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Fluctuations in fruit fly abundance and infestation in sweet gourd fields in relation to varied meteorological factors

Md Ruhul AMIN[1], Nabanita Paul NANCY[1], Md Ramiz Uddin MIAH[1], Md Giashuddin MIAH[2], Ohseok KWON[3] and Sang Jae SUH[3]

[1] Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh
[2] Department of Agroforestry and Environment, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh
[3] School of Applied Biosciences, Kyungpook National University, Daegu, Korea

Correspondence
Sang Jae Suh, School of Applied Biosciences, Kyungpook National University, Daegu 41566, South Korea.
Email: sjsuh@knu.ac.kr

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Abstract

The study was conducted with the aim of furthering our understanding of seasonality in the population dynamics and infestation rates of the fruit fly *Bactrocera* spp. in sweet gourd (*Cucurbita moschata*) during winter and summer in 2017. We also investigated the effects of using methyl eugenol traps on fly abundance and infestation. Two fruit fly species, namely, *B. cucurbitae* and *B. dorsalis*, were present in the sweet gourd field, and we observed fluctuations in their abundance. Compared to *B. dorsalis*, *B. cucurbitae* was significantly more abundant in both winter and summer. Infestation level was found to be the highest in fields lacking methyl eugenol traps in both seasons. Fruit fly larval population per infested fruit was higher in summer than in winter. Fly abundance was significantly and positively correlated with mean temperature and rainfall but significantly and negatively correlated with light intensity. Relative humidity was insignificantly but positively correlated with fly abundance. The temperature, light intensity, relative humidity, and rainfall individually explained 48.9, 24.1, 0.8, and 1.6% of variation in fruit fly abundance, respectively. The combined effect of the weather parameters on fruit fly abundance was 75.4% and was significant predictor of fruit fly abundance.

Key words: *Bactrocera* spp., *Cucurbita moschata*, larvae, methyl eugenol.

Introduction

Sweet gourd (*Cucurbita moschata*) belongs to the family Cucurbitaceae and is a nutritive and unique crop that grows in tropical to temperate regions worldwide. It contains various phytoconstituents including flavonoids, alkaloids, and oleic, palmitic, and linoleic acids (Yadav *et al*. 2010). The fruit fly *Bactrocera* spp. is the most destructive pest of sweet gourd and other cucurbitaceous vegetables in Bangladesh and other tropical and subtropical regions. The flies can infest various cucurbit crop species in different seasons, and with infestation rates ranging from 30 to 100%, and they can heavily reduce both the yield and quality of fruits (IPM CRSP 2004; Nath & Bhusan 2006).

Seasonal variation in weather factors plays a vital role in the reproduction, growth, development, and distribution of insects and influences their population dynamics and infestation rates (Dhaliwal & Arora 2001). In a study of weather effects by Khan *et al*. (2003), rainfall showed to have the greatest effect on fruit fly population dynamics. Cue lure traps employ effective sex attractants that attract *Bactrocera* males, and thus, allowing the study of their population dynamics (Liu & Lin 1993; Zaman 1995). Cue lure traps can be used throughout the year to capture male flies regardless of variations in temperature, relative humidity, rainfall, and sunshine.

Bangladesh is a subtropical country where sweet gourd as well as other cucurbitaceous vegetables especially bottle gourd, bitter gourd and ash gourd have been cultivated year round all over the country. Due to the availability of the host sources, fruit flies prevail in Bangladesh throughout the year and cause infestation in sweet gourd and other cucurbitaceous vegetables. Prevailing higher temperature, relative humidity and rainfall in Bangladesh is favorable for growth and reproduction of the flies and variation of the weather factor in different season interrupts the population dynamics of the insect.

Farmers in Bangladesh have mostly relied on synthetic chemical insecticides for the management of fruit fly but they have not received sufficient output because of the internal feeding behavior of the larvae. Data on population dynamics can provide information for forecasting, allowing farmers to take precautions for integrated management of the pest. Methyl eugenol traps are used in eco-friendly pest management programs.

In Bangladesh, there is scarcity of information on the population dynamics of fruit flies on sweet gourd regarding meteorological factors. The primary objective of the present study was to monitor fruit fly populations during the winter and summer seasons to determine the influence of meteorological factors such as temperature, light intensity, relative humidity, and rainfall on the population dynamics of this pest. The overall goal was to monitor the seasonality of fruit flies with the aim of using any newfound knowledge to formulate further effective control strategies for this pest.

Materials and methods

The study was conducted in the experimental field of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh from November 2016 to February 2017, and from March 2017 to June 2017. The area is located at 25°25′N, 89°5′E and has a subtropical *climate*.

Experimental design and cultivation of sweet gourd

Sweet gourd (*Cucurbita moschata*) was cultivated in six plots following a randomized complete block design with a plot size of 9.0 × 6.0 m. The spacings between blocks and between plots were 1.5 m and 1.0 m respectively. The plots were separated by cultivations of maize which acted as fences. Fertilizers were purchased from the Bangladesh Agricultural Development Corporation (BADC) enlisted shop at Gazipur in Bangladesh, and were applied according to the Fertilizer Recommendation Guide (FRG 2012) (N, 120 kg; P, 70 kg; K, 40 kg; S, 20 kg per hectare). The subsequent two sowings were done in each plot on November 02, 2016 for the winter plantation and March 15, 2017 for the summer plantation. All the plots contained three rows and each row contained five pits spaced 60 cm apart from one another. After the emergence of seedlings, the plants were supported by bamboo scaffolds to facilitate creeping. Intercultural operations were performed whenever necessary.

Observation of fruit fly abundance, rate of fruit infestation and abundance of larva per fruit

The abundance of adult fruit flies was monitored using methyl eugenol traps (Ispahani Biotech, Gazipur, Bangladesh) during the fruiting stage of the plants. The traps were set in three plots according to the methods of Khan and Naveed (2017). In each experimental plot, one trap was set to catch male flies. Traps were not placed in three plots, which were used as control plots. Monitoring continued from transplantation through to harvesting and data were recorded from January 10 to February 28 for the winter plantation, and from May 08 to June 20 for the summer plantation. Traps were checked weekly and the number of males caught in each trap was counted. During every inspection, the number of fruit per plot and the number of infested fruit per plot were counted and the percentage of fruits which were infested was calculated. To ascertain larval abundances, the infested fruits were brought to the Entomology Laboratory of BSMRAU and the number of larvae found inside the fruits was counted. In total eight fruits were investigated in each season to count the abundances of larvae.

Collection of weather data

Light intensity was measured using a digital light meter positioned at the height of the plant canopy (Model 401025, Extech Instruments Corporation, Nashua, NH, USA) throughout the fruiting period. Data were collected weekly between 10.00 h and 11.00 h during day. Mean daily temperature, relative humidity, and rainfall data were collected from the BSMRAU weather station which is located 250 m away from the experimental field.

Data analysis

One-way analysis of variance (ANOVA) followed by Tukey post-hoc testing was used in the analysis of fly abundance and infestation level. Comparisons were made between the number of observed larvae per fruit in the winter and summer plantations using a Student's t-test (paired sample). Linear regression between fly abundance and meteorological parameters followed by ANOVA and multiple regression model along with fly abundance and meteorological factors were calculated. All the analyses were performed using IBM SPSS 19.0.

Results and discussion

Two fruit fly species, namely, *B. cucurbitae* and *B. dorsalis*, were observed in the sweet gourd field during both winter and summer. Fluctuations in the abundances of these two species were also observed (Fig. 1). In winter, *B. cucurbitae* increased in abundance from the second week of January, increasing before reaching peak abundance in the fourth week of February. Temperature, light intensity, and relative humidity at this time were 25.5°C, 620 lx, and 91%, respectively, and there was no rainfall during this period (Table 1). *B. dorsalis* reached peak abundance in the second week of February. At this time, temperature, light intensity, and relative humidity were 25.5°C, 510 lx, 82%, respectively, and there was no rainfall during this period (Table 1). In summer, *B. cucurbitae* increased in abundance from the second week of May and reached peak abundance in the second week of June, at which point temperature, light intensity, relative humidity, and rainfall were 26.5°C, 241 lx, 85%, and 120.1 mm, respectively (Table 1). *B. dorsalis* reached peak abundance in the third week of May when temperature, light intensity, relative humidity, and rainfall were 27.5°C, 225 lx, 91%, and 35.7 mm, respectively (Table 1).

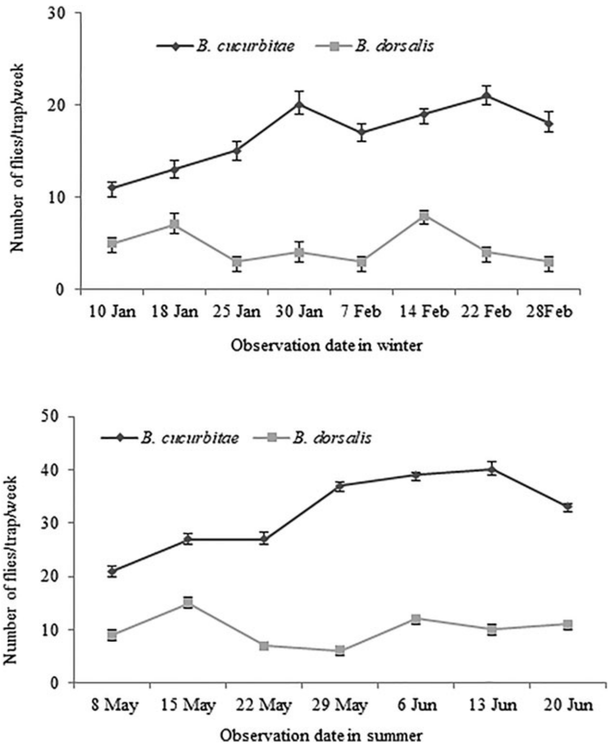

Figure 1 Abundances of fruit fly species in the sweet gourd field during winter and summer 2017.

Abundance of fruit fly varies with geographical locations, season of the year, host plants and fruiting period of the host plants. Raghuvanshi *et al.* (2012) monitored the abundance of fruit fly by using parapheromone baited traps and found that the male *B. cucurbitae* were prevalent throughout the period except for a few weeks in January. Kawashita *et al.* (2004) studied the population dynamics of fruit fly *B. cucurbitae* in Sri Lanka and reported the peak abundance of the fly from April to July.

The mean abundances of both fruit fly species during the study ranged from 4.6 ± 0.7 to 30.0 ± 2.7/trap/week and differed significantly from one another (Fig. 2; $F_{3, 26} = 55.8$, $P < 0.001$). *B. cucurbitae* was present at significantly higher abundances than *B. dorsalis* in both seasons, being the most abundant in summer. The emergence of fruit flies was associated with the reproductive stages of the plants, and their abundance also depended on the weather conditions and the time of the season. These findings are in accordance with those of Fayyaz *et al.* (2016), who observed fluctuations in insect abundances in sweet gourd fields in Pakistan. They also

Table 1 Meteorological data during winter and summer in 2017 in Bangladesh

Observation date	Fly population	Mean temperature (°C)	Light intensity (lx)	Relative humidity (%)	Rainfall (mm)
10 January	16	19.0	530	81	0.0
18 January	20	18.0	560	89	0.0
25 January	18	19.5	520	90	0.0
30 January	24	20.0	586	80	0.0
07 February	20	22.5	557	90	0.0
14 February	27	22.5	510	82	0.0
22 February	25	25.5	620	91	0.0
28 February	21	22.5	700	82	0.0
08 May	30	29.5	380	78	0.0
15 May	42	27.5	225	91	35.7
22 May	34	31.5	410	79	0.0
29 May	43	30.5	389	85	0.0
06 June	51	27.0	400	85	0.0
13 June	50	26.5	241	85	120.1
20 June	44	25.0	330	92	6.5

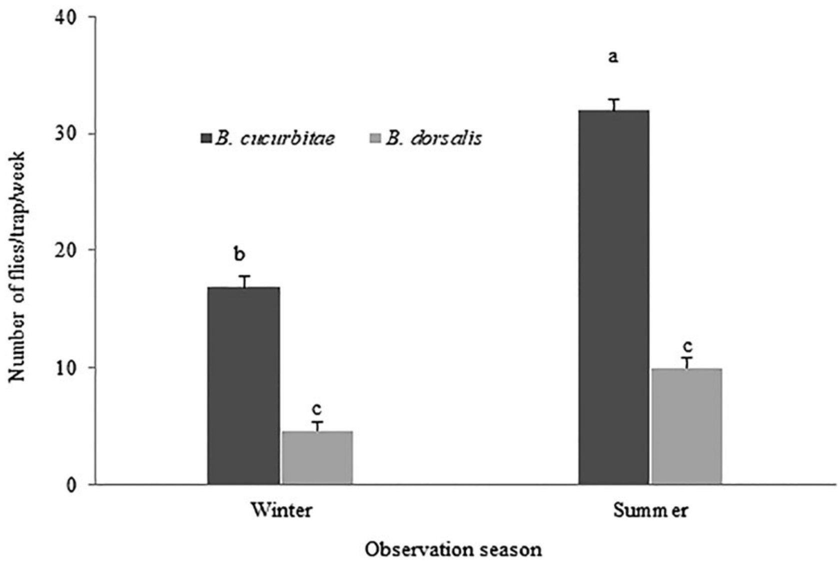

Figure 2 Abundances of fruit fly species in winter and summer in 2017. Data are expressed as mean ± SE. Bars with common letter are not significantly different based on Tukey post-hoc tests with a significance of $P < 0.05$.

reported that the insects were the most abundant in October and September but decreased in abundance toward July and August. There are large differences in the climatic conditions of Bangladesh and Pakistan, which may explain the variation in the timings of insect peak abundances when compared to our study. Vera *et al.* (2002) reported close relationship between fruit fly abundance and abiotic factors of the environment.

Both trapping treatment and season had significant effects on infestation rate (Fig. 3; $F_{3,\ 12} = 7.9$, $P < 0.05$). Fruit infestation level varied from 2.5 ± 2.5 to 66.7 ± 11.8%, with the highest infestation rate occurring in summer in plots without traps and the lowest in plots with traps during winter. The larval population per infested fruit varied from 404.6 ± 88.5 to 813.6 ± 88.6, and the results differed significantly between the seasons, with larval population per fruit being the highest in summer (Fig. 4; $T_7 = 3.3$, $P < 0.05$). Amin *et al.*(2011) reported that *B. cucurbitae* infested 71.5% of sweet gourd fruits and that the insect infested different cucurbitaceous crops to varying extents. Atwal and Dhaliwal (2005) reported that fruit flies infested 50% of cucurbit crops in India. The infestation level of fruit flies can vary from 30 to 100% based on variation in environmental conditions and the susceptibility of crop species (Dhillon *et al.* 2005; Gupta & Verma 1992). Chen and Ye (2006) reported that temperature also played a significant role in determining the infestation patterns of *B. dorsalis*.

Relationship between fly abundance and meteorological parameters are presented in Figure 5. Daily mean temperature was significantly and positively correlated with fly abundance ($y = -16.94 + 1.95x$, $r^2 = 0.489$, $F_{1,\ 13} = 12.5$, $P < 0.01$). Light

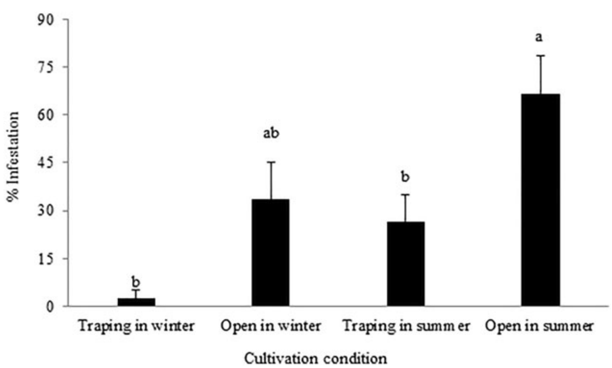

Figure 3 Effect of methyl eugenol trapping on the fruit infestation of sweet gourd by fruit flies in winter and summer 2017. Data expressed as % mean ± SE. Bars with common letter(s) are not significantly different based on Tukey post-hoc tests with a significance of $P < 0.05$.

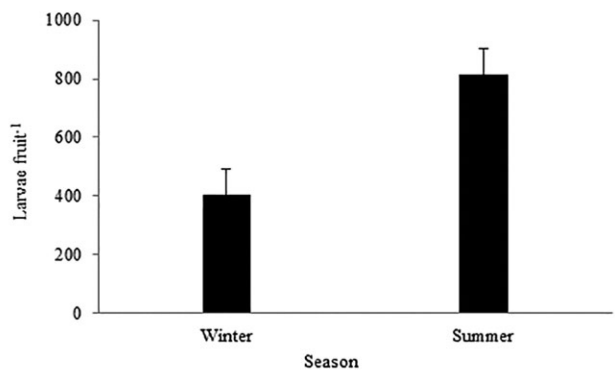

Figure 4 Seasonal abundances of fruit fly larvae in the infested fruits of sweet gourd. Data are expressed as mean ± SE number/fruit.

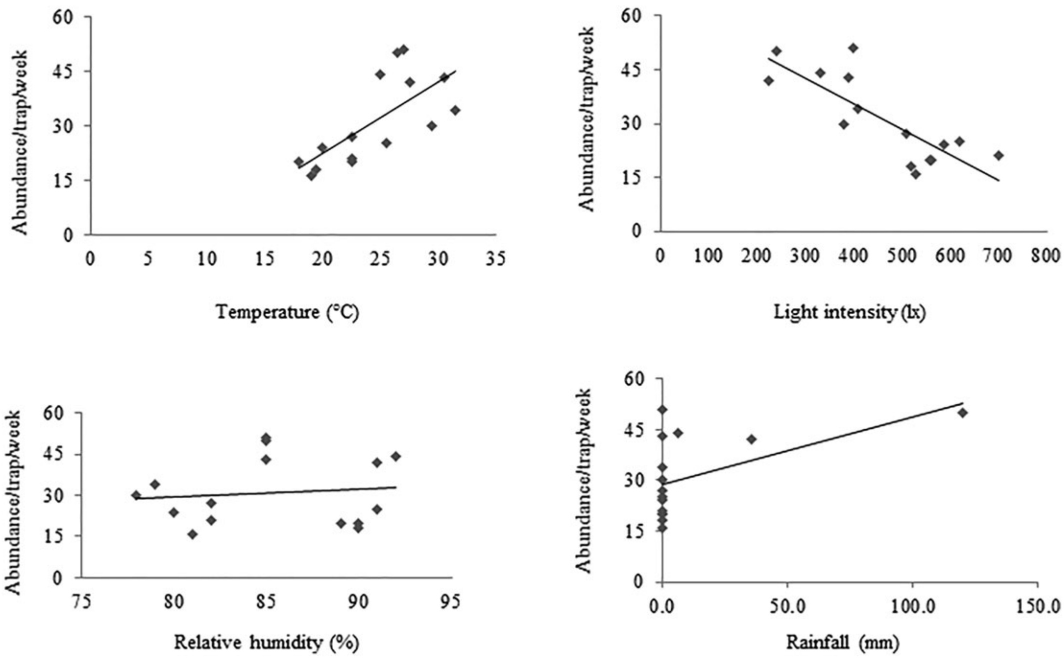

Figure 5 Relationship between meteorological parameters and fruit fly abundance in sweet gourd field during winter and summer in 2017.

intensity was significantly and negatively correlated with fly abundance (y = 64.01–0.071x, r^2 = 0.662, $F_{1,\ 13}$ = 25.5, P < 0.001). Relative humidity was positively but non-significantly correlated with fly abundance (y = 9.493 + 0.252x, r^2 = 0.010, $F_{1,\ 13}$ = 0.1, P = 0.72). Rainfall was significantly and positively correlated with fly abundance (y = 28.86 + 0.197x, r^2 = 0.266, $F_{1,\ 13}$ = 4.7, P < 0.05). Table 2 shows the results of the multiple regression analyses. Temperature explained 48.9% of the variation in fly abundance, and its effect on fly abundance was significant. Including light intensity in the regression model allowed explaining 73.0% of variation in abundance, which was, again, statistically significant. Variation in light intensity was thus responsible for 24.1% of the variation in fly abundance. Including both temperature and light intensity, as well as relative humidity, explained 73.8% of the variation in fly abundance, which was statistically significant. Humidity alone thus explained 0.8% of the variation in fly abundance. Rainfall explained 1.6% of the variation in fly abundance. Combining all measured meteorological variables explained 75.4% of the variation in fruit fly abundance, which was statistically significant. Fruit flies remain active on various host plants throughout the year, but they commonly hide and aggregate under the dried leaves of bushes and trees during the cold season. High temperatures, long periods of sunshine, and plantation activity have strong influences on their reproduction and abundance (Lee *et al.* 1992).

Weather factors, particularly temperature and rainfall, are the main meteorological parameters influencing the distribution of fruit flies. Papadopoulos *et al.* (2001) reported that both weather factors and host plants have significant effects on the population dynamics of fruit flies. The abundances of fruit flies were positively correlated with temperature and slightly negatively correlated with relative humidity (Khan & Naveed 2017).

Bactrocera spp. are highly polyphagous and they infest more than 300 host plants under 40 families.

Table 2 Multiple regression models along with coefficients of determination (R^2) analyzing the effect of weather parameters on the seasonal abundances of fruit flies during winter in 2016 and summer in 2017

Regression equation	R^2	%Role of individual factor	F statistic	
$Y = -16.949 + 1.96 X_1$	0.489	48.9	$F_{1,13} = 12.5$	$P < 0.01$
$Y = 33.616 + 0.915 X_1 – 0.054X_2$	0.730	24.1	$F_{2,12} = 16.2$	$P < 0.01$
$Y = 8.183 + 1.028X_1 – 0.051X_2 + 0.248X_3$	0.738	0.8	$F_{3,11} = 10.4$	$P < 0.01$
$Y = -2.299 + 1.157X_1 – 0.040X_2 + 0.268X_3 + 0.061X_4$	0.754	1.6	$F_{4,10} = 7.6$	$P < 0.01$

Y, insect population/trap/week; X_1, temperature (°C); X_2, light intensity (lux); X_3, relative humidity (%); X_4, rainfall (mm).

Kapoor (1993) reported that the fruit fly species *B. cucurbitae* and *B. zonata* were active in India throughout the year except for a short period from December to the middle of February when the temperature was very cold. Nasiruddin *et al*. (2004) showed that the incidence of fruit flies on cucurbit in Bangladesh was throughout the year and reached to the highest in February and in September. The population of fruit fly declines during the hot and dry season, when they take shelter in humid and shady places and feed on honeydew of aphids infesting the fruit trees.

The present findings show that the abundance of fruit flies was lower during the colder and drier months and that their abundances only begin to increase with the onset of the rainy season, coinciding with the production of tender fruits. Methyl eugenol trapping reduced infestation rate in both seasons, and so we recommend its incorporation into control regimes as an eco-friendly method of pest control in sweet gourd fields.

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