Research Article

Seasonal Abundance of Fruit Fly, *Bactrocera* species (Diptera: Tephritidae) with Respect to Environmental Factors in Guava and Mango Orchards

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Abstract | The tephritid fruit flies are the major pests of horticultural crops across the globe. In Pakistan, two fruit fly species, *Bactrocera zonata* (Saunders) and *B. dorsalis* (Hendel) cause severe qualitative and quantitative damages to various fruits. The present study was executed to record the population dynamics of these fruit fly species in guava and mango orchards with respect to meteorological factors using methyl eugenol-baited traps. The results revealed that population of both the species highly fluctuated round the year. *B. zonata* appeared to be the most abundant species both in mango and guava orchards as compared to *B. dorsalis*. The highest mean number of *B. zonata* (3690.57 flies/trap) was captured in August 2018 in guava orchard. From October, 2018 onward up to February 2019, population of *B. zonata* tended to decline with the lowest catches (122.5 and 152.8 flies/trap, respectively) in January and February, 2019. In mango orchard, peak population of *B. zonata* (4062.8 flies/trap) was recorded in May, 2019. Abundance of *B. dorsalis* in guava orchard reached to its peak (394.625 flies/trap) in August, 2018. However, in mango orchard, an increasing trend in population was observed from April onward with the highest catches of 521.4 flies/trap in June. The correlation matrix revealed a significantly positive relation among the incidence of *B. zonata* and minimum and maximum temperatures and sunshine hours whereas relative humidity (R.H.) and rainfall were found to have a negative correlation with *B. zonata* abundance. Correlation analysis of *B. dorsalis* catches with respect to meteorological data revealed a significantly positive correlation of monthly captured flies with all the climatic factors such as maximum temperature, minimum temperature, R.H. and sunshine duration except the mean monthly rainfall.

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Introduction

The tephritid fruit flies being deleterious pests of horticultural crops are distributed worldwide (Stephen *et al.*, 2007; Rasool *et al.*, 2017; Khan *et al.*, 2019). Fruit flies are responsible for causing significant yield losses, dropping the values and creating hindrances in the exports of agricultural produces (Sarwar, 2015). Fruit flies are transported across borders with international trade of fruits and vegetables and hence are regarded as major quarantine pests (Permalloo, 1998; Peck and McQuate, 2004). The damages inflicted by the fruit flies lead to reduced farm produce and hence to limited exports

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(Khan *et al*., 2020). The genus *Bactrocera* contain some of the highly harmful fruit fly species. About 50 species in this genus are major polyphagous pests of horticultural crops (Ali *et al*., 1999; Vargas *et al*., 2015) of which the *Bactrocera zonata* (Saunders) and *B. dorsalis* (Hendel) cause heavy losses to a wide range of fruits in Pakistan (Ahmad *et al*., 2005)

Peach fruit fly, *B. zonata* is reported to have been originated in South and South-East Asia where it has a wide host range of about more than 50 fruits (White and Elson-Harris, 1992). In Pakistan, heavy infestation of *B. zonata* has been recorded in a number of fruits particularly mango, guava, citrus, banana, chiko etc. from the coastal and sub-coastal regions of Sindh and Baluchistan. It has also been recorded in and hillocks of Islamabad and different areas of Khyber Pakhtunkhwa and Punjab (Marwat *et al*., 1992; Khan and Naveed, 2017). Oriental Fruit fly, *B. dorsalis* is also one of the major polyphagous pests infesting over 300 host fruits in tropical and subtropical habitats worldwide (Chen and Ye, 2007). In 1912, the first record of this species was traced in Taiwan. Presently *B. dorsalis* is widely distributed in Asia-pacific region (Ye and Liu, 2005; Mahmood and Mishkatullah, 2007).

The meteorological factors including temperature, relative humidity, photoperiod, rainfall, wind etc. have great influence on the abundance of fruit flies round the year (Chen and Ye, 2007). *B. dorsalis* has a strong correlation with the local temperatures which plays important role in regulating its population abundance. (Jiang *et al*., 2001; Liu and Ye, 2006). To develop an effective integrated pest management (IPM) program, it is important to understand the year round population fluctuation of a pest with respect to metrological factors. Sex attracting pheromone trap is a good tool for monitoring the population trend of fruit flies (Alyokhun *et al*., 2000). Such pheromone traps have been extensively used in many countries to assess the abundance of fruit fly population (Marwat and Baloch, 1986; Gillani *et al*., 2002; Abro *et al*., 2020). The importance of methyl-eugenol is well documented in attracting *B. zonata* and *B. dorsalis* males and hence the toxicant mixture of this attractant and insecticide can be used in traps for monitoring population dynamics of these species (Chen *et al*., 2006; Chen and Ye, 2007; Mahmood and Mishkatullah, 2007). The present study was planned to record the population trend of *B. zonata* and *B. dorsalis* year round in relation to environmental factors such as temperature, relative humidity, photoperiod, rainfall etc.

Materials and Methods

The current study was conducted at the experimental farm i.e. mango and guava orchards of Nuclear Institute of Agriculture (NIA), Tandojam by installing traps containing methyl eugenol as bait in guava (Aug, 2018 to Mar, 2019) and mango (Apr-Jul, 2019) orchards. The guava orchard was approximately two hectares whereas the mango orchard covered an area of almost four hectares. The fruit fly traps used in the experiment were made up of 1.5 liter of transparent plastic jars (8 x 4 inch) by making two holes, one in the bottom and the other in the lid. About 3 inches of PVC pipe of one inch diameter was fitted in these holes to allow entry of fruit flies and prevent their escape (Figure 1). A binding wire was also fixed on PVC pipe on the lid side for holding the cotton swab inside the trap. The toxicant mixture of sex pheromone (95% methyl eugenol + 5% Thiodan insecticide) was applied to the cotton swabs. The lid of each trap was removed and the cotton swabs were fixed in the metal wire on PVC pipe so that they were kept suspended in the middle of the traps after closing the lid. All the traps were suspended in the fruit orchards on trees with the help of metal wire (@ 20 traps/ha) at a height of about 2 m from soil and at appropriate distance from each other. The cotton swab was replenished after every 15 days with fresh ones. The male flies of *B. zonata* and *B. dorsalis* caught in the traps were removed, separated and counted at fortnightly interval. The same data were then transformed into mean number of flies/trap (ten traps/observation) for further analysis and correlation with metrological parameters.

Statistical analysis

Data recorded on the population dynamics of fruit fly, *Bactrocera* species in fruit orchards of mango and guava were first transformed to $\sqrt{x+0.5}$ values to stabilize the variance. The resulting means were then subjected to analysis of variance (one-way ANOVA). Multiple omparisons among the means were done through Tukey's HSD test ($P < 0.05$). Data regarding various meteorological parameters such as temperature (minimum and maximum), relative humidity, rainfall, sunshine were obtained from Regional Agro-metrological Centre Tandojam. Correlation of *B. zonata* and *B. dorsalis* with individual weather parameters was computed through StatSoft Statistica 10.

Figure 1: *Mehyl eugenol baited-trap installed on guava tree by metal wire.*

Results and Discussion

Population trend of B. zonata

The highest mean number of *B. zonata* (3690.57/trap) was captured in August, 2018 (Figure 2) in guava orchard (mean of 2 observations from traps replenished at fortnightly interval) where temperature ranged between 38.2-27.49 ˚C with R.H. 62.2% and sunshine 8.44 h (Figure 4). It was followed by male catches of 3652.13/trap in the next successive month of September (minimum temperature 22.54˚C, maximum temperature 36.83˚C, R.H. 61.25% and sunshine 8.64 h). From October onward up to February, population of *B. zonata* tended to decline with the lowest catches (122.5 and 152.8 flies/trap, respectively) in Jan and Feb, 2019 with minimum temperature of below 20˚C. Population buildup appeared to start in March which suddenly rose up to 3428.2 flies /trap in April and 4062.8 flies/trap in May in mango. In June 2019, again there was found a notable decline in population which was further reduced to 899.8 flies/trap in July (Figure 2). Correlation matrix reflected that there was significantly strong positive relationship between the incidence of *B. zonata* and maximum and minimum temperature and sunshine hours (Table 1). However, R.H. and rainfall were found to have negative correlation with *B. zonata* captures. The R.H. ranged between 40-61% in all the months and hence did not appear to have any significant impact on population buildup. Results regarding multiple linear regression models revealed that minimum temperature was directly associated with population dynamics of peach fruit fly *B. zonata* with percent impact of 28.5 whereas maximum temperature, R.H, sunshine and rainfall showed to have non-significant influence on population dynamics of the pest (Table 2).

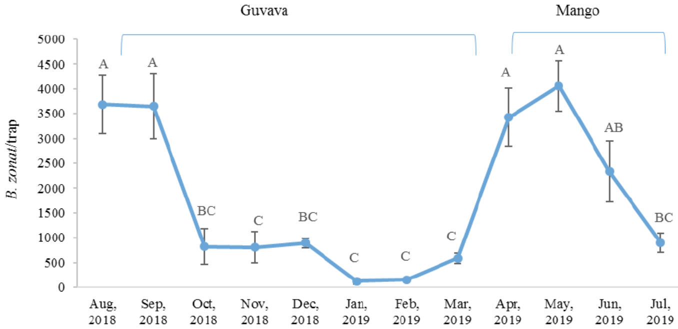

Figure 2: *Population trend of B. zonata (mean ±SE) round the year in guava and mango orchards. Means followed by different letters are significantly different at P < 0.05.*

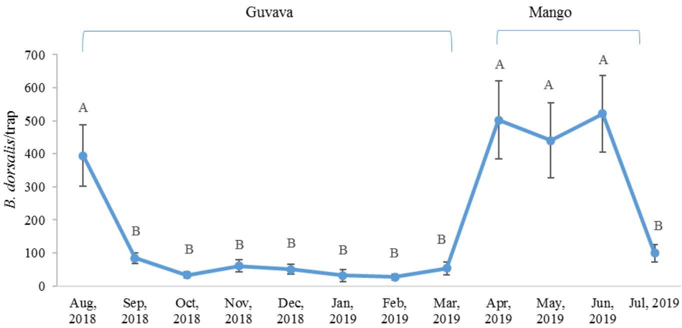

Figure 3: *Population trend of B. dorsalis (mean ±SE) round the year in guava and mango orchards. Means followed by different letters are significantly different at P < 0.05.*

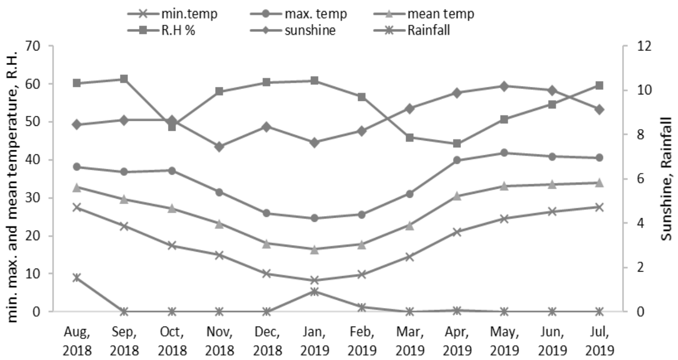

Figure 4: *Meteorological data (min. max. mean temperature, RH, Sunshine and Rainfall).*

Population trend of B. dorsalis

Prevalence of *B. dorsalis* was found to be far below than that of *B. zonata*. In guava orchard *B. dorsalis* catches was 394.625 flies/trap in August, 2018 which was then suddenly dropped and fluctuated between 84.2 and 26.53 from September, 2018 to March, 2019 (Figure 3). In mango orchard, an increasing trend in population was observed from April onward with highest catches of 521.4 flies/trap in June with minimum temperature of 26.33 ˚C, maximum temperature of. 40.865˚C, R.H. 54.63% and sunshine of 10 h (Figure 4). In July, when the mango crop was almost over, population tended to drop again with a catches of 98.8 flies/trap. Correlation analysis of *B. dorsalis* abundance with respect to meteorological data revealed a significantly positive correlation of monthly captured flies with all the climatic factors such as maximum temperature, minimum temperature, R.H. and sunshine duration except the mean monthly rainfall (Table 1). Regression models for *B. dorsalis* displayed that sunshine hours and minimum and maximum temperatures had a substantial impact on the population fluctuation of the fruit fly with percent impact of 17.9, 10.4 and 17.1 respectively. Whereas R.H and rainfall were found to have no impact on the population buildup of the flies (Table 2).

Population of both the species highly fluctuated round the year. *B. zonata* appeared to be the most abundant species both in mango and guava orchards compared to *B. dorsalis*. Our study revealed that *B. zonata* showed higher activity from August to September in guava and April to May in mango with moderate population in June. Similarly, *B. dorsalis* incidence was found to be higher in August in guava whereas from April to June in mango. Higher occurrence of fruit flies in these months could be attributed to favorable weather conditions and availability of hosts. Similar studies conducted in India also reported a higher population trend of *B. zonata* in June (Agarwal and Kumar, 1999) whereas that of *B. dorsalis* in July (Makhmoor and Singh, 1998). Likewise, Gillani *et al.* (2002)

Table 1: *Correlation and regression values of different meteorological factors in relation to fruit fly (B. zonata and B. dorsalis) abundance.*

Parameters		Overall			
		r	r^2	p	Regression equation
B. zonata	Min. Temperature	0.5337	0.284	0.0072	y = -1025.374 + 154.880 x
	Max. Temperature	0.5132	0.263	0.0103	y = -3502.364 + 154.017 x
	Mean Temperature	0.5306	0.281	0.0076	y = -2375.889 + 158.647 x
	R.H (%)	-0.0568	0.792	0.0032	y = 2668.188 - 17.159 x
	Sunshine (hours)	0.3346	0.112	0.1100	y = -3893.908 + 638.131 x
	Rainfall	-0.2168	0.047	0.3089	y = 1845.110 - 1129.478 x
B. dorsalis	Min. Temperature	0.4234	0.1793	0.0392	y = -122.8936 + 16.1058 x
	Max. Temperature	0.5038	0.2538	0.0121	y = -509.443 + 19.8159 x
	Mean Temperature	0.4691	0.2200	0.0208	y = -312.0851 + 18.3835 x
	R.H (%)	0.4223	0.1783	0.0398	y = 1081.9653 – 16.718 x
	Sunshine (hours)	0.6979	0.4871	0.0001	y = -1373.0549 + 174.458 x
	Rainfall	-0.1301	0.0169	0.5447	y = 172.5618 - 88.8174 x

Table 2: *Multiple linear regression models between B. zonata and B. dorsalis catches and weather factors.*

Regression equations	R^2	Impact	P
B. zonata			
$Y = -1025 + 155X_1$*	28.5	28.5	0.007
$Y = -1411 + 135X_1 + 22X_2$	28.5	0	0.029
$Y = -2990 + 102X_1 + 60X_2 + 16.0X_3$	28.7	0.2	0.075
$Y = -4668 + 88X_1 + 63X_2 + 28X_3 + 132X_4$	28.8	0.1	0.147
$Y = -4750 + 86X_1 + 62X_2 + 30X_3 + 139X_4 - 183X_5$	28.9	0.1	0.249
B. dorsalis			
$Y = -123 + 16.1X_1$	17.9	17.9	0.039
$Y = -823 - 20.2X_1 + 39.6X_2$	28.3	10.4	0.031
$Y = 418 + 5.7X_1 + 9.8X_2 - 12.6X_3$	32.4	4.1	0.046
$Y = -1637 - 11.2X_1 + 14.3X_2 + 1.6X_3 + 162X_4$	49.5	17.1	0.009
$Y = -1602 - 10.3X_1 + 15.1X_2 + 0.4X_3 + 159X_4 + 77X_5$	50.5	1.0	0.018

x_1: minimum temperature; x_2: maximum temperature; x_3: Relative humidity; x_4: Sunshine; x_5: rain fall; Y: number of fruit flies.

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reported *B. dorsalis* occurrence in April with peak population in August. The population of both species tended to increase as fruit ripening started (Mwatawala *et al*., 2006) which suggests that presence of fruits in general and their ripening in particular also had a direct impact on the occurrence of flies (Abdel-Galil *et al*., 2010; Khan and Naveed, 2017). Similar results have also been reported by Aluja *et al*. (1996) who found direct relation of fruit fly abundance with the availability of host fruits. The length of fruiting period also indicated a significant influence on the occurrence of both the *Bactrocera* species (Ye, 2008). Moreover, volatiles from ripened fruit serves as a mean to attract more flies to the orchards. In both fruit orchards population of *Bactrocera* species tended to suddenly decline after the fruits being harvested (Drew and Hooper, 1983). The same could also be linked with to the onset of winter where a very little catches of fruit flies was witnessed from October to February (Dalia *et al*., 2014). This decline trend in population density was evidently due to harsh environmental conditions and unavailability of hosts. The increasing trend from March onward could be related to the abundance of fruits and favorable weather factors as stated earlier (Vayssières *et al*., 2005; Win *et al*., 2014; Khan and Naveed, 2017). Our results also partially tally to that of Mahmood and Mishkatullah (2007) who reported a decline trend in the occurrence of *Bactrocera* species from November onward up to February and an increasing tendency starting in March to August with peak of the incidence in July and August.

The abiotic factors of the environment showed a significant effect on the abundance of fruit flies. The correlation matrix revealed that there was a significantly positive correlation between the population of *B. zonata* and temperature (minimum and maximum) and sunshine hours. Khan and Naveed (2017) observed positive correlation between temperature and *B. zonata* population however no correlation of sunshine hours and relative humidity was found on the population. The correlation analysis of *B. dorsalis* with respect to meteorological data revealed a significantly positive relation of monthly captured flies with all the climatic factors except the mean monthly rainfall. However, contrary to this, Vayssières *et al*. (2015) stated that the seasonal occurrence of fruit flies is mainly correlated with the rainfall. Minimum temperature especially lower than 20 °C appeared to have been critical for the survival of the pest as a very small number of both *Bactrocera* species was observed. The positive connection of temperature with the fruit fly abundance was also described by Kannan and Venugopala (2006). Similarly, Amice and Sales (1997) also reported that temperature had a significant impact on the occurrence of fruit flies. Whereas Bota *et al*. (2018) described that temperature together with rainfall have a synergistic effect on the population fluctuation of fruit fly.

Conclusions and Recommendations

In conclusion of the present research findings, population of *B. zonata* and *B. dorsalis* highly fluctuated round the year in mango and guava orchards. *B. zonata* appeared to be the most abundant species in both orchards as compared to *B. dorsalis*. Furthermore, availability of host fruits combined with meteorological factors especially minimum and maximum temperatures are the main factors that have significant influence on the year round fluctuation of fruit flies population.

Novelty Statement

In current scenario of climate change and its impact on the abundance of different insect species, it is highly important to have relevant data on the population fluctuation of different insect species from time to time. In this regard, we studied the seasonal abundance of two fruit fly species, *Bactrocera zonata* and *B. dorsalis* with respect to environmental factors in Hyderabad region. This paper provide novel data on population trend of fruit fly species with respect to meteorological data in Hyderabad region of Sindh. The study would be helpful in timely initiating various control tactics for fruit fly management in orchard agro-ecosystem of Sindh.

Author's Contribution

Muhammad Hamayoon Khan: Conceived the idea, conducted experiment, wrote the article and did overall management of the article.
Niaz Hussain Khuhro: Technical Input at every step, methodology.
Muhammad Awais: Data collection.
Muhammad Usman Asif: Did SPSS analysis.
Raza Muhammad: Critical review, improved technical writing.

Conflict of interest

The authors have declared no conflict of interest.

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