Seasonal variations of peach fruit fly, *Bactrocera zonata* Saunder under the impact of host fruits and meteorological factors

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Abstract
Peach fruit fly, *Bactrocera zonata* is a widely distributed and devastating pest of fruit with global significance. Its population dynamics are greatly influenced by the climatic factors and availability of fruits. In the present study, we monitored the *B. zonata* in mango, guava and citrus with the help of specially designed methyl eugenol traps. The climatic factors were also recorded at the same time for the detailed analysis. The results revealed two population peaks throughout the year, one in the month of May, whereas the other in the month of August and September. The temperature was determined as the major factor in population buildup associated with the availability of ripened fruits. The other factors such as rainfall and relative humidity played minor role as determined by the multivariate analysis. These results will help us to devise an IPM program to control the menace of peach fruit fly before the population buildup.

Key words: *Bactrocera zonata;* Population dynamics; Methyl eugenol; Climatic factors; IPM

INTRODUCTION

The peach fruit fly is a polyphagous pest in nature. It is an important pest species and cause severe damage to peach, mango and guava including many other vegetables and fruits in Pakistan, India and Egypt. In some areas of Pakistan, it has been more destructive than *Bactrocera dorsalis* (Qureshi et al., 1991; Kapoor, 1993).

Studies have established the dispersal of peach fruit fly from its primary habitats in India and Pakistan to new locations such as Reunion islands and Mauritius in the Indian Ocean and north-eastern countries namely, Egypt and Somalia (Ni et al., 2012). More recently, peach fruit fly has been detected in southern coastline of Mediterranean and also in great number in Libya and Egypt (Mohamed et al., 2012). The presence of *B. zonata* has also been confirmed in California and Northern parts of North America (Papadopoulos et al., 2013).

Among the recently invading fruit flies, *B. zonata* with aggressive and invasive nature has established in Egypt, Sudan and Libya are instances concerning the economic significance of newly invasive fruit fly species (Mohamed et al., 2012; Ali et al., 2012). Around 4000 species of true fruit flies including several most important economic pests worldwide, invading soft fruits (White & Elson-Harris, 1994). From an economic viewpoint, these fruit flies cause heavy damage to fruits and vegetables, impose quarantine restrictions on areas of reported infestation, necessitate the post-harvest treatment before export and responsible for the breeding source for the invasion in the new areas of the world (Vargas et al., 2010c). The peach fruit fly, *B. zonata* is among the most notorious member of the Tephritidae family (Carey & Dowell, 1989; Metcalf & Metcalf, 1992).

In Egypt studies showed that fruit fly traps positioned in the northwest part of the peach plants captured highest population of *B. zonata* with two fold compared to the south and 1.7 fold in the eastern part (El-Gendy, 2012). Together, this information showed that in temperate climates, the fruit flies prefer warmer parts of the tree, while in warmer climates seek cooler places.

In Pakistan, the total production of mango, guava and citrus for the year 2016-17 remained at 1.6, 5.52 and 2.34 million tones, respectively, with a total fruit export of 6.7 million tons having a value of PKR 44,607 million. According to an estimate export income from fruits indicated a drop of 8.6 percent in value and 25.5 percent in quantity (Anonymous, 2019).

In our present studies fruit fly species, *B. zonata* was monitored in mango, guava and citrus using methyl eugenol traps throughout the year. The trap data were compared with the meteorological factors such as maximum and minimum temperatures, relative humidity (RH %) and rainfall. Correlation and multivariate regression analysis was also carried out to get more precise influence of these factors on population fluctuation.

MATERIALS AND METHODS

Experimental location

The experimental work was executed in the Nuclear Institute for Agriculture & Biology (NIAB) experimental farm, Faisalabad during the year 2019, located at geographic coordinates, 73°1′49″′ E, 30°24′0″′ N, with an altitude of 469.16 feet.

Sex pheromone traps

Transparent plastic bottles were transformed into the fruit fly traps (Fig. 1). The plastic bottles were holed from both sides at 180° and the holes were fitted with plastic pipes. A capsule was fitted in the center for application of pheromone. Each time 2 ml of pheromone was dispensed to the center after every 15 days. All the traps were then suspended with the twigs of fruit trees at an appropriate height with steel wire.

Sex pheromone used for monitoring

Methyl eugenol as commercial formulation was used for the attraction of male member of *Bactrocera zonata*. A total of 2 ml of methyl eugenol was applied to the capsule after every 15 days. All the captured fruit flies were collected from the traps and counted at every 15 day intervals.

Figure 1. Specially designed transparent plastic jar into methyl eugenol fruit fly trap to capture *B. zonata* in the orchards

Climatic data acquisition

Climatic yearly data, such as maximum and minimum temperature (°C), relative humidity (RH %) and rainfall (mm) were acquired from a mini. weather station with data logger installed on the NIAB experimental farm. Mean maximum, minimum temperature, relative humidity and rainfall for each month were calculated from the daily yearly data (Table 1).

Data analysis

A Two-Way Analysis of Variance (ANOVA) was used to analyze the experimental data and subsequently means were separated for statistical significance by Tuckey's Multiple Comparison Test (TMCT) at the ≤0.05 alpha level of significance using statistical software (Statistix 8.1, Tallahassee, Florida, USA). Seasonal incidence of fruit fly was plotted against maximum, minimum temperature, relative humidity (RH %) and rainfall. Simple correlation studies were performed between fruit fly infestation level with temperature and humidity, whereas multivariate regression analysis, $Y = a + b1\ X1 + b2\ X2 + b3\ X3$, was performed for the assessment of the discrete and collective effects of climatic factors such as, temperature, humidity and rainfall on population levels of fruit fly using Microsoft Excel, 2013.

Table 1. Abundance of fruit fly population in relation to annual metrological data

Months	Fruit fly population (Mean)			Temperature °C		Rainfall (mm)	RH %
	Mango	Guava	Citrus	Maxi.	Mini.		
January	1.53^{E}	2.66^{F}	2.22^{G}	17.31	7.73	0.42	74.38
February	10.75^{DE}	9.83^{F}	4.33^{G}	23.09	9.35	0.25	58.90
March	5.75^{E}	13.5^{F}	7.5^{FG}	26.77	15.58	2.15	59.74
April	53.25^{C}	100.66^{BC}	56.83^{CD}	34.22	20.12	0.18	34.67
May	142.5^{A}	140.5^{A}	110.16^{B}	36.60	23.68	1.05	33.19
June	44.62^{C}	47.67^{DE}	21.5^{EF}	40.22	28.47	1.31	38.67
July	51.25^{C}	48.83^{DE}	31.33^{E}	36.59	27.38	6.24	59.61
August	84.91^{A}	104.77^{A}	91.55^{A}	35.67	26.51	1.55	62.22
September	77.75^{B}	110.66^{B}	102.67^{B}	36.50	25.45	0.38	53.77
October	52.37^{C}	89.33^{C}	85^{C}	34.28	20.38	0.71	51.29
November	25.62^{D}	62.17^{D}	48.835^{D}	27.78	12.55	0	60.22
December	16.25^{DE}	36^{E}	24.67^{E}	23.70	8.64	0	68.67

RESULTS AND DISCUSSION

Significant variation in fruit fly population captured were recorded during different months of the year. The highest mean population of 142.5, 140.5 and 110.16 were recorded in mango, guava and citrus respectively in the month of May, whereas the lowest catch of 1.53, 2.66 and 2.22 was recorded in mango, guava citrus respectively in the month of January. The most active months noted for fruit fly were from April to September, whereas inactive months noted were December to March. The population remained at the moderate level in the months of October and November. The optimum level of maximum, minimum temperature, rainfall and RH for the population growth were 36.60, 23.68 oC, 1.05 mm and 33.19% respectively (Table 1).

The fruit fly peak mean population of 142 in mango corresponds to the maximum temperature at 36.8°C and minimum temperature at 23.5 °C and the month of May. The other peak mean population of 102 corresponds to the maximum temperature at 33.8°C and minimum temperature at 24°C in the month of August. In guava the peak fruit fly population of 140 corresponds to the maximum temperature of 36.6°C and minimum temperature of 22.6°C in the month of May, whereas the other peak population of 110 correspond to the maximum temperature of 36.4°C and minimum temperature of 25.8°C in the month of September. In case of cit-

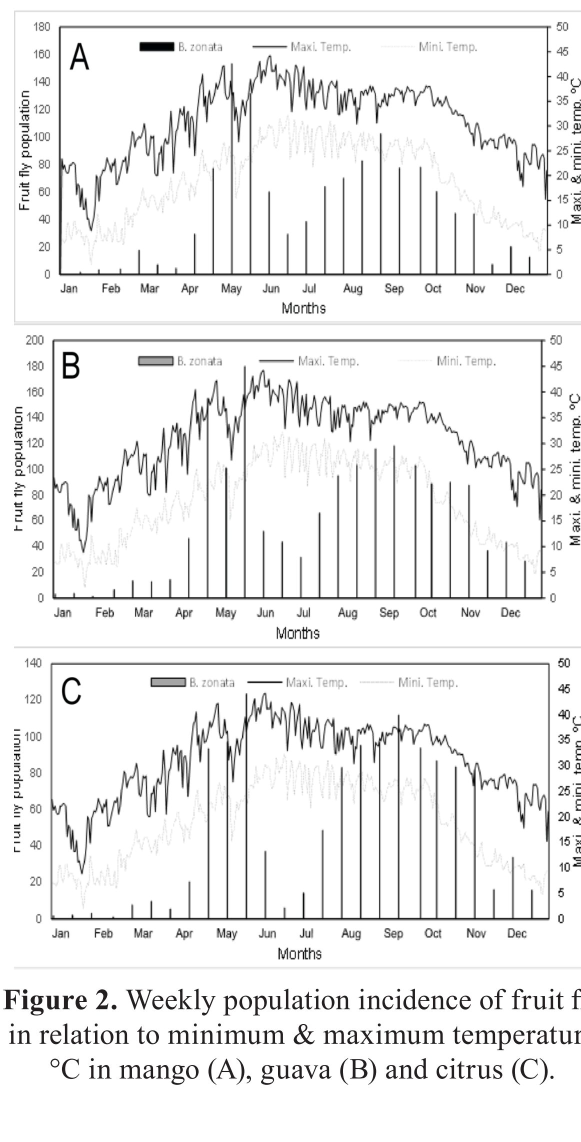

Figure 2. Weekly population incidence of fruit fly in relation to minimum & maximum temperature °C in mango (A), guava (B) and citrus (C).

rus the mean peak population 110 corresponds to the maximum temperature of 36.6°C and minimum temperature of 22.6°C in the month of May, whereas the second peak population of 102 corresponds to the maximum temperature of 36.6°C and minimum temperature of 25.3°C in the month of September (Fig. 2).

As far as the humidity is concerned, the fruit fly peak population in mango correspond to 38% RH in the month of May. For guava and citrus the mean peak population corresponds to 35% RH in the month of May (Fig. 3).

Correlation studies were also carried out to see the level of impact of temperature and humidity on fruit fly population. The fruit fly population showed a positive correlation with temperature (Fig. 4), whereas negative correlation was noticed for the relative humidity (Fig. 5) for all the three fruits i.e., mango, guava and citrus.

Multivariate regression analysis was also carried out to see the individual impact of temperature and humidity on the fruit fly population. From the results of the analysis is was confirmed that temperature is the most limiting factor for the population growth of fruit fly. Other meteorological factor such as humidity did not support the population growth (Table 2).

In our investigation, we used methyl eugenol as an attractant source for male *B. zonata* in specially designed traps. In an earlier investigation, methyl eugenol, has been documented as an extraordinary source of male attraction for the males of many decine species. It is considered to be effective in population monitoring *B. zonata* and attracts flies at a

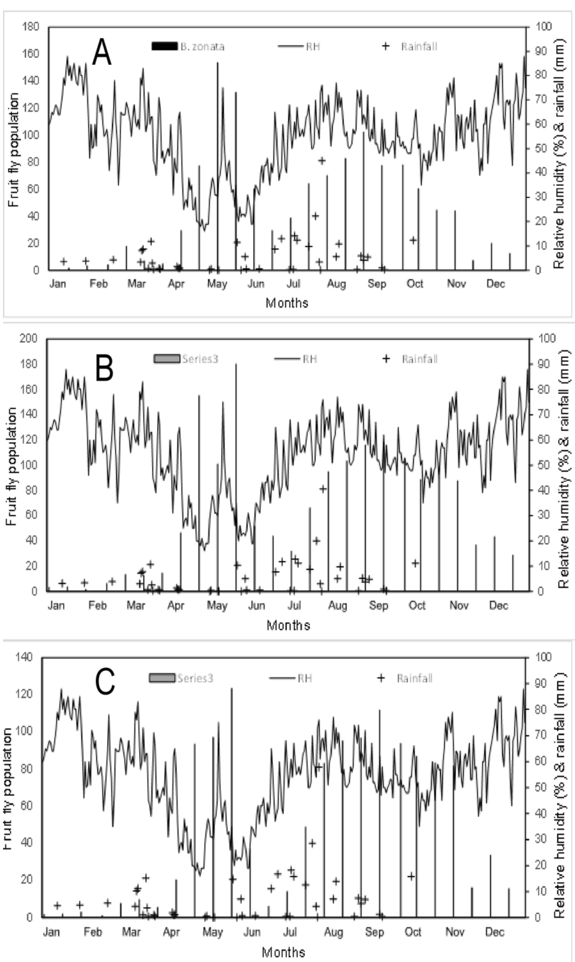

Figure 3. Weekly population incidence of fruit fly in relation to relative humidity (%) and rainfall (mm) in mango (A), guava (B) and citrus (C).

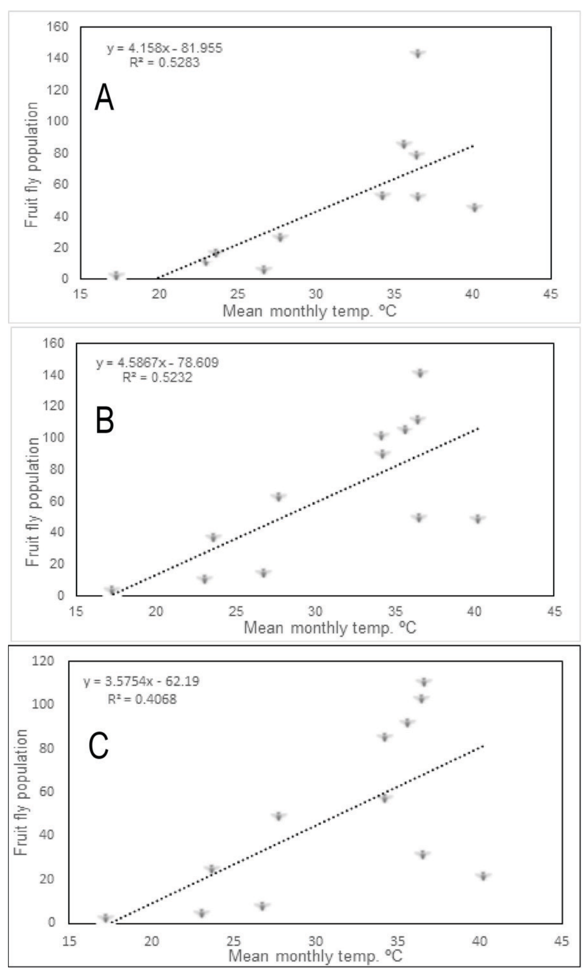

Figure 4. Correlation of fruit fly number with mean monthly temperature °C in mango (A), guava (B) and citrus (C).

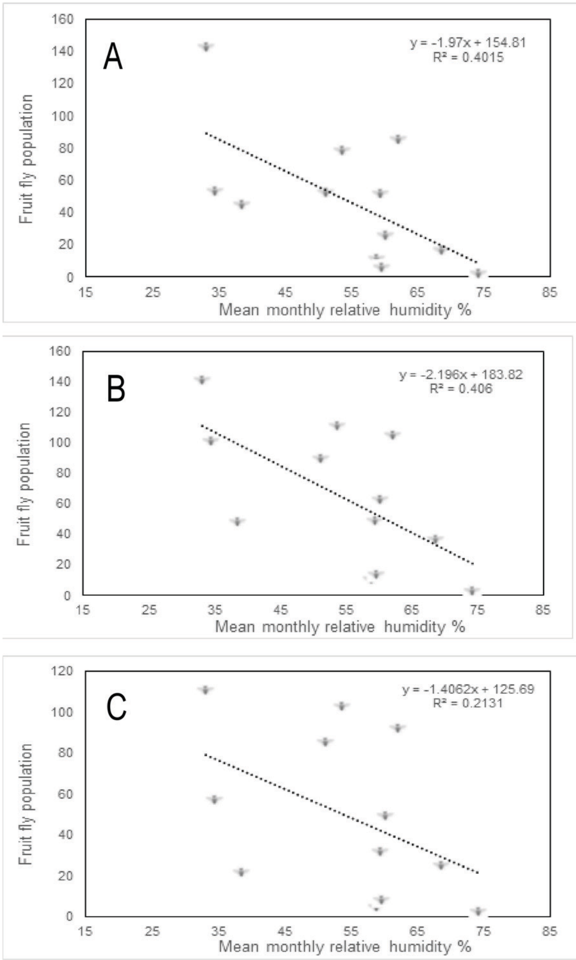

Figure 5. Correlation of fruit fly number with mean monthly relative humidity (%) in mango (A), guava (B) and citrus (C).

very low concentration (Qureshi et al., 1992; Dalia et al., 2015).

In the past several researchers have studied the influence of climatic factors on the population of fruit flies (Agarwal & Kumar, 1999; Makhmoor & Singh, 1998; Afia, 2007; Mwatawala et al., 2009; El-Keroumi et al., 2010). The majority of the previous investigators came to the conclusion that climatic factors, especially temperature, relative humidity and rainfall correlate with the population fluctuation significantly. Though the significance of each factor varies among population over the time (Mohamed, 2002). The temperature fall was the main cause of the end of adult activity of fruit fly (Papadopoulos et al., 2001). The temperature plays a significant role in the development of immature stage of *B. zonata* and as a result determines the timing of population increase (Fletcher, 1989). Abiotic factors, especially temperature as a key factor in seasonal occurrence of fruit fly (Amice & Sales, 1997; Chen & Ye, 2007).

Similar to our studies in India Ravikumar, (2006) also documented similar results. In his investigations, he determined the impact of temperature, humidity, rain on three fruit fly species especially B. zonata in guava and mango orchards, and found that all climatic factors influence the trap catches efficiency to some extent.

In another similar studies Afia (2007), reported the effect of climatic factors on the population of *B.*

Table 2. Multivariate regression analysis of specific climatic factor on population variation of fruit fly in mango, guava and citrus

Insect/ Fruit	Regression Equation	100 R^2	Impact
B. Zonata /Mango	$Y = -81.95 + 4.15 X_1$	52	52
	$Y = -81.20 + 4.15 X_1 + 0.05 X_2$	52	0
	$Y = 49.86 + 0.28 X_1 + 2.39 X_2 - 1.03 X_3$	56	4
B. zonata /Guava	$Y = -78.60 + 4.58 X_1$	52	52
	$Y = -135.05 + 8.87 X_1 - 4.07 X_2$	56	4
	$Y = -81.08 + 7.30 X_1 - 3.11 X_2 - 0.42 X_3$	56	0
B. zonata /Citrus	$Y = -62.18 + 3.57 X_1$	40	40
	$Y = -93.89 + 5.98 X_1 - 2.29 X_2$	42	2
	$Y = -145.06 + 7.47 X_1 - 3.20 X_2 + 0.40 X_3$	42	0

Where, Y= Infestation of insect pests; X_1= Maximum temperature; X_2= Minimum temperature; X_3= Mean relative humidity *zonata* did not appear to have significant influence during the active period of the fruit fly. According to her conclusion, climatic elements were not the main driving force for population fluctuation but the main factor was the appropriate stage of host fruit. Resultantly, she determined the appropriate stage of host fruit as a limiting factor for pest abundance. In other similar studies, the availability and abundance of cultivated fruits such as guava and mangoes are important factors for the fluctuation of the fruit fly, *Bactrocera species* (Drew & Hooper, 1983).

Our present findings were further endorsed by the reports of the researchers who documented and concluded that the abundance of mature fruits determines the highest densities of respective fruit fly species (Abu-Manzar & Srivastava, 2004; Robacker, 2006; Chen & Ye, 2007).

CONCLUSIONS

It is concluded from the present findings that fruit maturity and its type along with abiotic factors especially temperature plays important role in determining the population density of the fruit fly. Moreover, among the fruits mango was the most preferred fruit by the fruit fly, *Bactrocetra zonata* with the highest recorded population density followed by guava and citrus, respectively.

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