              | 1.02    | 0.365   | ns           |

ns = Not significant at 0.05

### **Implications for fruit fly management**

The findings of this study demonstrate that *O. canum* can function as an effective trap plant for managing *B. dorsalis* in mango orchards. The strong attraction of male flies observed across two agro-ecological zones highlights the potential of this plant as a sustainable pest management tool.

Although chemical analysis was not conducted in the present study, later investigations confirmed the presence of methyl eugenol in *O. canum* collected from Senegal and The Gambia (Tine *et al.*, 2024). This compound is well known for its role in attracting male *Bactrocera* species and enhancing pheromone production in fruit flies (Nishida *et al.*, 1990; Tan & Nishida, 1996).

The consistent reduction in fruit infestation observed at higher *O. canum* densities further supports the potential use of this plant as part of an integrated pest management (IPM) strategy for fruit fly control in West African mango production systems.

### **Conclusion and recommendations**

This study provides strong evidence that *O. canum* can be deployed as a trap plant to suppress *Bactrocera dorsalis* populations in mango orchards across diverse agro-ecological zones of The Gambia. An 8-plant density per 10 mango trees consistently yielded the highest trapping efficiency and significantly reduced fruit infestation, while morning trapping enhanced capture rates.

The implications extend beyond pest suppression: reduced infestation translates into improved fruit quality, higher yields, and greater marketability, thereby enhancing farmer livelihoods and food security. Environmentally, the use of *O. canum* offers a low-cost, pesticide-free alternative that reduces reliance on synthetic lures and chemical controls, aligning with climate-smart agriculture and biodiversity conservation goals.

The study recommends that integrating *O. canum* into orchard management enables smallholder farmers to adopt a sustainable, locally available, and ecologically sound strategy for fruit fly control. This approach enhances resilience against pest outbreaks, supports regional Integrated Pest Management (IPM) programmes, and contributes to the long-term productivity and sustainability of mango production systems in The Gambia and across West Africa.

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