Research article

Effects of Trap Height on the Capture of *Bactrocera* spp. (Diptera: Tephritidae) in Mango Orchard of Tagum City, Davao del Norte, Philippines

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Abstract

Fruit flies are one of the major pests infesting varieties of economically important fruits worldwide. This pest represents one of the most damaging groups of polyphagous flies. One of the alternatives for the control of the fruit fly that attacks mangoes is the use of pheromone-baited traps. The effectiveness of the pheromone traps depends on several factors such as field conditions, trap location, and environmental conditions. Therefore, this study evaluated the effect of different trap heights (1, 2, 3, 4, 5, 6, and 7 feet above the ground) on fruit fly trapping with traps baited with methyl eugenol. The trap installed at 5 feet above the ground had the highest number ($p<0.05$) of captured fruit flies compared to other heights evaluated. These results imply that for the effective monitoring and management of fruit flies, pheromone baited traps must be placed 5 feet from the ground level. The results further revealed that weather parameters did not appear to have a significant correlation ($p<0.05$) with the average population count of the pest. Because of the importance and usefulness of the findings of this study, further research that integrates this technology with other pest management tactics against the tephritid flies infesting mango at farmers' level is recommended. Optimizing this technology may offer a cost-effective and practical pest management approach for small hold mango farmers.

Keywords

fruit fly;

mango;

methyl eugenol;

pheromone;

trap height

1. Introduction

Mango (*Mangifera indica* L.) is a fleshy fruit in the family Anacardiaceae. It is endemic in South Asia and has been spread throughout the world to become one of the most frequently cultivated tropical plants [1]. Mango trees usually grow between 10 and 33 feet tall, but they can exceed 100

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feet in height in some forest settings. Both animals and humans benefit from the mango's thick canopy, which provides shelter and shade [2]. In the Philippine context, mangoes rank third among the most important fruits both in terms of production and value after bananas and pineapples. Hence, the mango industry has been an essential role in the country's economy, providing a source of livelihood to about 2.5 million farmers in the country [3].

However, mango is known to be attacked by an insect pest called the oriental fruit fly, *Bactrocera* spp. (Diptera: Tephritidae), which is one of the most notorious insect pest species globally, damaging a wide range of fruits especially in mango throughout tropical and sub-tropical areas. This insect pest species can inflict a lot of damage to its host which results in the development of major control and eradication programs to counter the flies in different major agricultural areas of the world [4]. This pest is considered the most destructive insect pest, especially for high-valued fruits and vegetables [5]. Its infestation can result in significant trade value losses and a threat to quarantine security and the international fruit and vegetable trade [6]. Infestations of this fly could cause significant fruits and vegetables yield loss of between 90-100% depending upon the environmental conditions, host-seasonality, and pest population dynamics [7].

The detection and monitoring of fruit flies is critical and essential to the sustainability of the agricultural sector. This has led to the evolution and development of various trapping systems that have improved crop protection practices. Fruit fly monitoring systems require an area-wide approach that covers all possible areas such as endemic and invasive species, economic pressure, and human needs [8]. Pheromone traps using methyl eugenol (ME) have been gaining popularity nowadays because it is used as an essential tool in monitoring crop pest. These traps attract and capture male insects since they contain sex pheromone, and the traps therefore reduce the fertile egg production of female flies [9].

The use of methyl eugenol traps is the most viable and best alternative among the different fruit fly management strategies available [10]. Methyl eugenol is extensively employed in fruit fly pheromone traps. It can attract male fruit fly adults as far as 800 m from the source due to a combination of phagostimulatory and olfactory action [11]. Moreover, methyl eugenol baited traps have been reported as one of the most cost-effective and essential methods of determining fruit fly species' existence and population level [12, 13].

Regardless the type of pheromone trap, the placement of the trap at the correct height is critical for effective mango fruit fly mass trapping [12]. Trap height is helpful in reducing the number of flies. A recent study conducted by Naganna *et al*. [13] in mango orchards about the effects of trap placement on capturing of mango fruit fly revealed that traps installed at the height of 6 and 9 feet above the ground level significantly captured the highest number of fruit flies, while traps installed at the height of 1 m from ground level had a lower catch and fruit fly activity. However, in a study by Hasnain *et al*. [9] conducted at mango orchard in Pakistan, it was found that the height at which the most fruit flies were being captured was 5 feet above ground level.

The aforementioned differences and variations in previous research motivated the researchers to replicate those studies in the Philippine context. Hence, this experimental study was conducted to determine the height for the placement of handmade methyl eugenol-baited traps that would optimize their capacity to capture the largest number of male oriental fruit flies. Moreover, this study determined the relationship between the fruit fly population and the prevailing agrometeorological parameters in the mango orchard.

2. Materials and Methods

2.1 Location and duration of the study

This study was conducted in a mango orchard at Apokon, Tagum City, Davao del Norte, Philippines (7.43707 N, 125.82273 E) from November 2021 to January 2022, during the mango fruiting stage. The site was characterized by mango trees that were 17 years old with overlapping canopies between trees spaced at 10 m×10 m planting distances (Figure 1).

Figure 1. Mango orchard at Apokon, Tagum City, Davao del Norte

2.2 Experimental design and treatments

The research was conducted using a randomized complete block design (RCBD), with eight treatments replicated three times. The different treatments, including their descriptions, are shown in Table 1.

Table 1. The treatments of the study with their corresponding trap height placement

Treatment Code	Trap Height Placement
T1	Ground Level
T2	1 foot above the ground
T3	2 feet above the ground
T4	3 feet above the ground
T5	4 feet above the ground
T6	5 feet above the ground
T7	6 feet above the ground
T8	7 feet above the ground

2.3 Preparation and installation of trapping materials

A 1 L of transparent plastic bottle was used as a trap for this study (Figure 2a). Each bottle had four window-type holes measuring 1 cm in diameter in the upper one-third portion that served as the entry point for fruit flies. A cotton ball was impregnated with 0.5 mL methyl eugenol (Figure 2b), placed inside the bottle trap, and hung about 15 cm below the lid of the bottle. The bottle trap was provided with 100 mL of ethyl alcohol in order to kill and suspend the insects for counting. Each trap was charged with methyl eugenol weekly, and the ethyl alcohol was also replenished weekly. Each trap was hung on different heights (ground level, 1, 2, 3, 4, 5, 6, and 7 feet above the ground) as indicated in the treatments, and a distance of 20 m was maintained between traps [14] throughout the study period (Figure 2c). Data on the attracted and trapped male oriental fruit flies were collected on a weekly basis (Figure 2d). The trapped male oriental fruit flies were identified on the basis of morphological characteristics according to the available keys [15]. Counting of the fruit flies was done in the Entomology laboratory of the University of Southeastern Philippines Tagum-Mabini Campus, Mabini, Davao de Oro, Philippines (Figure 3).

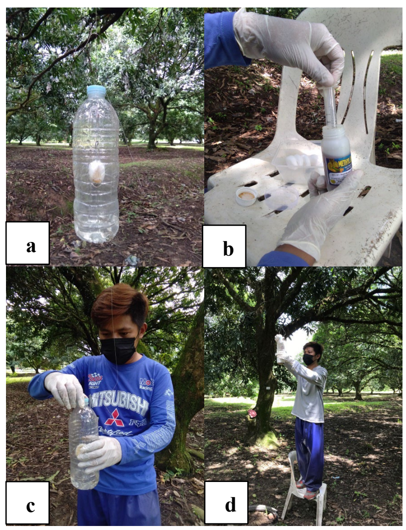

Figure 2. Preparation of trapping materials. (a) traps used during the experiment (b) preparation of cotton ball impregnated with 0.5 ml of methyl eugenol (c) installation of traps (d) collection of trapped fruit flies.

Figure 3. Counting of trapped male fruit flies in the laboratory

2.4 Data gathered

The population of male oriental fruit flies was determined by counting the total number of trapped insects from each treatment on a weekly interval for up to eight weeks after trap installation. Meanwhile, agrometeorological data such as temperature, relative humidity, rainfall, and windspeed were collected to determine the relationship of these factors to the population catch of fruit flies during the study period. These data were taken from the PAGASA Agrometeorological station of the University of Southeastern Philippines (USeP) Tagum Campus from November 2021 to January 2022.

2.5 Data analysis

Data on the number of fruit flies trapped on a weekly basis was analyzed using the analysis of variance (ANOVA) with a 0.05 level of significance. Using Tukey's Honest Significance Different Test, mean differences were separated with a 95% confidence level whenever ANOVA revealed a significant result. The population of fruit flies was subjected to Pearson's correlation analysis with the agrometeorological data such as temperature, rainfall, relative humidity, and wind speed observed during the study to determine the relationship between weather conditions and the average population of the fruit flies. Data analyses were performed using the Statistical Tool for Agricultural Research (STAR) software [16].

3. Results and Discussion

3.1 Effects of trap height on the population catch of oriental fruit fly

A summary of the mean numbers of trapped fruit flies within eight weeks of the collection as influenced by different trap height at the mango orchard of Apokon, Tagum City, Davao del Norte is presented in Table 2. The results revealed that there were no significant differences among weekly mean captures of fruit flies during the duration of the experiment (F=0.59; df=7; p=0.76). This indicates that date of collection does not appear to affect the population of captured fruits flies in mango.

Similarly, no significant differences were observed during the first week up to the fourth week of the collection period. The mean population count of male fruit flies ranged from 127.33 to 337.67 during the first week (F=0.11; df=7; p=0.19) and 144.67 to 256.67 fruit flies during the second week of collection (F=0.09; df=7; p=0.27). The fruit fly population remained consistent during the third week of collection (F=0.15; df=7; p=0.35) with population count ranged from 126 to 212, while the population count during the fourth week ranged from 129.00 to 233.33 fruit flies (F=0.98; df=7; p=0.09).

The results of statistical analysis during the fifth week of collection period revealed significant differences (F=17.53; df=7; p=0.016) among treatments (Table 2). Traps placed at 5 feet above the ground obtained the greatest density of trapped fruit flies which was statistically comparable with the populations trapped at 4 and 3 feet above the ground; the population means were 251.00, 245.33 and 228.00 fruit flies, respectively. Meanwhile, the lowest catch of fruit flies was observed in traps placed at 1 foot above the ground with a population count of 124.67, and this was comparable with traps hung at ground level with a population count of 133.67 fruit flies.

During the sixth week of collection, statistical analysis revealed significant differences among treatments (F=56.19; df=7; p=0.02). Traps placed at 5 feet above the ground consistently captured the highest density of fruit flies among the treatments with a population count of 272.33

fruit flies, which was statistically on par with traps hung at 3 feet above the ground, which had a population count of 237.33 fruit flies. The lowest number of trapped fruit flies was observed in traps placed at ground level with a population count of 116.0 fruit flies.

On the seventh week of collection, traps hung at 5 feet above the ground continuously obtained the greatest density of trapped fruit flies ($F=25.23$; $df=7$; $p<0.01$) with a mean number of 309.00, and this was significantly comparable with traps placed at 4, 3, and 6 feet above the ground with population means of 271.00, 239.33, and 237.33 fruit flies respectively.

Finally, on the eighth week of collection, traps hung at 4 feet above the ground caught the greatest density of fruit flies ($F=70.52$; $df=7$; $p=0.02$), which was statistically comparable with traps placed at 5 and 6 feet above the ground, for which the population counts were 296.00, 279.33, and 256.00 fruit flies, respectively. Meanwhile, the lowest catch of fruit flies was observed in traps placed at ground level with a population count of 114.67 which was comparable with traps hung at 1 and 2 feet above the ground with population counts of 142.67 and 130.33 fruit flies, respectively.

The mean numbers of fruit flies captured during the eight week experiment are presented in Figure 4. There were significant differences regarding the mean fruit fly capture of each trap height placement during the eight week experiment ($F=5.57$; $df=7$; $p<0.001$). The traps hung at 5 feet above the ground significantly captured the highest mean density of fruit flies, which was 248.96 captured individuals. This was followed by the traps hung at 3 feet and 6 feet above the ground, which captured 238.88 and 214.00 fruit flies, respectively. The traps hung at 4 feet above the ground recorded 191.15 fruit fly individual capture and showed comparable efficacy to traps hung at 5 feet above the ground.

The results of the present study strongly affirm the results of Hasnain *et al*. [9], who concluded that traps should be hung at a height of 5 feet above the ground to get the maximum catch of oriental fruit flies, and that traps placed at ground level obtained the minimum catch of the pests. Moreover, Marwat *et al*. [17] stated that pheromone traps hung at 5 feet above the ground trapped a higher number of fruit flies which was confirmed by the present results. The present study also supports with the study of El-Gendy [18], who revealed that the optimal trap height for hanging pheromone-baited traps in mango orchards was 5 feet above the ground.

An implication of the present result is that most of the male fruit flies are active at 3 to 6 feet from ground level since most of the higher catches (a total of more than 1,500 flies) were registered in these trap placements (Table 1). This is probably because most of the mating activity of fruit flies happens within the tree canopy, mostly on leaves, and branches. This explains why pheromone traps hung at 5 feet above the ground effectively captured the maximum number of fruit flies as indicated by the present result. Furthermore, it was reported previously that male fruit flies have a high tendency in forming aggregations in the middle portion of the host plant rather than on the lower part near the ground, or on the top most portions where the fruits can be found [19]. As a result, a higher population was caught by the traps hung at 5 feet above the ground.

However, the present result contradicted some previous findings. For instance, in a study conducted by Siddiqui *et al*. [20] in a guava orchard, it was shown that the significantly highest number of trapped fruit flies was captured in the traps placed 10 feet above the ground. Hooper and Drew [21] also found that the most effective trap height for trapping in the orchard was about 6.5 feet above the ground, and in the case of the rain forest, traps should be hung as high as 40 feet within the canopy to attract more flies.

These contradictory results are most probably due to the differences in the shapes and structures of the mango canopies of the present experiment. The more the canopies of the trees are closed, the greater the tendency for the fruit flies to aggregate on the middle parts of the tree because they are protected from direct sunlight exposure and winds. Whereas, when the tree canopies are open, the tendency is for most of the fruit flies to concentrate in the upper middle parts of the tree

Table 2. Number of trapped male oriental fruit fly, *Bactrocera* spp. in mango as an influence by different trap height in a mango orchard, Apokon, Tagum, Davao del Norte

Treatments	Weekly Average Population Catch of Oriental Fruit Fly								
	Week 1^{ns}	**Week 2^{ns}**	**Week 3^{ns}**	**Week 4^{ns}**	**Week 5****	**Week 6****	**Week 7****	**Week 8****	**Total Trapped**
ME baited traps placed at ground level (Control)	224.67	166.67	153.67	188.00	133.67^{d}	116.00^{c}	119.00^{d}	114.67^{c}	1216.35
ME baited traps placed at 1 ft above the ground	239.67	171.33	168.67	181.33	124.67^{d}	130.00^{bc}	140.67^{cd}	130.33^{bc}	1286.67
ME baited traps placed at 2 ft above the ground	193.67	188.67	162.33	170.00	193.00^{bc}	154.00^{bc}	192.33^{bcd}	142.67^{bc}	1396.67
ME baited traps placed at 3 ft above the ground	337.67	249.67	218.33	230.67	228.00^{ab}	237.33^{a}	239.33^{abc}	170.00^{b}	1911.00
ME baited traps placed at 4 ft above the ground	127.33	144.67	126.00	129.00	245.33^{ab}	190.67^{abc}	271.00^{ab}	296.00^{a}	1530.00
ME baited traps placed at 5 ft above the ground	258.33	208.33	203.33	210.00	251.00^{a}	272.33^{a}	309.00^{a}	279.33^{a}	1991.65
ME baited traps placed at 6 ft above the ground	217.67	256.67	177.00	207.33	160.33^{cd}	199.67^{ab}	237.33^{abc}	256.00^{a}	1712.00
ME baited traps placed at 7 ft above the ground	177.67	219.67	212.00	233.33	159.00^{cd}	156.67^{bc}	152.00^{cd}	185.67^{b}	1496.01
CV%	**22.65**	**21.60**	**11.10**	**21.60**	**9.95**	**7.65**	**18.98**	**5.48**	**-**

Mean values followed in a column with similar superscripts did not differ significantly at 0.05 after Tukey's HSD Test.

** Significant at 0.01% level of significance

ns- not significant

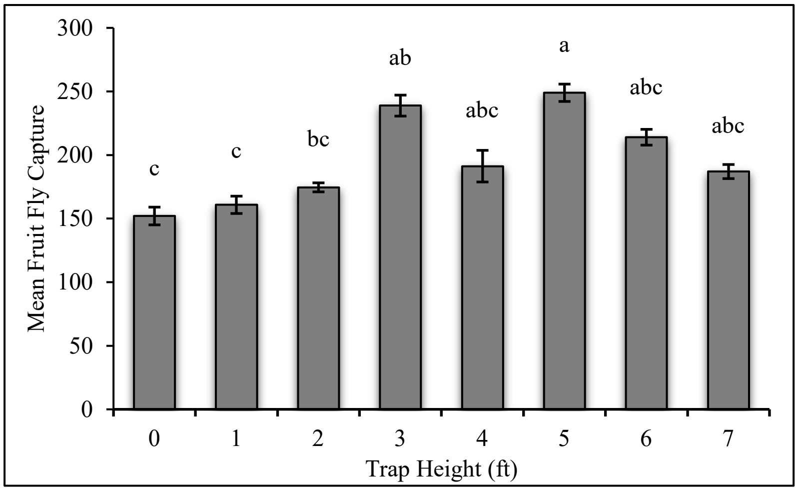

Figure 4. Average number of fruit fly capture per trap height from week 1 to week 8 of the experiment

meddling with foliage to prevent direct exposure to extreme winds and sunlight. As a consequence, higher placements of the traps are needed for an efficient trapping system. In the present study, the mango trees have overlapping canopies (can be seen in Figure 1) and therefore a higher number of the fruit flies were caught within 3 to 6 feet above the ground.

Plant canopies and sizes generally serve as crucial insect microenvironments, affecting insect behavior, distribution, and population growth [22]. Larger and denser canopies provide abundant shelter and suitable breeding sites, creating favorable conditions for fruit fly populations to thrive [23]. Moreover, dense canopies can impede sunlight penetration, leading to increased humidity and reduced temperature fluctuations, further promoting fruit fly survival and reproduction [24]. On the other hand, the size of the host plants also plays a significant role as larger plants typically support a greater abundance of fruit and provide more food resources for fruit fly larvae to develop and mature [25]. However, larger plant sizes can also make fruit detection and pest control more challenging, leading to the potential expansion of fruit fly infestations. Understanding factors such as plant canopy characteristics, plant sizes, and fruit fly population dynamics is vital for implementing effective pest management strategies in any agricultural setting [26].

3.2 Correlation of fruit fly population and weather parameters

The peak of the fruit fly population was observed during the first week of trapping with a pooled average population of 222.08 fruit flies and an average temperature of 25.95°C, which was also the highest temperature among other weeks of trapping (Figure 5). The highest relative humidity on the other hand was observed in the sixth week with an average of 95%, with a pooled mean population of 186.88 fruit flies, while the lowest relative humidity was observed during the third week with a pooled population count of 179.96 fruit flies. Meanwhile, the highest amount of rainfall was recorded during the eighth week of trapping, with an average rainfall of 14.4 mm and a pooled population count of 196.83 fruit flies while the lowest amount of rainfall was recorded during the seventh week, with an average of 0.8 mm recorded and a pooled average population of 207.58. Lastly, the highest wind speed was observed during the fifth week with an average wind speed of 3.60 km/h, and a pooled mean population of 193.71 fruit flies recorded.

Correlation tests with these data showed that no weather parameters significantly affected the population catch of fruit flies during the duration of the experiment (Table 3). It can be observed that temperature, relative humidity, and rainfall showed positive coefficients, while windspeed showed a negative coefficient. Numerically speaking, temperature was the most notable weather parameter that was closely related to the population dynamics of fruit flies during the eight-week trapping. Bagle and Prasad [27] reported that pheromone trapped fruit flies were highest in number when the temperature was high. Verghese *et al*. [28] revealed that wind speed and minimum temperature had a substantial positive relation with the population of fruit flies. Additionally, Sahoo *et al*. [29] concluded that abiotic parameters such as day temperature, night temperature, and heat sum had a substantial positive relation with the mango fruit fly population. The insignificant result of the present study is likely due to the overlapping canopies of the mango trees. It is speculated through this study that due to the closed canopies of the mango trees, weather parameters such as sunlight, rainfall, and windspeed probably cannot directly affect the population structure of the fruit flies within the orchard. In such conditions, weather parameters may not be suitable data for characterizing the fruit fly dynamics. Therefore, pheromone trapping must be carried out systematically to generate reliable data regarding the activity of fruit flies in the mango orchard.

The population of fruit flies in mango orchards is generally affected by temperature, relative humidity, and rainfall. These factors were all critical in regulating fruit fly development, dynamics, and reproduction [30]. However, in certain instances, the population dynamics of fruit flies in mango farms may not be responsive to temperature, relative humidity, and rainfall. Fruit fly populations can display resilience and adaptability to varying environmental conditions [31]. For instance, fruit fly species with wider temperature and humidity tolerances may remain relatively stable regardless of fluctuations in these factors [32]. Other factors, such as the availability of suitable host fruits, natural predators, and agricultural practices, can also affect fruit fly population dynamics [33]. Moreover, the interplay of some ecological interactions and random events can also contribute to fluctuations in population sizes, sometime masking the direct impact of specific weather variables [33]. Therefore, understanding the multifaceted dynamics governing fruit fly populations in mango farms requires a comprehensive approach considering both abiotic and biotic factors.

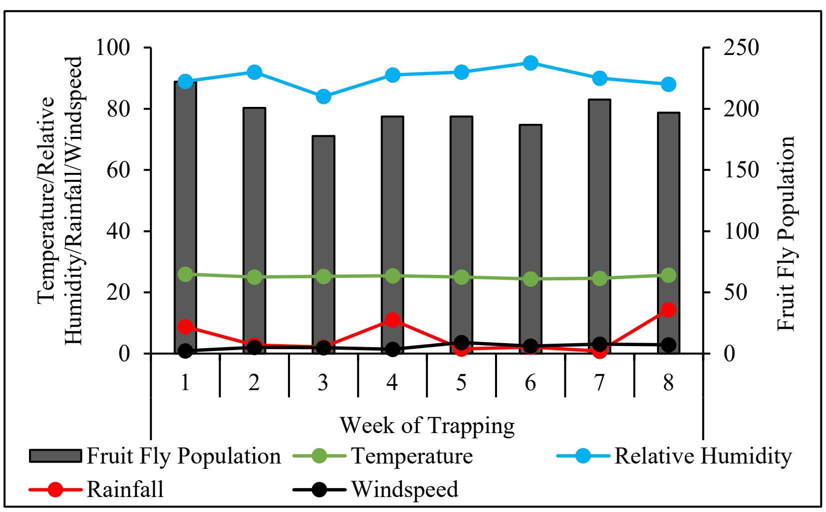

Figure 5. Average fruit fly population during the eight week trapping duration in relation to prevailing weather parameters

Table 3. Correlation coefficients of the weekly fruit fly capture and agrometeorological parameters

	Pearsons r Coefficient	Significance
Weekly Fruit Fly Capture	1.00	-
Temperature	0.41	0.31
Relative Humidity	0.12	0.77
Rainfall	0.24	0.57
Windspeed	-0.27	0.53

4. Conclusions

Based on the result of the study, a trap hung at 5 feet above the ground containing 0.5 ml methyl eugenol proved to be the most effective technique for trapping mango fruit flies, while the least effective treatment was a trap placed at ground level. The research also revealed that agrometeorological parameters barely affected the dynamics of the pests. The researchers recommend that further evaluation of these findings for other commodities that are hosts for the pestiferous fruit flies should be undertaken. It is also suggested that future research should involve an integration of this technology together with other cultural management tactics such as the use of various bagging materials in order to further reduce fruit damage brought about by fruit flies.

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