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Population fluctuations of economically important male Dacine fruit flies (Diptera: Tephritidae) at Savar, Dhaka

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Abstract
Population fluctuations of male fruit flies were monitored using Hawaii traps baited with parakairomone lures (methyl eugenol, cue lure and zingerone) for one year (Nov 2017–Oct 2018) at ten different sites at Savar, Dhaka, Bangladesh. A total of 73,188 flies were collected, which belong to 16 species and dominated by *Bactrocera dorsalis* (56.99%), *Zeugodacus cucurbitae* (22.90%), *Z. tau* (14.30%) and *B. rubigina* (3.40%). *B. zonata*, *B. correcta* and *Dacus longicornis* were collected in much smaller numbers. Population fluctuations of *B. dorsalis*, with peaks in July, was positively correlated with minimum temperature (r=0.68), maximum temperature (r=0.50), rainfall (r=0.86) and host availability. It was similar to *B. zonata* and *B. rubigina*. *Z. cucurbitae* population peaked in March and have no clear correlation with maximum temperatures and rainfall. Captures of *Z. tau* and *D. longicornis* were inversely related to rainfall, having abundance peaks in the dry winter months.

Keywords: Fruit fly, population fluctuation, parakairomone lures, temperature, rainfall

Introduction
True fruit flies (Diptera: Tephritidae) are the most devastating insect pests of horticultural crops throughout the tropical and subtropical regions [6, 7, 16, 36]. They lay eggs in the fruits, vegetables and cucurbit flowers. Fruit fly larvae feed in the fruit, vegetable and flower flesh, infested crops quickly become rotten and inedible, resulting significant yield losses, between 30 and 100% on the basis of the fruit species and season [10]. Besides causing a huge direct losses to a wide variety of horticultural crops, fruit flies limit the development of commercial agriculture in many countries because of strict quarantine restrictions imposed to prevent their spread [17]. Dacini fruit flies are frugivorous or florivorous, and among them, about 10% of the reported species are considered as the pests of commercial fruits and vegetables [11, 13, 36, 41]. The fruit fly genera *Bactrocera*, *Zeugodacus* and *Dacus* are of serious concern throughout the Old-World tropics, causing a significant problem to agricultural commodities. Among the 34 recorded dacini fruit flies of Bangladesh, 13 are pest and 21 are non-pest species. The most destructive fruit fly pest in this country are *Bactrocera dorsalis* (Hendel), *Zeugodacus cucurbitae* (Coquillett), *Zeugodacus tau* (Walker), *Bactrocera zonata* (Saunders), and the recently discovered *Bactrocera carambolae* (Drew & Hancock) [26-28, 30]. In Bangladesh, most of these species have been found repeatedly in survey and monitoring traps in all the 64 districts. Field research on different dacine fruit flies in Bangladesh has mainly focused on surveying the species diversity [27-29]; studying their damage [2, 20]; developing management strategies for cucurbit infesting species [3, 9, 22-23]; and preliminary population cycle monitoring [5, 8, 34]. Traditional control methods, including the use of the chemical pesticides have many disadvantages, for example, pesticide residues in food, environmental pollution and the ineffectiveness of the pesticides to penetrate infested crops to kill larvae. Moreover, the peoples demand for pesticide-free fresh crops is increasing day by day, eventually the use of environmentally benign methods of pest suppression have been encouraged. Fruit flies of the tribe Dacini is a well-suited insect group to demonstrate how pests can be efficiently managed using minimal quantities of pesticide by integrating the use of parakairomone lures, food-based attractants, augmentative parasitoids releases, crop sanitation, and sterile male insect fruit fly suppression program in a specific agro-ecosystem, baseline information on levels of fruit infestation and the releases into an AW-IPM program, as was successfully implemented in Hawaii [33, 35, 37].

For designing an effective seasonal occurrence of the pest species relating to host species availability and weather parameters is essential. That data will help to formulate the appropriate process of fruit fly suppression and timing of taking action [24]. One of the prime requirements for an effective AW-IPM program, with a view to establishing sustainable agriculture in Bangladesh, is to monitor populations of fruit flies regularly. The investigation shows the outcome of one year of parakairomone lure trapping for 7 dacine fruit flies i.e., *Zeugodacus cucurbitae*, *Z. tau*, *Dacus longicornis* (Wiedemann) infesting of cucurbit vegetables; *B. dorsalis*, *B. correcta*, *B. zonata* (Bezzi) infesting common fruits; and non-pest *B. rubigina* in relation to environmental abiotic factors (temperature and rainfall) and seasonal abundance of host in Bangladesh, to help improve management of these notorious fruit fly species.

Materials and Methods

The experiment was conducted for one full year (November2017 to October 2018) at different parts of the Atomic Energy Research Establishment (AERE) (N 23.954° E 90.280°), Savar, Dhaka, Bangladesh, a 263.5-acre Government owned office area having agricultural lands, orchards, ponds, dendrarium and concrete buildings. Different kind of vegetables (cucurbitaceous and solanaceous vegetables) and fruit trees (mango, banana, guava, starfruit, citrus, sapodilla, etc.) are grown in village-style small gardens (in front of the residential buildings). There are some large orchards of mango and jackfruit. This campus was selected because of convenient access, and for a huge variety (almost all the common vegetables and fruits) of fruit and vegetable crops cultivated in Bangladesh were represented and commonly affected by the fruit flies. Starting November 01, 2017, 3 traps containing the parakairomone lures (methyl eugenol, cue-lure, and zingerone) were set in the branch of trees, (height-1.8 m). Each of the 10 sampling sites were about 10 m apart, throughout the AERE area as described by Hossain *et al*., 2019 [18].

Fig 1: Fruit fly collection trap with plastic rooftop.

Tangle-Trap adhesive was added on the wire with which the traps were hung for avoiding the ant attack. Plastic plates (Diameter= 15 cm) were placed over the traps as rooftop to protect traps flooding by the rain. To get fresh fruit fly specimens for the molecular study about 10ml of 25% Propane 1,2diol (PPG) was poured inside the plastic traps. The flies in the traps were collected, brought at the fruit fly research laboratory, Insect Biotechnology Division, Institute of Food and Radiation Biology, Savar, Dhaka. After that the flies were counted and identified observing its morphological features. For the confirmation of the identified species, samples were preserved in 95% alcohol and sent to Dr. Luc Leblanc, taxonomist of University of Idaho, USA. Host plant diversity (at the fruiting stage) was recorded monthly. The data regarding the temperature and rainfall were collected from the Bangladesh Meteorological Department, Dhaka, Bangladesh. Mean (±SE) monthly FTD (flies-per-trap-per-day) was calculated using the Microsoft excel. The population fluctuations of these fruit fly species in relation to different abiotic factors (i.e., rainfall, temperature) and host fruit availability (no. of fruiting host species available monthly) were analyzed using the Pearson correlation coefficient, based on monthly FTD for the ten trapping or sampling sites regularly monitored throughout the one year (Table 2).

Results

A total of 16 species and 73,188 dacine fruit flies were captured throughout a full year of trapping or sampling (Table 1). The four major or dominant species were *B. dorsalis* (56.99%), followed by *Z. cucurbitae* (22.90%), *Z. tau* (14.30%), and *B. rubigina* (3.40%). There are three other fruit fly species, collected in smaller numbers, *viz*., *B. zonata* (673 specimens) and *B. correcta* (115 specimens) and cucurbit pest *D. longicornis* (753 specimens) (Table 1). Other species collected in minuscule numbers and not included on the figures were *B. nigrifacia* (59 specimens), *Z. diversus* (51), *B. abbreviata* (27), *B. digressa* (26), *B. syzygii* (17), *B. nigrofemoralis* (13), *B. propinqua* (7), *B .tuberculata* (2) and *Z. cilifer* (1). Documented host plant gives information that a wide diversity of host fruits and vegetables were present throughout the whole year at AERE (Table 3).

Table 1: Summary of collected fruit fly species at AERE, Savar, Dhaka from Nov. 2017-October 2018.

Name of the species	Lures	No. flies collected	Pest status
Bactrocera dorsalis (Hendel)	Methyl eugenol	41712	Major polyphagous fruit pest
Bactrocera zonata (Saunders)	Methyl eugenol	673	Major polyphagous fruit pest
Bactrocera correcta (Bezzi)	Methyl eugenol	115	Polyphagous fruit pest
Bactrocera rubigina (Wang & Zhao)	Cuelure and Zingerone	2507	Non pest
Bactrocera abbreviata (Hardy)	Zingerone	27	Non pest
Bactrocera nigrifacia Zhang, Ji& Chen	Cuelure and Zingerone	59	Non pest
Bactrocera nigrofemoralis White &Tsuruta	Cuelure	13	Non pest
Bactrocera propinqua (Hardy & Adachi)	Cuelure	7	Non pest
Bactrocera tuberculata (Bezzi)	Methyl eugenol	2	Oligophagous fruit pest
Bactrocera syzygii White &Tsuruta	Zingerone	17	Non pest
Bactrocera degressa Radhakrishnan	Cuelure	26	Non pest
Zeugodacus cucurbitae (Coquillett)	Cuelure and Zingerone	16759	Major pest of Cucurbitaceous and Solanaceous vegetables
Zeugodacus tau (Walker)	Cuelure	10466	Major pest of Cucurbitaceous and Solanaceous vegetables
Zeugodacus diversus (Coquillett)	Methyl eugenol and Zingerone	51	Pest of Cucurbits at the flowering stage
Zeugodacus cilifer (Hendel)	Cuelure	1	Non Pest
Dacus longicornis (Wiedemann)	Cuelure	753	Minor pest of Cucurbits (*Luffa, Trichosanthes*)

Table 2: Correlation (Pearson) of captures of seven species of fruit flies (monthly) to the monthly mean rainfall, minimum and maximum temperature.

Species	parameters	R value	Comments
Bactrocera dorsalis	FTD vs min Temp	0.68	Positive correlation
	FTD vs max Temp	0.50	Positive correlation
	FTD vs Rainfall	0.86	Positive perfect correlation
Zeugodacus cucurbitae	FTD vs min Temp	-0.59	Negative correlation
	FTD vs max Temp	-0.48	Not significant
	FTD vs Rainfall	-0.47	Not significant
Zeugodacus tau	FTD vs min Temp	-0.85	Negative perfect correlation
	FTD vs max Temp	-0.91	Negative perfect correlation
	FTD vs Rainfall	-0.67	Negative correlation
Bactrocera rubigina	FTD vs min Temp	0.42	Not significant
	FTD vs max Temp	0.43	Not significant
	FTD vs Rainfall	0.50	Positive correlation
Dacus longicornis	FTD vs min Temp	-0.03	Not significant
	FTD vs max Temp	-0.17	Not significant
	FTD vs Rainfall	-0.16	Not significant
Bactrocera zonata	FTD vs min Temp	0.41	Not significant
	FTD vs max Temp	0.60	Positive correlation
	FTD vs Rainfall	0.21	Not significant
Bactrocera correcta	FTD vs min Temp	0.36	Not significant
	FTD vs max Temp	0.2	Not significant
	FTD vs Rainfall	0.34	Not significant

*FTD= Fruit fly trapped per day

Table 3: List of Major Host plants at AERE campus, Savar, Dhaka from November 2017-October 2018.

Months	Vegetable hosts	Fruit hosts
November'17	Sponge gourd, *Luffa aegyptiaca* Mill.; Bottle gourd, *Lagenaria siceraria* (Molina) Standl.; Snake gourd, *Trichosanthes cucumerina* L.)	Papaya, *Carica papaya* L.; Banana, *Musa* spp.; Star fruit, *Averrhoa carambola* L.; Lemon, *Citrus limon* (L.)
December'17	Bottle gourd, sweet gourd, *Cucurbita maxima* Duchesne;egg plant, *Solanum melongena* L.	Banana, Orange, *Citrus reticulata* Blanco; Papaya, Lemon
January'18	Bottle gourd, Sweet gourd, egg plant, tomato, *Solanum lycopersicum* L.	Jujube, *Zizyphus* spp.; Banana, Orange
February'18	Bottle gourd, Sweet gourd, Egg plant, Tomato	Jujube, Banana, Orange
March'18	Bottle gourd, Sweet gourd, Bitter gourd, *Momordica charantia* L.; Egg plant	Jujube, Papaya, Lemon, Banana
April'18	Teasel gourd, *Momordica dioica* Roxb.exWilld., Ribbed gourd, *Luffa acutangula* (L.) Roxb., Bitter gourd,	Mango, *Mangifera indica* L.; guava, *Psidium guajava* L.; Banana, Sapodilla, *Manilkara zapota* (L.)
May'18	Ribbed gourd, Bitter gourd, Cucumber, *Cucumis sativus* L.; Teasel gourd	Mango, Guava, Sapodilla, banana
June'18	Bitter gourd, Sponge gourd, sponge gourd, Ash gourd, *Benincasa hispida* (Thunb.) Cogn.; Teasel gourd, Cucumber	Mango, Guava, banana, sapodilla, Custard apple, *Annona squamosa* L.;
July'18	Snake gourd, Sponge gourd, Ash gourd, Bitter gourd, Teasel gourd	Mango, Guava, Sapodilla, Custard apple, Banana, Pumello, *Citrus maxima* Merr.
August'18	Sponge gourd, Ash gourd, Snake gourd, Teasel gourd	Guava, Mango, Banana, Custard apple, pumello, Star fruit, *Averrhoa carambola* L.
September'18	Sponge gourd, Snake gourd, Teasel gourd, Egg plant	Star fruit, papaya, Banana, Pumello
October'18	Sponge gourd, Snake gourd, teasel gourd	Star fruit, papaya, banana, Pumello

B. dorsalis

The abundance of male oriental fruit fly at different months of the year has been shown in Fig 2. The highest fruit fly population trapped per day was recorded in the month of July (67.04±7.08.69) and the lowest was in February (5.27±0.80). The results revealed that the population increase of *B. dorsalis* starts from April onwards and the maximum population is recorded during May-August with a major peak in July (Table 1). The population declines slowly from October to November after which it is a few existents up to March. From the Co-efficient of correlation (r) value (Table 2) it was clearly observed that fruit fly population mostly varies with rainfall (r=0.86), maximum temperature (r=0.68), minimum temperature (r=0.50), and host availability (Table 3). In the month of December-February a few fruit flies were captured in the methyl eugenol traps.

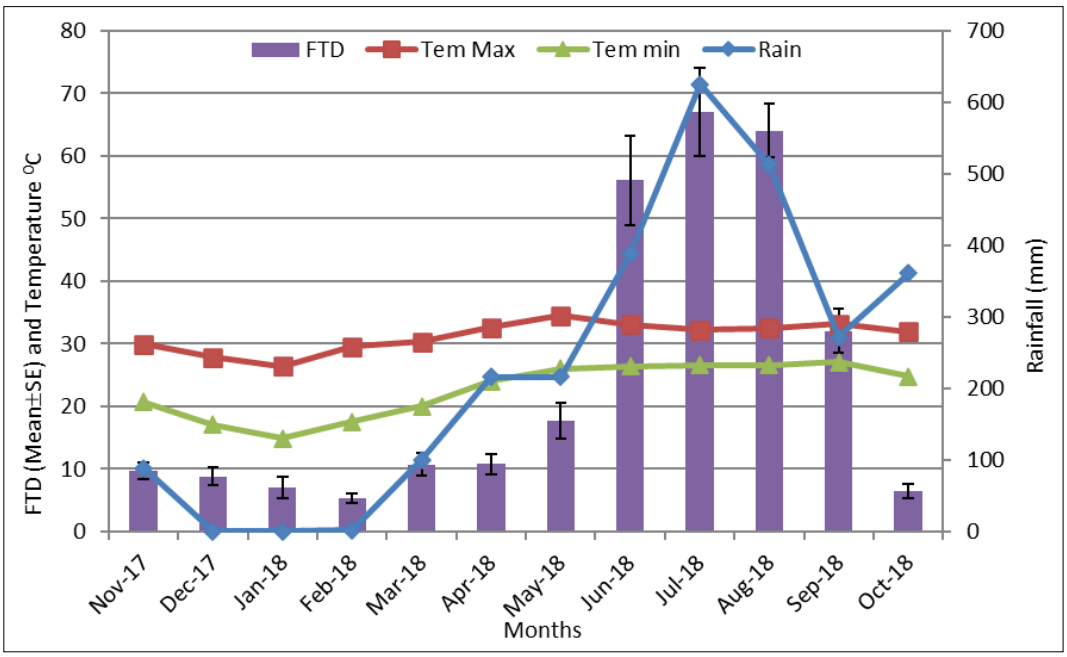

Fig 2: Month-wise population fluctuations of *B. dorsalis* in relation to rainfall, minimum and maximum temperature.

Z. cucurbitae

The abundance of *Z. cucurbitae* in different months has been presented in Fig 3. The highest *Z. cucurbitae* population trapped per day was recorded in the month of March (21.46±3.19) and the lowest was in October (2.39±0.53). It was observed that the population increase of melon fly starts from November onwards and the maximum population is recorded during February-April with a major peak in March. The population declines slowly from May to September after which it is a few existent up to October. Month wise population fluctuation of *Z. cucurbitae* was negatively correlated (r=-0.59) with minimum temperature and host availability. No significant correlation was found with rainfall and maximum temperature (Table 2).

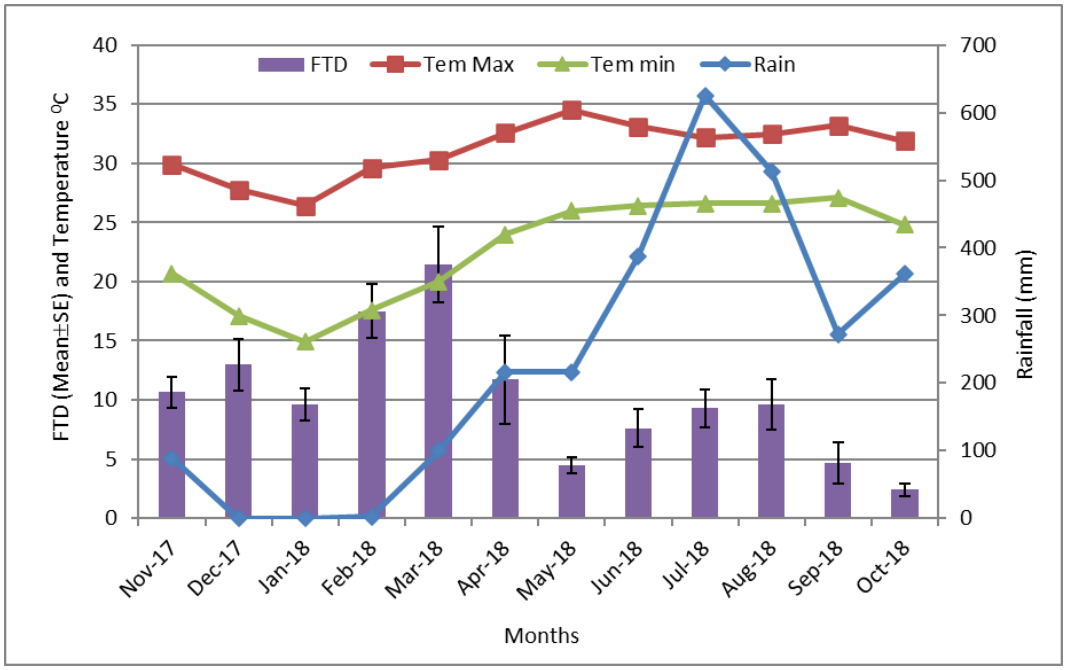

Fig 3: Month wise population fluctuations of *Z. cucurbitae* in relation to rainfall, minimum and maximum temperature.

Z. tau

The population fluctuation of male pumpkin fruit fly at different months of the year has been presented in Fig 4. The highest *Z. tau* population trapped per day was recorded in the month of July (16.53±4.3) and the lowest was in February (1.04±0.20). It was noted that the population increase of pumpkin fly starts from October onwards and the maximum population is recorded during December-February with a major peak in January. From r value (Table 2) it was clearly observed that fruit fly population mostly varies with rainfall (r= -0.67), maximum temperature (r=-0.85), minimum temperature (r=-0.91) and host availability (Table 3).

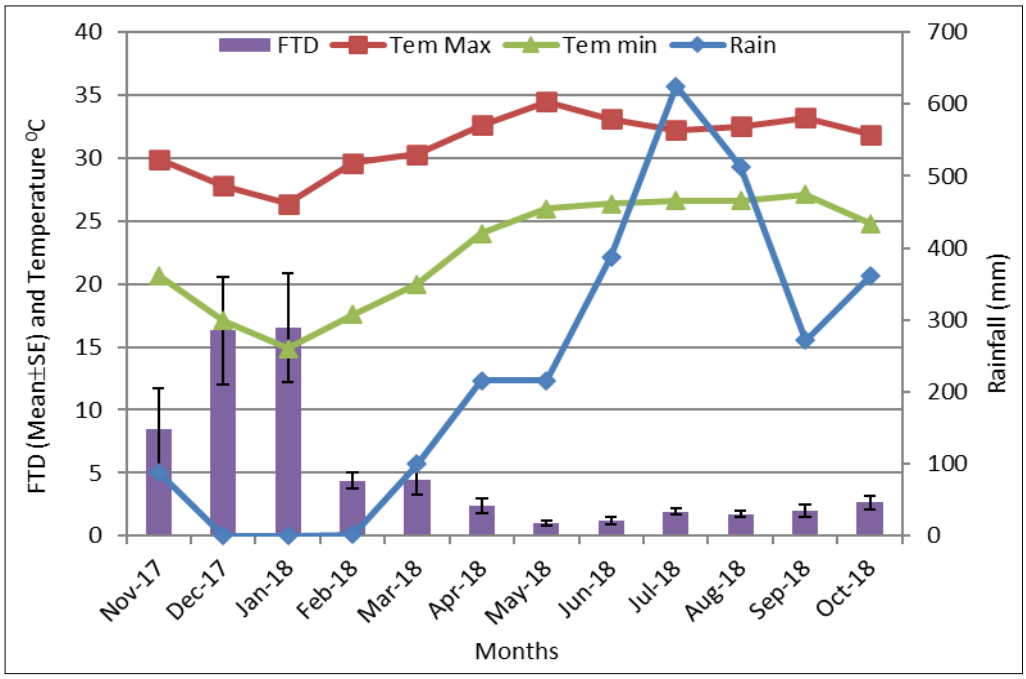

Fig 4: Month wise population fluctuations of *Z. tau* in relation to rainfall, minimum and maximum temperature.

B. zonata

The abundance of *B. zonata* in different months has been presented in Fig 5. The highest peach fruit fly population trapped per day was noted in the month of May (3.05±0.05). Month wise population fluctuation of *Z. zonata* was positively correlated with maximum temperature (r=-0.60) and host availability. No significant correlation was found with rainfall and minimum temperature (Table 2).

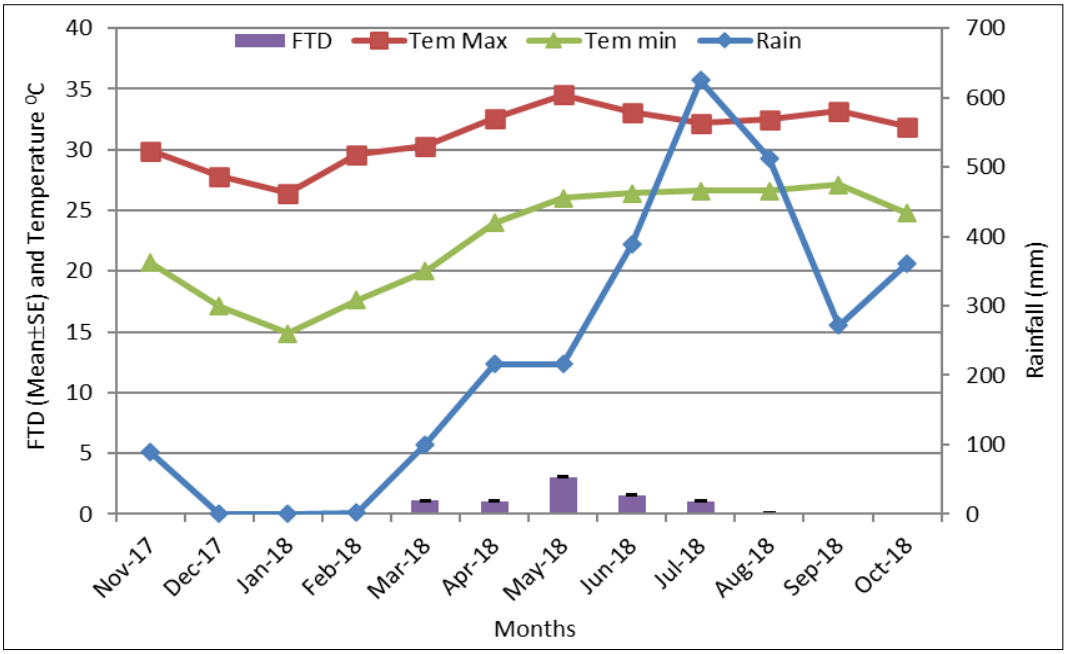

Fig 5: Month wise population fluctuations of *B. zonata* in relation to rainfall, minimum and maximum temperature.

B. correcta

The population fluctuations of male *B. correcta* at different months of the year has been presented in Fig 6. From the result, it was noted that the *B. correcta* population at AERE campus was very low. The highest fruit fly population trapped per day was noted in the month of October (1.50±0.005). No significant correlation was found with rainfall and temperature (Table 2).

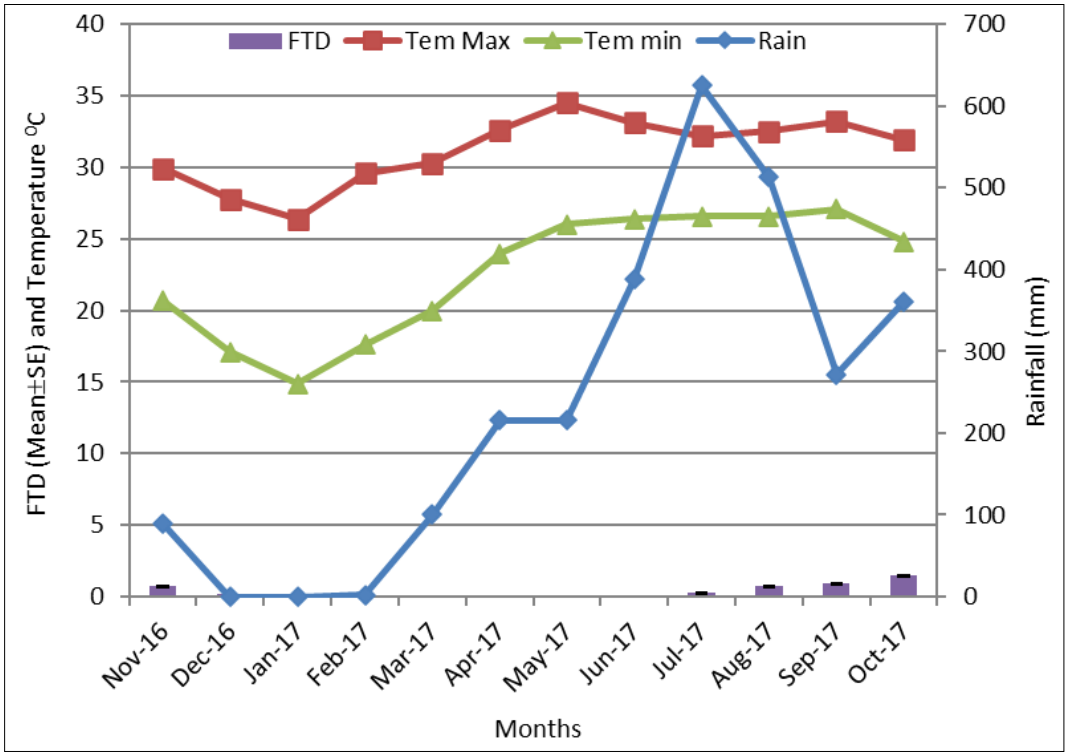

Fig 6: Month wise population fluctuations of *B. correcta* in relation to rainfall, minimum and maximum temperature.

B. rubigina

The population fluctuations of male *B. rubigina* at different months of the year and trapped by using cuelure and Zingerone baited traps has been presented in Fig 7. The highest fruit fly population trapped per day was recorded in the month of June (1.69±0.52) and the lowest was in October (0.10±0.05). Month wise population fluctuation of *B. rubigina* was positively correlated (r=0.50) with rainfall. No significant correlation was found with temperature (Table 2). The host plant of *B. rubigina* has yet to be recorded in the world.

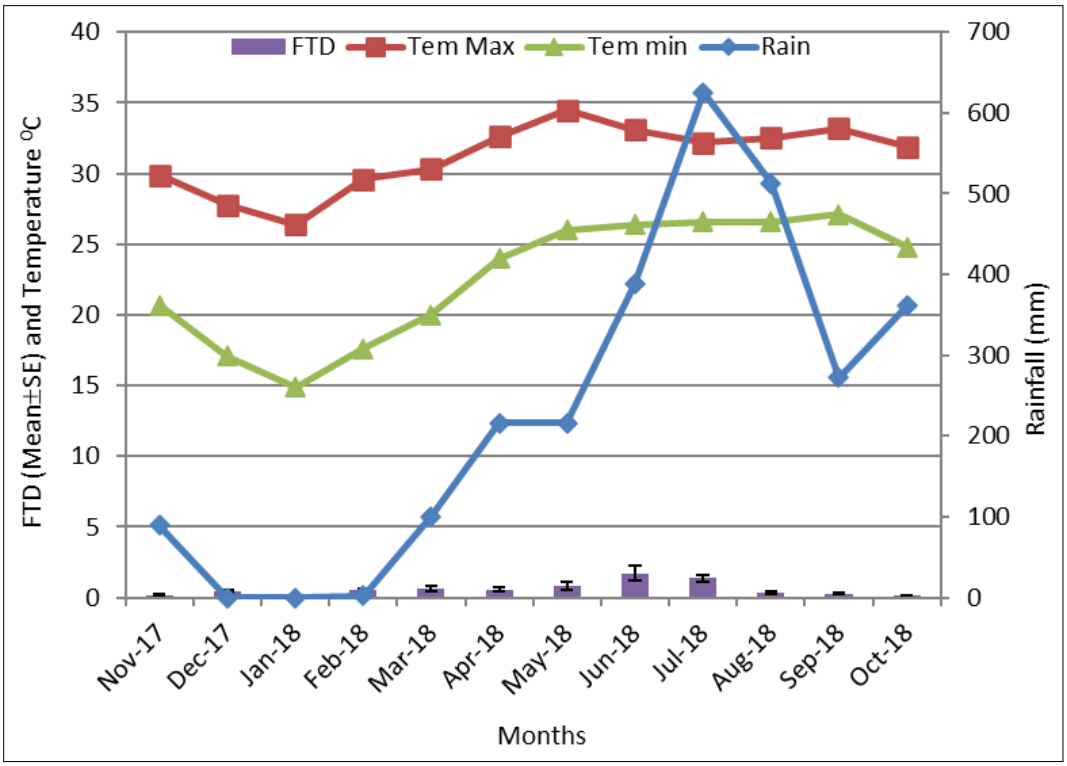

Fig 7: Month wise population fluctuations of *B. rubigina* in relation to rainfall, minimum and maximum temperature.

D. longicornis

The population fluctuation of *D. longicornis* male at different months of the year has been presented in Fig 8. The highest fruit fly population trapped per day was noted in the month of October (1.81±0.18). No significant correlation was found with rainfall and temperature (Table 2).

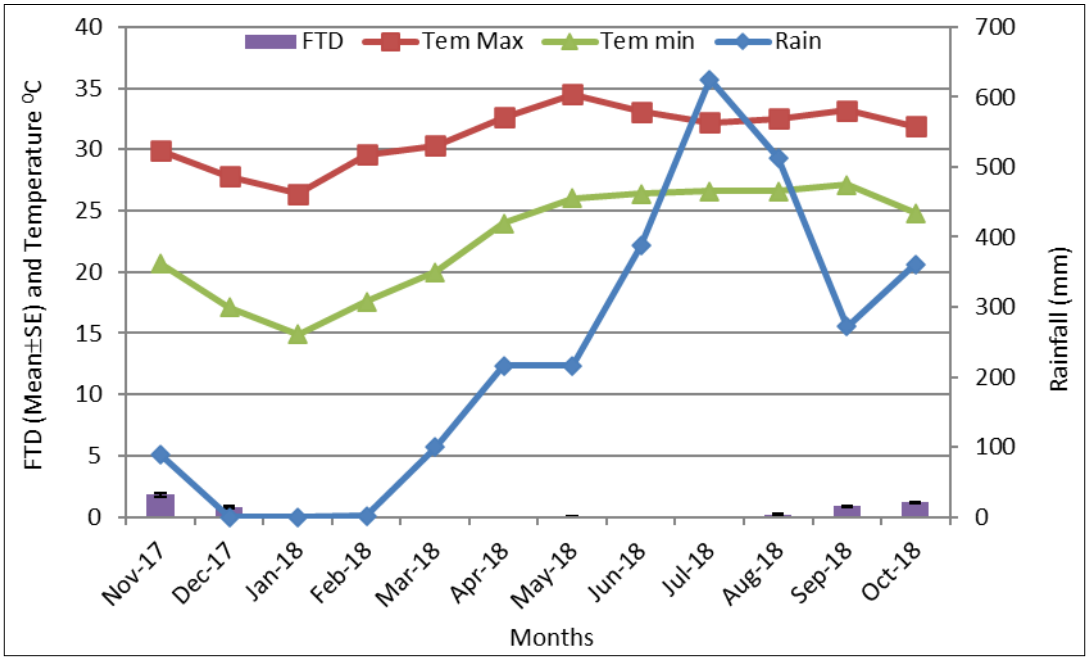

Fig 8: Month wise population fluctuations of *D. longicornis* in relation to rainfall, minimum and maximum temperature.

Discussion

For most of the fruit-infesting species especially for *B. dorsalis*, there is positive correlation between monthly population fluctuation and the abiotic factors i.e., rainfall, temperature, and host availability. At AERE campus, capturing the colossal amount of *B. dorsalis* in methyl eugenol baited traps and its peaks of abundance in the month of July aligns with the findings of the studies in Chapai Nawabganj, Bangladesh [34], Hawaii [26, 38-40], Kunming, China [42], and India [14]. Most of the non-grafted gutti varieties were matured in the month of May throughout Bangladesh, and the no. of fruit fly populations started increasing. During the harvesting time of mangoes, guavas and carambola (June to August), the fruit flies species were found most abundant. Population fluctuations of *B. zonata* at AERE campus were similar to that of *B. dorsalis*, even though comparatively captured in much lower numbers, having slightly earlier peaks during wet season. A strong and positive correlation was found with the rainfall again within the peak season of two of its main hosts i.e., mango and guava. These are in accordance with the findings of several studies which are related to seasonal trends documentation, under higher levels of pest population, in Bangladesh [18-19], India [1], Pakistan [32], and Egypt [4, 12]. Abundance of *B. rubigina* were also similarly correlated with rainfall and temperature [28]. Although being widely distributed throughout tropical Asia including Bangladesh, its major host plant, different from the *Litsea verticillata* host which has lower distribution, recorded in China [31], has yet to be described in Bangladesh. It is suspected that it may lay eggs on Melastomataceae flowers, as two other very closely related pest species do [25]. The first report of *B. correcta* from Bangladesh is in 2014 and it is not so common as pest in this country [26], and associated with locally cultivated fruit for example guava, mango, and sapodilla [21]. Its number of captures were not high enough to conclude about the seasonal abundance and correlation of it to different factors.

On the other hand, captures of *Z. cucurbitae*, the second most abundant fruit fly species at the investigation area, peaked in March 2018, starting of the rainy season. While at the last part of the rainy season melon fly populations decreased. Summer population peaks for *Z. cucurbitae* were strongly aligns with those studies reported in Hawaii [15, 26, 39-40], West Bengal, India [24] and Bangladesh [5, 18].

The number of captures of *Z. tau* and *D. longicornis* were inversely related to abiotic factors i.e., temperature and rainfall (Table 2). The highest population of these fruit fly species was found in the dry and cooler months of winter. The population of *Z. tau* increased in December but during the month of rainy seasons its scarcity was observed at AERE which is similar to that of Hossain *et al.* 2019 [18]. The seasonal abundance of these species may be driven by a locally dominant cucurbit host, possibly pumpkin (*Cucurbita maxima*) for *Z. tau* and *Luffa* gourds for *D. longicornis*. To confirm this hypothesis, further investigation regarding the systematic host fruit surveys will be required.

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