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Influence of Weather Parameters and Mango Fruiting Season on Adult Male Mango Infesting Fruit Fly Population Dynamics in Peradeniya, Sri Lanka

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ABSTRACT

Fruit flies (Diptera: Tephritidae) are globally recognized as major pests of fruits, causing both direct and indirect damage. Out of over 4000 species of fruit flies, approximately 350 are of significant economic concern. Monitoring pest populations is a key component of Integrated Pest Management (IPM). The dynamics of insect populations are closely influenced by weather conditions in both preceding and subsequent periods. This study aimed to assess the impact of specific weather variables on the fluctuation of adult male mango infesting fruit fly populations in various mango cultivation areas. The fluctuations in the adult male populations of mango fruit flies were monitored at three locations in Peradeniya University premises. Sampling took place twice a month over an eight-months period, using Methyl Eugenol traps, in line with agricultural guidelines recommending three traps per 0.0404 km² at each site. Data on temperature, relative humidity, rainfall, and wind speed were also collected. A total of 27,883 male fruit flies were caught, comprising Bactrocera dorsalis (64.71%), Bactrocera correcta (18.37%) and Bactrocera kandiensis (16.92%). The highest number of fruit flies were recorded at the Meewathura site (52.82%), which consists of a small forest patch near the Mahaweli River, providing a favorable environment for the growth of fruit flies with minimal human interference. The major peak in adult male fruit fly captures across all sites coincided with the mango fruiting season (from early February to late March). The populations showed significant positive correlations ($p<0.05$) with monthly maximum average temperatures at Meewathura ($r=0.501$) and Bowalawatta ($r=0.453$), as well as with monthly average rainfall at Hilda Obeysekara Hall ($r=0.289$) and Meewathura ($r=0.277$), indicating that these weather conditions are favorable to fruit fly growth. The use of sex pheromone traps to capture adult male fruit flies can reduce mating possibilities and contribute to population management. Furthermore, knowledge of the peak activity periods and seasonal population dynamics of the principal mango tephritid species is fundamental for developing effective and targeted pest control strategies.

KEYWORDS: *Bactrocera*, Fruit fly, Methyl Eugenol, Pest Management, Weather parameter

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1 INTRODUCTION

1.1 Fruit flies as major pests of crops

Fruit flies (Diptera: Tephritidae) are documented worldwide as the most injurious horticultural insect pests of fruits causing direct and indirect damages (Drew *et al*., 2005; Vayssieres *et al*., 2008; Ekesi *et al*., 2009). A wide range of fruits are potentially vulnerable and direct damage has been caused by fruit fly attacks. Fruit flies attack to many important fruit crops, including citrus (Rutaceae), mangoes (Anacardiaceae), apples (Rosaceae), peaches (Rosaceae), apricots (Rosaceae) as well as some vegetables (especially cucurbits), seed crops and also many wild plants. Indirect damage is associated with quarantine restrictions to prevent entry and establishment in the international market. The export of host fruit species of *Bactrocera invadens*, such as mangoes from Uganda, Tanzania and Kenya, are already banned by the Seychelles, Mauritius and South Africa (Kibira *et al.*, 2015).

Numerous fruit fly species pose significant threats to fruit and vegetable production worldwide, causing both quantitative and qualitative losses. There are nearly 4000 species of fruit flies in the family Tephtritidae of which around 350 species are of economic importance in the world (Plant Health Australia, 2016). The genus *Bactrocera* is extensively dispersed throughout tropical Asia, the south Pacific and Australia and comparatively few species exist in Africa, and only olive fly, *Bactrocera oleae*, occurs in Southern Europe (White and Elson-Harris, 1992). In Africa, the economically important species belong to the genera *Bactrocera, Ceratitis*, *Dacus* and *Trirhithrum* (De Meyer *et al*., 2014; Kibira *et al.*, 2015). The genera *Ceratitis*, *Dacus* and *Trirhithrum* are known to be indigenous to Africa and the *Bactrocera* are native to Asia (Kibira *et al.*, 2015). There are some fruit flies related studies done in Sri Lanka. Tsuruta *et al*. (1997) have published a list of host plants of Dacinae while Tsuruta *et al*. (1998) have provided a pictorial key to Sri Lankan fruit fly species. A recent study on the Sri Lankan Dacinae fauna records 28 species (Tsuruta and White, 2001).

Economic losses due to fruit flies go over two billion dollars worldwide (Zucchi *et al.*, 2004). In Brazilian fruticulture, losses related to these pests vary between 120 and 200 million dollars annually, due to the high cost of control (Felix *et al*., 2009) and phytosanitary barriers of importing countries (Paranhos *et al*., 2007). Consequently, fruit losses at the farm level in Pakistan cause an estimate of 200 million dollars annually with added losses to traders, retailers and exporters (Mustafa *et al.*, 2011).

Fruit flies have imposed considerable yield losses especially in mangoes in Uganda (Nankinga *et al.*, 2014). The fruit fly not only damages the fruit quality but also it causes premature dropping of infested fruits (Boopathi *et al.*, 2013). Without control measures, direct damage to mango trees in central Tanzania has been reported to range from 30% to 100%, depending on fruit maturity stage, variety, location, and season (Mwatawala *et al.*, 2006).

1.2 Mango cultivation and associated problems in Sri Lanka

Mango (*Mangifera indica* L.) is an evergreen tree, grown for its edible fruit which is thought to have evolved in the Northeast Indo- Burmese region (Peiris, 2016). Mango trees are a popular plant in many home gardens in Sri Lanka and the fruit has a high demand in local markets. Mangoes collected from home gardens make up the majority of the fruit supplied to the market, whereas commercial production remains more limited (Peiris, 2016).

Weed control and management, pests and diseases, postharvest losses and abiotic stresses like wild fires are some of the problems associated with mango cultivation in Sri Lanka. Among them, pest and diseases must be controlled effectively to ensure a good harvest of high-quality fruit. The major economically important pests that severely affect mango in Sri Lanka include mango leaf hoppers, fruit flies, and mango weevil (Peiris, 2016).

1.3 Importance of the Study

Fruit production, especially mango, provides vital nutrients for people's diets and nourishment while also serving as an important source of income in Sri Lanka. Therefore, maintaining high fruit quality is essential. Fruit flies pose a serious threat to a variety of agricultural crops due to their highly invasive nature and the fact that the majority of fruit fly species are polyphagous, targeting many essential fruits and vegetables.

Controlling fruit fly populations is a major concern in agriculture due to the significant damage they cause to fruits and crops. Therefore, monitoring of the pest population is important as one of the measures in the Integrated Pest Management (IPM) concept (Hasyim *et al.*, 2016). The population dynamics of any insect is very strongly linked with the weather parameters existing during preceding and consequent periods (Vayssieres *et al.*, 2009). As a result, the pest status of fruit flies varies throughout the year, depending on abiotic conditions such as temperature, relative humidity, rainfall, wind patterns, and so on. Temperature and humidity have the greatest effects on population fluctuations (Khan *et al.*, 2003). Population of melon fruit fly (*Bactrocera cucurbitae*) increases when the temperature drops below 32˚C and relative humidity between 60-70% (Dhillon *et al.*, 2005).

Changing patterns of population in each fruit fly species vary with the availability and fruiting season of the host plant. These variations could be in relation with the ripening times of different mango varieties (Vayssieres *et al.*, 2009). Since the available information on this aspect is lacking, studies to understand the role of weather factors and host plants in influencing fruit fly occurrences is necessary in Sri Lanka. This will assist not only in making sound pest management decisions, but also in putting them into action at the appropriate time. Therefore, this study was conducted to determine the effect of selected weather variables and mango fruiting season on the adult male population fluctuation of mango infesting fruit flies in the selected mango cultivated sites in Peradeniya, Sri Lanka.

2 MATERIALS & METHODS

2.1 Study sites

Three sites comprising mango orchards in Peradeniya, Sri Lanka were selected to determine the adult male population fluctuation of mango infesting fruit flies during a period of eight months. A home garden in Bowalawaththa situated in a sub-urbanized setting, which has an area of 0.028 km^2 was selected as one site for sampling. Other than mango trees, there were other species of fruit trees such as lemon (Rutaceae), roseapple (Rosaceae), citrus (Rutaceae) and other flowering plants.

The second site is Meewathura agricultural farm at the University of Peradeniya which has an area of 0.068 km^2 and a backyard that consists of uninterrupted forest patch closer to Mahaweli River. Apart from mango trees there were several other fruit tree species such as avocado (Lauraceae), uguressa (Salicaceae), jackfruit (Moraceae), guava (Myrtaceae) *etc*. The third site at Hilda Obeysekara Hall Garden at University of Peradeniya has an area of 0.027 km^2 and has a well-managed patch in an open area mainly with mango trees with other flowering plants.

2.2 Placement of traps and collection of fruit flies

Steiner traps were used to collect the fruit flies. This dry trap was a horizontal plastic cylinder with two openings at each end as shown in figure 1 and made out of a wide plastic bottle (12 cm in length). Two plastic tubes were inserted in those two openings with 6.0 cm and 2.5 cm in length and diameter respectively. This trap is equipped with a piece of cotton wool impregnated with Methyl Eugenol (ME) (2 ml) hung inside the trap body. Traps were intended to attract flies into the container and retain them inside (Figure 2).

In each study site, the traps were suspended to prevent contact with foliage, minimizing access by ants and other predatory insects that could prey on the collected fruit flies (Figure 2). The central coil of wire holding the trap was coated with thick grease in order to avoid insects crawling along the wire. Traps were suspended twice a month in the afternoon (during the first week and third week of each month) at each site, constituting a total of 11 traps. The number of traps to be hanged at each site was decided following the agricultural recommendation which is three traps per 0.0404 km^2. Accordingly, three traps were located in Bowalawatta home garden (one trap in the border and two traps in the centre), five traps at Meewathura agricultural farm at University of Peradeniya (two traps in the border and three traps in the centre) and three traps at Hilda Obeysekara Hall at University of Peradeniya (one trap on the border and two traps in the centre). Before placing the traps in trees, the attractant was applied to cotton wool inside the trap after thoroughly washing it. When placing the traps they were placed 2-3 m above the ground level.

Traps were collected after four days in the afternoon of the corresponding day and brought to the Entomology Laboratory of the Department of Zoology, Faculty of Science, University of Peradeniya. Collected fruit flies from different sites were kept separately in plastic bottles (separate bottles were used for each trap) with labels indicating the date, collection site and placement of trap in each site (indicating border or center) and stored them for further identification using standard identification keys (Drew and Romig, 2016; Plant Health Australia, 2016).

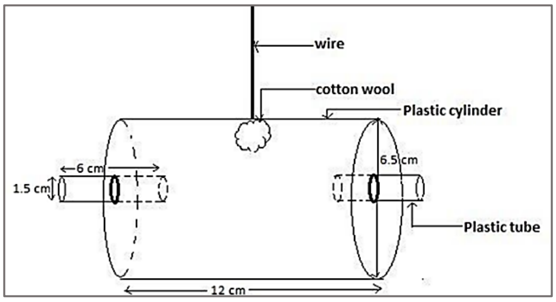

Figure 1. Dimensions of the Steiner trap used in the fruit fly collection (not to scale)

Figure 2. Methyl Eugenol trap hanging from a branch of a mango tree at Bowalawatta site

2.3 Obtaining weather data for the study period

For the study period, weather data including temperature (minimum-maximum), relative humidity (RH), rainfall and wind speed were obtained monthly from the National Resources Management Centre at Peradeniya, Sri Lanka.

2.4 Data analysis

Minitab 14 statistical software and Microsoft Excel 2007 were used to analyze data. A correlation test was performed to check the relationship between the number of male fruit fly adults caught in Methyl Eugenol traps and weather parameters.

3. RESULTS

3.1 Species composition and abundance of male fruit fly species

During the study period, three fruit fly species were recorded from the Methyl Eugenol (ME) traps. The fruit fly species which was collected from selected study sites (Bowalawatta-BW, Meewathura-MW, and Hilda Obeysekara Hall-HO) were *Bactrocera dorsalis*, *Bactrocera kandiensis* and *Bactrocera correcta* (Figure 3). A total of 27,883 male fruit flies were caught, comprising *Bactrocera dorsalis* (64.71%), *Bactrocera correcta* (18.37%) and *Bactrocera kandiensis* (16.92%).

3.2 Temporal variations in male fruit fly captures in ME traps across study sites

There is a difference in the population fluctuation of the three species *Bactrocera dorsalis*, *Bactrocera kandiensis* and *Bactrocera correcta* during the study period in each site (Table 1). The study revealed distinct seasonal fluctuations in fruit fly populations across the three study sites. Adult male fruit fly catches increased steadily from late February and reached a major peak in early March (4–7), while the lowest catches were recorded during January (7–10). Following the peak, fruit fly abundance declined from early April to late July 2017.

Figure 3. Adult male fruit fly species caught in Methyl Eugenol traps installed in three sites (A- *Bactrocera dorsalis*, B- *Bactrocera kandiensis*, C- *Bactrocera correcta*)

Among the three species recorded, *B. dorsalis* was the dominant species throughout the study period, occurring in substantially higher numbers than *B. kandiensis* and *B. correcta*. Both *B. dorsalis* and *B. kandiensis* exhibited peak populations from early February to early April across all sites, whereas *B. correcta* reached its highest abundance from early July to late August, a period when the other two species were at their lowest levels.

Table 01. Total number of adult male fruit fly species caught in Methyl Eugenol traps installed in the three sites

	BW site			MW site			HO site		
Time period	***B. dorsalis***	***B. kandiensis***	***B. correcta***	***B. dorsalis***	***B. kandiensis***	***B. correcta***	***B. dorsalis***	***B. kandiensis***	***B. correcta***
Jan 7-10	**396**	**42**	**18**	**292**	**107**	**109**	**32**	**6**	**20**
Jan 23-26	403	58	23	283	134	127	40	6	27
Feb 3-6	922	76	24	464	122	79	120	15	32
Feb 20-23	1126	63	29	537	110	53	130	75	12
Mar 4-7	**970**	**385**	**112**	**1281**	**542**	**303**	**878**	**121**	**137**
Mar 25-28	715	371	121	1240	260	159	386	61	153
Apr 3-6	457	66	32	837	157	126	118	24	16
Apr 25-28	458	178	96	998	208	64	95	17	12
May 8-11	245	55	18	688	125	73	69	16	48
May 23-26	259	54	20	700	163	88	52	15	45
Jun 6-9	161	44	21	522	154	96	66	10	55
Jun 23-26	150	38	15	467	100	70	54	9	31
Jul 2-5	93	59	20	308	214	580	47	16	104
Jul 20-23	103	44	23	153	85	309	55	12	95
Aug 4-7	134	47	103	130	93	397	17	8	389
Aug 22-25	131	30	79	205	107	310	55	21	250

(Bowalawatta-BW, Meewathura-MW, and Hilda Obeysekara Hall-HO)

3.3 Correlation of the abundance of male fruit flies caught in Methyl Eugenol traps and weather parameters

The relationship between fruit fly abundance and weather parameters varied among the study sites (Table 2). Among the climatic factors examined, temperature and wind velocity showed the strongest associations with fruit fly populations. Maximum temperature was positively associated with fruit fly catches, with a significant relationship observed at Meewathura, whereas minimum temperature showed a significant negative relationship at Bowalawatta. In contrast, rainfall and relative humidity had little influence on fruit fly abundance, as their correlations were generally weak and non-significant across the study sites. Wind velocity exhibited a significant negative relationship with fruit fly catches at Meewathura and Hilda Obeysekara Hall (Table 2).

Table 2. Correlation coefficient of the total number of adult male fruit flies with weather parameters

Weather parameter	**Correlation coefficient (r) and p-value (p) of male fruit fly catches**					
	BW		**MW**		**HO**	
	r	**p**	**r**	**p**	**r**	**p**
Average maximum temperature	0.453	0.078	0.501	0.048	0.173	0.521
Average minimum temperature	-0.507	0.045	0.056	0.836	0.033	0.904
Average rainfall	-0.003	0.990	0.277	0.299	0.289	0.278
Average wind velocity	-0.395	0.129	-0.570	0.021	-0.514	0.042
Average relative humidity	-0.298	0.263	0.020	0.941	0.015	0.957

Significant at 0.05 level

4 DISCUSSION

4.1 Species composition of adult male fruit fly species caught in ME traps

Plant Health Australia (2016) has stated that Methyl Eugenol (ME) is an attractant that is widely used in collecting *Bactrocera* and *Dacus* species of fruit flies and it is a para-pheromone which attracts the male fruit flies. *B. dorsalis* and *B. kandiensis* were recorded in higher numbers, possibly due to the availability and easy access to their host plant (mango) across the three sites. Moreover, Ganie *et al*. (2013) reports that ME is a highly potent attractant for the males of *B. dorsalis.*

Bactrocera correcta which showed lowest abundance may be due to the smaller number of other host plants (*B. correcta* prefer) in the sites apart from mangoes. The highest number of fruit flies recorded in the Meewathura site could be due to the presence of a small forest patch closer to Mahaweli River and low human intervention compared to the other two sites Bowalawatta and Hilda Obeysekara Hall.

4.2 Temporal variations in male fruit fly captures in ME traps across study sites

In general, the pattern of the adult male fruit flies, *B. dorsalis*, *B. kandiensis* and *B. correcta* population in each site may be coinciding with optimal weather conditions, lack of natural enemies, mango fruiting season and non-fruiting season of mangoes. The major peak of adult male fruit fly catches in the three sites coincide with the mango fruiting season (early February to late March). It probably results from the availability of more susceptible host (mango) varieties during the fruiting season. Similarly, Mwatawala *et al*. (2006) have recorded that mango orchards carry high numbers of flies coinciding with their fruiting season in Benin. These findings indicate that the period from early February to late March represents the most critical time for fruit fly activity and therefore provides an optimal window for implementing monitoring and management interventions.

The observed differences in seasonal abundance patterns among species highlight the importance of species-specific management strategies. In particular, the dominance of *B. dorsalis* and its pronounced population peak during the fruiting season underscore its potential as the primary target for effective fruit fly control programs in mango-growing areas.

Ronchi-Teles and Silva (2005) have found that this may be due to temporal overlap of fruit production by different plant species permitting the maintenance of fruit fly populations. The higher population of *B. correcta* observed during the non-fruiting season of mango (early July to late August) may represent a migratory population originating from adjacent orchards, as indicated by its persistent capture in traps placed within mango orchards across all study sites. This may also be attributed to the reduced presence or absence of natural enemies of *B. correcta* during this period, as well as decreased interspecific competition resulting from the low abundance of other fruit fly species in the non-fruiting season of mango, particularly the major mango-infesting species *B. dorsalis* and *B. kandiensis*.

4.3 Effect of weather parameters on the population fluctuation of male fruit flies

Rainfall may have an impact on the growth of fruit flies, as the lowest fly catches in ME traps installed in Bowalawatta and Meewathura were recorded at a minimum rainfall of zero. Most possible reason for this was that is rainfall makes the soil moist and thus provides some favorable conditions for developing of adults from their puparia. Similar studies that have been carried out in China, Chen *et al*. (2007) have underlined that the monthly rain days were the strongest one among all the climatic factors. Vayssières *et al*. (2009) have reported that correlation of trap catches with rainfall is not always positive though these data are suggestive to a positive link. Patel *et al*. (2013) have observed that fruit flies cause up to 40 percent yield loss in heavy rainfall zone of south Gujarat in India.

Temperature may be another factor that affects the growth of fruit flies especially for egg hatching and it plays a major role in the entire life of the fruit fly. Therefore, the high fruit fly catches coincided with maximum temperature. *B. dorsalis* which was the leading species among the three sites was showed a strong positive correlation with the maximum average temperature and average rainfall since it scores the highest abundance among the three species caught in ME traps. That means this weather conditions ensure the advances of adult male population of *B. dorsalis.* Sahoo *et al*. (2016) reported that abiotic factors such as, day temperature, night temperature, heat sum have significantly positive correlation with mango fruit fly population and direct effect on the growth and development. Similarly, Shukla and Prasad (1985) have shown a positive correlation between the populations of the captured *B. dorsalis*, temperature and maximum relative humidity. The results of the present investigation contradict the findings of Verghese *et al*. (2006) who have reported that wind speed and minimum temperature showed significant and positive correlation with *B. dorsalis*. Jalaluddin *et al*. (2001) have recorded the same positive correlation with minimum temperature and relative humidity with the guava fruit fly, *B. correcta* which was counted with the findings of *B. correcta* from the current study. Hilda Obeysekara Hall, indicated that higher wind speeds may suppress fruit fly activity or reduce trap effectiveness.

CONCLUSION

Overall, the populations of the mango-infesting fruit flies *Bactrocera dorsalis* and *Bactrocera kandiensis* increased during the mango fruiting season, whereas the population of *B. correcta* increased towards the end of the fruiting period. Across all three study sites, average maximum temperature and rainfall showed a positive relationship with the abundance of all fruit fly species. The trapping method proved to be highly effective for monitoring fruit fly incidence. Furthermore, information on the peak activity periods and seasonal population dynamics of the major mango tephritid species is essential for developing timely, appropriate, and effective control strategies.

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