Article

Comparative effectiveness of *Bactrocera* spp. trap spacing in chili and tomato fields

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Abstract

Bactrocera spp. are major insect pests causing economic losses in chili (*Capsicum annuum*) and tomato (*Solanum lycopersicum*) crops. This study evaluated the population dynamics of *Bactrocera* spp. and the effectiveness of fruit fly traps at different installation distances. The study was conducted from August 2024 to July 2025 at six cultivation fields in Batu City, East Java, Indonesia, consisting of three *C. annuum* and three *S. lycopersicum* fields approximately 1.500 m^2 each. Trap-placement treatments included distances of 5, 10, and 20 m, and weekly catches of *B. dorsalis* and *B. carambolae* were analyzed using the Kruskal–Wallis test. The highest *B. dorsalis* population was recorded in *C. annuum* fields at C2 in September 2024 approximately 50 individuals per trap per month, whereas populations in *S. lycopersicum* fields were lower, with the highest abundance observed at T3 in October 2024 approximately 20 individuals per trap per month. The results of this study suggest that attractant traps are recommended primarily as a monitoring tool for detecting population fluctuations of *Bactrocera* spp., although they also show potential for reducing fruit fly populations in *C. annuum* and *S. lycopersicum* agroecosystems.

Keywords: *Capsicum annuum*; *Solanum lycopersicum*; methyl eugenol; fruit fly monitoring

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1. Introduction

Bactrocera spp. are among the major pests of chili peppers (*Capsicum annuum* L.) and tomatoes (*Solanum lycopersicum* L.), as the eggs are laid inside the fruit and develop into larvae. These larvae feed on the fruit, causing tissue damage, rot, and a decline in harvest quality, which can result in significant economic losses as infested fruit is unfit for market. *B. dorsalis* and *B. carambolae* are species with high adaptability to various host plants and can proliferate rapidly under favorable environmental conditions (Sahetapy et al., 2023). Pheromone traps have long been used to control fruit flies. However, there is little information on the ideal spacing between traps in chili and tomato farming ecosystems in tropical highlands. The different plant characteristics, vegetation density, and microclimatic conditions between these two crops influence the dispersion of attractants and the effectiveness of fruit fly control. To date, no specific studies have examined the effectiveness of trap placement distances in chili and tomato cultivation systems in Batu City. Therefore, this research is important to support better pest control approaches tailored to the local environment.

Trap-based fruit fly management is an environmentally friendly approach for reducing *Bactrocera* spp. populations (Fais et al., 2025). The use of methyl eugenol as a fruit fly attractant can serve as an alternative to chemical pesticides (Pangaribuan et al., 2025). The principle underlying this technique is to attract fruit flies into the traps. Continuous trapping reduces the number of male fruit flies in the wild, thereby decreasing the likelihood of mating and producing new offspring (Bhav Kumar Sinha et al., 2018). Environmentally friendly control methods must be effective and easily accessible to farmers for field application (Mulyadi et al., 2021). The effectiveness of fruit fly traps is influenced by several factors, including the distance between traps (Howarth & Howarth, 2000). However, information regarding the optimal spacing of methyl eugenol traps in conventional chili and tomato agroecosystems in tropical highland regions remains limited. Previous studies have generally focused on the attractiveness of lures or trap types under specific environmental conditions, whereas long-term evaluations of population fluctuations of *B. dorsalis* and *B. carambolae* across various trap spacing configurations remain scarce, particularly in Batu City, East Java, Indonesia, which is one of the major centers for chili and tomato cultivation. Therefore, this study was conducted to evaluate the effectiveness of various trap placement distances and to examine population fluctuations of *Bactrocera* spp. in conventional chili and tomato cultivation systems in Batu City, East Java, Indonesia.

2. Materials and Methods

2.1. Study area

The study was conducted from August 2024 to July 2025 in three conventional chili fields (C1, C2, and C3) and three conventional tomato fields (T1, T2, and T3) located in Batu City, East Java, Indonesia. Each study site covered approximately 1,500 m².

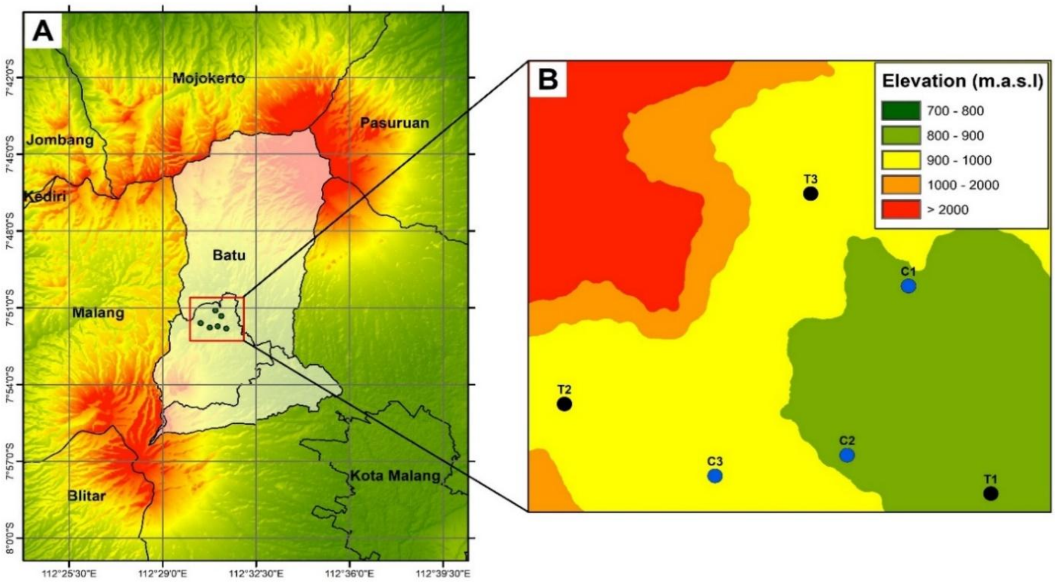

Figure 1. Sampling location: (A) Map of the study site in Batu City, East Java, Indonesia; (B) Close-up photographs of six farm sites, consisting of three tomato (*Solanum lycopersicum*) fields (T1–T3) and three chili (*Capsicum annuum*) fields (C1–C3).

2.2. Equipment and materials

The equipment used included fruit fly traps, 1500-ml trap bottles, wire, hot glue, an injector, sponges, tie-down straps, 3-meter trap support poles, and writing utensils. The material used was a fruit fly attractant, specifically methyl eugenol.

2.3. Observation plan

The experiment consisted of three trap placement distances: 5 m, 10 m, and 20 m from the edge of the cultivation field. One trap was installed at each specified distance at every study site. Each cultivation plot measured approximately 1,500 m^2. The study was conducted in three conventional chili cultivation fields (C1, C2, and C3) and three conventional tomato cultivation fields (T1, T2, and T3), resulting in three replications for each crop type. Trap placements were arranged systematically around the cultivation plots to maintain consistent distances from the field edge and minimize interference among attractants during the observation period.

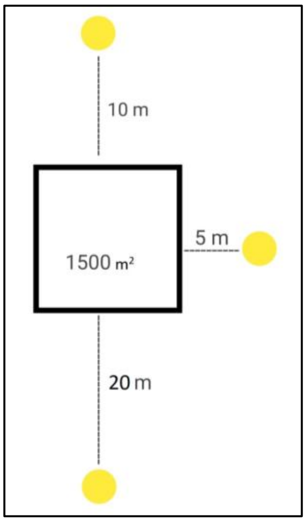

Figure 2. Trap locations on chili (*Capsicum annuum*) fields and tomato (*Solanum lycopersicum*) fields.

2.4. Data analysis

Population trends during the observation period were analyzed descriptively. Data on fruit fly catches were analyzed using the nonparametric Kruskal–Wallis test at a 5% significance level to determine the effect of three trap-placement distances (5 m, 10 m, and 20 m from the edge of the cultivation field) on the number of fruit fly catches. One trap was installed for each distance treatment at every study site.

3. Results

3.1. Population trends of Bactrocera spp. in C. annuum and S. Lycopersicum fields

Population fluctuations of *Bactrocera* spp. varied among locations and observation periods (Figure 3). In *C. annuum* fields, *B. dorsalis* consistently showed higher abundance than *B. carambolae*, with the highest populations recorded in September 2024 at C1 and C2, reaching approximately 45 and 50 individuals per trap per month, respectively, before declining in January 2025. In C3, populations were lower and more stable, peaking at approximately 25 individuals per trap per month during September to October 2024, while *B. carambolae* remained below 10 individuals per trap per month across all *C. annuum* fields. In *S. lycopersicum* fields, *Bactrocera* spp populations were generally lower. The highest *B. dorsalis* populations were recorded at T1 in September 2024, at approximately 12 individuals per trap per month, and at T3 in October 2024 and June 2025, at approximately 20 individuals per trap per month, whereas the lowest populations ranged from 0 to 5 individuals per trap per month during January to February 2025. Meanwhile, *B. carambolae* populations remained low across all tomato plots, averaging fewer than 10 individuals per trap per month.

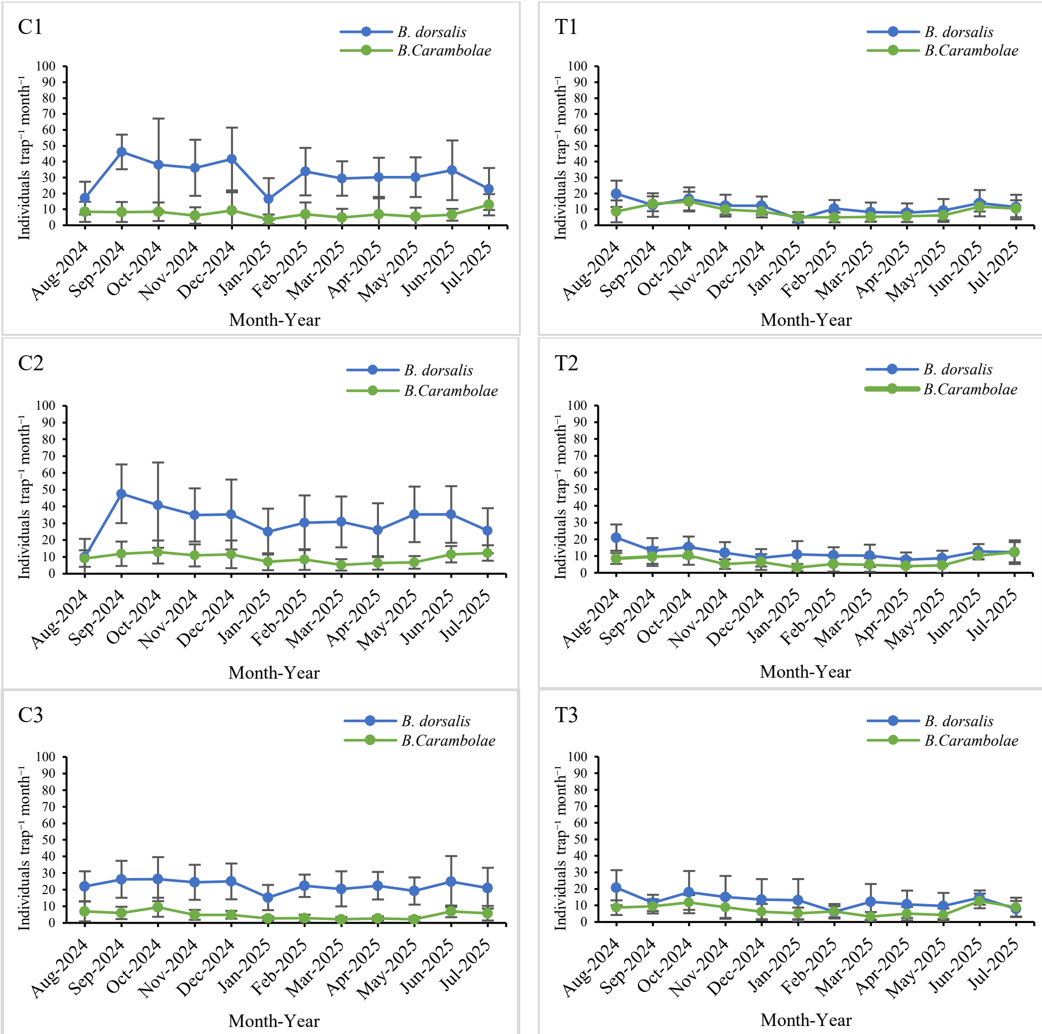

Figure 3. Monthly population fluctuations of *B. dorsalis* and *B. carambolae* in conventional *C. annuum* and *S. lycopersicum* cultivation fields in Batu City, East Java, Indonesia, from August 2024 to July 2025. C1–C3 represent *C. annuum* field, while T1–T3 represent *S. lycopersicum* field. Values are presented as the mean ± standard error (SE) per individual per month.

B. dorsalis consistently exhibited higher populations than *B. carambolae* at all study sites. *C. annum* plantations had higher populations of *Bactrocera* spp. than *S. lycopersicum* plantations. Population peaks generally occurred during the fruit ripening period. *Bactrocera* spp. populations declined during periods of reduced host fruit availability. The traps' success in continuously capturing fruit flies throughout the study indicates that they are effective for monitoring and have the potential to help reduce *Bactrocera* spp. populations in the field.

3.2. The effectiveness of traps based on variations in placement distance

The effectiveness of Bactrocera spp. traps was evaluated using three different trap placement distances: Tr1 (5 m), Tr2 (10 m), and Tr3 (20 m). The capture data were analyzed using the Kruskal–Wallis test. The results of the analysis showed that variations in trap placement distance did not have a significant effect on the number of fruit flies captured in either C. annuum or S. lycopersicum crops ($p > 0.05$). However, there were differences in the trends of the mean rank values among treatments (Table 1).

Table 2. Mean rank of fruit fly catch results at various trap placement distances.

Species	Fields	Mean rank on traps		
		Tr1 (5 m)	Tr2 (10 m)	Tr3 (20 m)
B. dorsalis	*C. annuum*	224,21	240,81	238,47
B. carambolae	*C. annuum*	241,61	228,57	233,31
B. dorsalis	*S. lycopersicum*	243,53	224,50	235,47
B. carambolae	*S. lycopersicum*	231,55	236,87	235,08

Tr = Trap.

In *C. annuum* fields, *B. dorsalis* showed the highest mean rank in the Tr2 (10 m) treatment at 240.81, followed by Tr3 (20 m) at 238.47 and Tr1 (5 m) at 224.21. Conversely, B. carambolae showed the highest mean rank value in the Tr1 (5 m) treatment at 241.61. In tomato fields, *B. dorsalis* showed the highest mean rank value in the Tr1 (5 m) treatment at 243.53, while *B. carambolae* showed the highest mean rank value in the Tr2 (10 m) treatment at 236.87. The results of the Kruskal–Wallis test indicated that variations in trap placement distance did not have a significant effect on the number of fruit fly captures in either *C. annuum* or *S. lycopersicum* fields ($p > 0.05$). The absence of significant differences between treatments indicates that all variations in trap placement distances may have remained within the effective range of the attractant on the study plot, which spans approximately 1,500 m^2. The attractant's scent is presumed to disperse evenly, allowing fruit flies to detect the traps across all treatments. Additionally, the high mobility of *Bactrocera* spp. allows them to easily reach all areas of the crop. *B. dorsalis* is known to have high adaptability and a wide range, making it more frequently captured compared to *B. carambolae*.

4. Discussion

4.1. Species composition and host preferences

The dominance of *B. dorsalis* and *B. carambolae* indicates that both species are well adapted to the agroecosystems of *C. annuum* and *S. lycopersicum* (Agustina et al., 2025). The higher abundance on *C. annuum* plants is thought to be related to host preference, as the characteristics of *C. annuum* fruit are more suitable for the oviposition activity of *Bactrocera* spp. The results of Syamsudin et al. (2022) indicate that higher carbohydrate content in *C. annuum* fruit positively correlates with oviposition activity of *Bactrocera* spp. females, who prefer fruits with higher carbohydrate abundance for egg-laying, making these fruits more susceptible to infestation. *Bactrocera* spp. consistently exhibit the highest population density on *C. annuum* plants, accounting for up to 98.18% of the fruit fly population in several studies (Muhlison et al., 2021; Susanto et al., 2017).

4.2. Behavioral response to attractants

The dominance of *B. dorsalis* observed in this study is thought to be related to its strong response to methyl eugenol and its ability to adapt to tropical agroecosystems. Methyl eugenol-based attractant traps are known to be effective in attracting male fruit flies of the genus *Bactrocera*, particularly *B. dorsalis*, thereby increasing the number of male flies captured and potentially contributing to population suppression. Wee & Hee (2018) reported that *B. dorsalis* exhibited the highest attraction response to methyl eugenol during the morning hours. Singh et al. (2013) also demonstrated that the continuous use of attractant traps can reduce fruit fly populations by more than 80% through the effective capture of male flies. Similar findings were reported by Shelly et al. (2020), who stated that attractant-based trapping systems contribute to the management of invasive *Bactrocera* spp. populations.

4.3. Implications for sustainable pest management

The use of attractant traps reduces the need for chemical insecticides, promotes sustainable agricultural practices, and protects beneficial insect populations (Saravanan et al., 2025). This approach aligns with the concept of integrated pest management (IPM) and supports sustainable agricultural practices by minimizing impacts on non-target organisms and the environment. Research results indicate that *B. dorsalis* is the dominant species on *C. annuum* and *S. lycopersicum* crops during the observation period. These findings are consistent with several previous studies reporting that *B. dorsalis* exhibits high adaptability to various horticultural crops, as well as high reproductive capacity and dispersal ability (Bernardo et al., 2025). It can complete several generations in a year, supporting rapid population growth (Traoré et al., 2024). The dominance of *B. dorsalis* is also thought to be related to its wide host range and its ability to exploit favorable environmental conditions (Qin et al., 2019). The higher population of *Bactrocera* spp. in *C. annuum* crops compared to *S. lycopersicum* indicates that *C. annuum* fields are preferred as hosts by *Bactrocera* spp. Egg-laying preference is influenced by fruit characteristics, particularly higher carbohydrate content, which attracts oviposition; however, according to Syamsudin et al. (2022), volatile compounds and nutrient content also play a significant role in feeding behavior, particularly in *B. dorsalis*.

Population fluctuations of *Bactrocera* spp. observed during the study, with population peaks occurring in September–November 2024 and May–June 2025, are likely related to the high availability of ripe fruit, which serves as a food source and oviposition site for fruit flies (Megha et al., 2023). Population peaks generally occur during the fruit ripening period when fruit is abundant and suitable for oviposition. Environmental factors such as temperature, humidity, and rainfall are also thought to influence the population dynamics of *Bactrocera* spp. through their effects on survival and reproduction rates (Majeed et al., 2024). The results of the Kruskal–Wallis test indicate that variations in trap-placement distance did not result in significant differences, as all trap treatments were able to continuously capture *Bactrocera* spp. throughout the study period. These findings suggest that the tested trap distances remained within the effective attraction range of methyl eugenol. Nevertheless, Shelly (2021) stated that trap spacing still plays an important role in determining capture probability and therefore requires careful consideration of trap density and placement based on the effective sampling range of the target species and the lure's attractiveness.

In a field experiment conducted by Tan et al. (2021), the attraction to the methyl eugenol source was significantly higher when the methyl eugenol was not enclosed within the trap, indicating that an open source at the trap opening allows for better dispersion of the volatile. The absence of significant differences between trap placement distances also indicates that *Bactrocera* spp. possess the mobility and foraging ability to detect the scent of methyl eugenol in traps across the entire cropland area. Trap placement can be adjusted to suit field conditions and ease of management without compromising trapping effectiveness (Bausin et al., 2024). The traps' consistent success in capturing *Bactrocera* spp. indicates that they can be used as a tool for population monitoring and support the implementation of integrated pest management, which is more environmentally friendly than the excessive use of chemical insecticides (Maula et al., 2022).

The lower population of *B. carambolae* compared to *B. dorsalis* indicates that this species is less dominant at the study site. However, the continuous presence of *B. carambolae* during the observation period suggests that this species remains a potential major pest if environmental conditions support its population growth (Kolopaking et al., 2023). Overall, this study demonstrates that traps are effective for population monitoring and can support integrated pest management strategies in *C. annuum* and *S. lycopersicum* fields. Future research should evaluate the effects of attractant type, trap density, environmental factors, and seasonal conditions on trap effectiveness and *Bactrocera* spp. population suppression under various agroecological conditions.

5. Conclusions

The study showed that *B. dorsalis* was the dominant species in *the agroecosystems of C. annuum and S. lycopersicum* in Batu City. Trap-placement distances of 5 m, 10 m, and 20 m did not significantly affect the number of *Bactrocera* spp. catches under the conditions of this study. These findings suggest that attractant traps can be applied flexibly within this distance range for *Bactrocera* spp. monitoring in conventional *C. annuum* and *S. lycopersicum* fields.

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