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Diversity and abundance of fruit flies (Family: Tephritidae) in Myanmar's tropical region and preliminary prospects for further AW-IPM

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Abstract
Because of flying distance, multi-host range, high reproduction, communication and adaptation to new environments, fruit flies were considered as one of the most destructive pests in the world. In this research, fruit flies surveillance, infestation percentages in mangoes and population dynamics of *Bactrocera dorsalis* were performed from 2016 to 2018 in Myanmar's tropical region. During three years survey, the abundance of oriental fruit flies, *B. dorsalis* on the tropical fruits is 57% among the other fruit flies. Twenty-one species of fruit flies were identified by collecting specimens from both traps and infested fruits. Among them, we found that *B. dorsalis*, *B. correcta* and *B. cucurbitae* are economically important fruit flies. The percentages of fruit fly infestations are increasing year by year from 2016 to 2018. The highest infestation on the host plant (mangoes) was 78.2±6.5%. According to the metrological data, *B. dorsalis* populations dynamic indicated that the highest flies/traps/days (FTD) numbers reached at a peak in June of each year (2016, 2017 and 2018). Therefore, our results reveal that the oriental fruit fly, *B. dorsalis* dominate among the other fruit flies and fruit fly infestation percentages are very high in Myanmar's tropical region.

Keywords: Surveillance, economically important fruit flies, fruit fly infestation, population dynamics

Introduction
Although there are many different kinds of fruit fly trapping agents, methyl eugenol (ME), trimedlure, cue-lure, protein bait were effectively used to monitor fruit fly surveillance with Steiner trap, McPhail trap among different kinds of traps [1]. ME with neonicotinoid insecticides were used to evaluate attract and kill system against male oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). [2]. The trapping system with the different formulation (ME+insecticides) caught *Dacus dorsalis* as predominant species in Malaysia [3]. Queensland fruit fly, *B. tryoni* (Frogatt), the Mexican fruit fly, *Anastrepha ludens* (Loew), the Pacific fruit fly, *B. xanthodes* (Broun), and the peach fruit fly *B. zonata* (Saunders) were also serious pests in Hawaii, USA [4]. Feeding lures increased fecundity of mated females on *B. tryoni* (Froggatt) (Diptera: Tephritidae) but direct fitness benefit was not appear on *B. dorsalis* (Hendel) and *Zeugodacus cucurbitae* (Coquillett) [5].
Analysis of structural genetic indicates that flying distance of fruit fly is freely long across the geographic regions [6]. Improving fruit fly control system such as suppression, detection, eradication by di or trifluorinated ME allows effectiveness but fruit fly mortality can boost through fluorination. Natural phenylpropanoid ME have strongly attractive activities on the male oriental fruit fly, *B. dorsalis* (Hendel) [7]. Trapping lures such as ME, cue-lure and trimedlure were used for the specific fruit flies such as oriental fruit flies (*B. dorsalis*), melon fly (*B. cucurbitae*) and Mediterranean fruit fly (*Ceratitis capitata*) respectively [8].
The population of *B. dorsalis* peaked in the three locations (Bangalore, India; Hawaii, USA; and Wuhan, China) by assessing Generic Pest Forecast System model although different situation were created [9]. The entries of fruit fly into traps were tracked by required optoelectric sensors in order to evaluate time-stamp, GPS tag and species identification [10]. The oriental fruit fly, *B. dorsalis* became one of the most serious pests in the mainland China. [11]. Specialized pheromone and lure application technology is an effective male annihilation controls [12].

Our research focus on the diversity and abundance of fruit flies on the tropical fruits of Myanmar in order to explore the economically important fruit flies in Myanmar. Preliminary research such as surveillance, morphological identification, fruit fly infestation in mangoes and population dynamics of *B. dorsalis* were conducted for further government plan of the area wide integrated pest management (AW-IPM) on fruit fly especially Sterile Insect Technique (SIT), with sanitation, bagging management, male annihilation technique, protein bait sprays production and biological control.

2. Materials and Methods

2.1 Fruit fly surveillance

2.1.1 Location of sites selection

This research was conducted from 2016-2018 in 6 location sites in Myanmar. These locations were chosen base on the presence of economically important fruit fly host plants and geographically important fruits production areas of each district. The project team of Biotechnology Research Department, Department of research and innovation, Ministry of Education (formerly science and Technology), Kyaukse, Myanmar performed fruit fly surveillance such as attracting agents, trap numbers, geographic location of trap sites and target host-plants (Table 1).

2.1.2 Trapping management

Traps were made by plastic container (by cutting the container one third from head and settling back to body). Three types of trapping agents (a)10 ul ME + 4 drops of local insecticides, (b) 10 ul cue lure + 4 drops of local insecticides, (c) 20 ml protein baits (prima) were prepared. Each trap was hanged around the 72-inch-high branch of host plants and more than 1000 m away from each other. Trapping managements were performed during 2016, 2017 and 2018 in 6 location sites shown in the Table 1.

2.1.3 Fruit sampling

Fruits samplings were performed from the six location sites. Mango (*Mangifera indica,* Anarcardiaceae) samplings were carried out according to their fruiting seasons (April to August) with 15 days interval in 2016-2018. Guava (*Psidium guajava*, Myrtaceafruits) samplings were examined the whole year with 30 days interval in 2016-2018. Jujube (*Zizyphus jujuba,* Rhamnaceae) samplings were performed along with their fruiting seasons (January to march) with 15 days interval in 2016-2018. All the samples were maintained individually in plastic containers prepared for pupation with sawdust. Before emerging adults, larvae and pupae were reared under room temperature in rearing cages (15 × 13 × 12 cm).

2.2 Morphological identification of fruit flies species

2.2.1 Specimens collection from infested fruits

The infested fruits were placed in plastic container with a sawdust layer in the bottom, covered by muslin cloths and kept at room temperature. After emerging adults, fruit flies were collected and stored in 80% ethanol before identification.

2.2.2 Specimens collection from traps

All the fruit flies captured by traps with trapping agent of ME, cue lures and protein baits were moved from the trap to laboratory and stored in 80% ethanol before identification.

2.2.3 Morphological identification

Fruit fly species were identified using stereo-microscope with binocular lens by observing the morphological characteristics [13-15].

2.3 Fruit fly infestation percentages on mangoes

Mangoes were used to evaluate the fruit fly infestation percentages in tropical region of Myanmar during 2016, 2017 and 2018. Every fruiting season (April to August), 100 fruits were randomly recorded with 15 days interval from the six location sites. All the samples were checked carefully on the presence of oviposition marks. The average fruit fly infestation percentages on mangoes were calculated [16, 17].

2.4 Population dynamic of *B. dorsalis*

The attracting agent, ME were chosen to examine the population dynamic of *B. dorsalis* in the tropical region of Myanmar from 2016-2018. Each trap was prepared with cotton wool soak of 10 ul methyl eugenol and 4 drops of local insecticides by refilling 15 days interval the whole year during 2016, 2017 and 2018. Fruit flies per traps per days (FTD) were studied. Data collected from the capture of *B. dorsalis* from different locations of Myanmar's tropical region were calculated with Analysis of Variance (ANOVA) and graph was designed in Microsoft Excel 2010.

3. Results

3.1 Fruit fly surveillance

The results of fruit fly surveillance with trapping agents (ME, cue lures and proteins baits) in the tropical region during 2016, 2017 and 2018 in Myanmar indicated that the abundance of oriental fruit fly, *B. dorsalis* was 57%. *B. correcta* and *B. cucurbitae* were followed as 23% and 11% respectively and others are 9% (Fig. 1).

3.2 Morphological identification

Twenty-one species of fruit flies were identified by collecting specimens from both traps and infested fruits during 2016, 2017 and 2018 in tropical region of Myanmar. These are *B. dorsalis, B. correcta, B. cucurbitae, B. latifrons, Carpomya vesuvina, B. cilifera, B. tau, B. carambolae, B arecae, B. zonata, B. latilineola, B. diversa, B. rubigina, B. neocognata, B. lateritaenia, B. caudate, B. kandiensis, B. malaysiensis, B. raiensis, B. verbascifoliae and B. nigrofemoralis.* Economically important fruit flies in tropical region of Myanmar (*B. dorsalis, B. correcta and B. cucurbitae)* are shown in Fig. 2.

3.3 Fruit fly infestation percentages on Mangoes

The percentage of fruit fly infestation on the host plants (Mangoes) were observed as 72.7±8.5%, 74.6±4.7% and 78.2±6.5% in 2016, 2017 and 2018 respectively. The fruit fly infestations discover that the percentage increase year by year during the study period.

3.4 Population dynamics of *B. dorsalis*

The meteorological data of annual rainfall and temperature in tropical region of Myanmar in 2016, 2017 and 2018 are shown in Fig. 3. The population dynamics of oriental fruit fly, *B. dorsalis* in tropical region of Myanmar, during 2016-2018 indicate that the highest population is around 120 FTD value in June of every year whereas the lowest population is around 5 in December. The results show that the population dynamics of *B. dorsalis* are not significantly difference in three years from 2016 to 2018 but increase steadily year by year (Fig. 4).

5. Discussion

The tropical fruits in Myanmar are listed as mango, guava, water melon, jujube, muskmelon, banana, mangosteen, rambutan, pomelo, permongnate, tamarind, custard apple, star apple, pineapple, dragon fruit, papaya, durian, lychee, jack fruit, lemon, lime, grape, chili, longon, avocado and various vegetables. Mangoes are the famous exported fruits and large geographically important area of fruit productions in tropical region. Therefore, Mangoes were selected to evaluate the fruit fly infestation percentages in tropical region of Myanmar during 2016, 2017 and 2018. Among them, the economically important fruits in tropical region of Myanmar are mango, guava, water melon and jujube because of their local consumption and higher exportation percentage to especially China, Singapore, Dubai and Japan.

ME, cue lures and protein bait were used to study the trapping survey for diversity and abundance of fruit flies in tropical region of Myanmar during 2016, 2017 and 2018. But, ME is the highest capture trapping agent and the most effective attracting agent in fruit fly trapping system [18]. Thus, attracting agent, ME were chosen to examine the population dynamic of *B. dorsalis.*

The highest fruit fly population is in july and the lowest is in January, during 2014 and 2015 in Papparampakkam village of Tiruvallur District in Tamil Nadu, India [19]. Our results show that the highest population is in June and the lowest is in December, from 2016 to 2018 in tropical region of Myanmar. June is higher fruit production than any other months especially mangoes in Myanmar. The fruit flies were present through the year except January in Islamabad, Parkistan [20]. In Myanmar, fruit flies were present through the year even December and January. This finding point out more technologies are needed not only uncoordinated used of orchard-by-orchard insecticide application.

Fruit flies population remained low from November to January and increased steadily from February until it reached a peak in June. Afterwards, the population declined until October during 1997, 2000, 2003 and 2004 in Ruili, Yunnan Province, China [21]. In tropical region of Myanmar, the population dynamics of *B. dorsalis* decline in the winter season (October, November, December and January). This finding shows that the fruit flies populations depend on the weather forecast especially temperature.

Among the four species of *B. invadens, Ceratitis rosa, Ceratitis cosyra and Ceratitis capitata,* the most abundant species is *B. invadens* as 97% in Cabo Delgado province, northern Mozambique at 2003 [22]. *B. dorsalis* (70.6%) and Ceratitis fasciventris Bezzi (22.4%) were the most abundant species by using both para-pheromone and food bait lures in the Albertine rift zone, Democratic Republic of the Congo [23]. In Myanmar, the most abundant species are *B. dorsalis* as 57% and followed by *B. correcta* and *B. cucubitae* as 23% and 11% respectively in 2016, 2017 and 2018. It indicated that oriental fruit fly, *B. dorsalis* is the most abundant species not only in Asia (Myanmar) but also in Africa (Congo).

A large scale practical experiment of ME by the feasibility of developing ME-airblown-aromatherapy enhances the mating competitiveness of sterile *B. dorsalis* males [24]. The percentage of infested fruit is 25 and 18 times lower in male annihalitation technique treated orchards compared to the control of fruit flies in Kenya in 2017 [25]. In here, the percentage of fruit fly infestation is 72.7±8.5%, 74.6±4.7% and 78.2±6.5% in 2016, 2017 and 2018 respectively. It indicated clearly that fruit fly infestation percentages are very high in Myanmar.

Table 1: Fruit fly surveillance (attracting agents, trap numbers, geographic location and target host-plants) in Myanmar's tropical region during 2016, 2017 and 2018.

Attracting agents	Trap numbers	Geographic locations of trap sites	Target Host-Plant
ME/Cure/protein bait	10/10/5	21° 45′ 0″ N, 96° 15′ 0″ E	Mango, guava, jujube, melon, vegetables
ME/Cure/protein bait	10/10/5	21° 0′ 0″ N, 96° 0′ 0″ E	Mango, guava, jujube, melon, vegetables
ME/Cure/protein bait	10/10/5	22° 2′ 0″ N, 96° 27′ 0″ E	Mango, guava, jujube, melon, vegetables
ME/Cure/protein bait	10/10/5	21° 58′ 0″ N, 96° 5′ 0″ E	Mango, guava, jujube, melon, vegetables
ME/Cure/protein bait	10/10/5	21° 15′ 0″ N, 95° 15′ 0″ E	Mango, guava, jujube, melon, vegetables
ME/Cure/protein bait	10/10/5	21° 5′ 0″ N, 95° 2′ 0″ E	Mango, guava, jujube, melon, vegetables
ME/Cure/protein bait	10/10/5	20° 15′ 0″ N, 96° 15′ 0″ E	Mango, guava, jujube, melon, vegetables

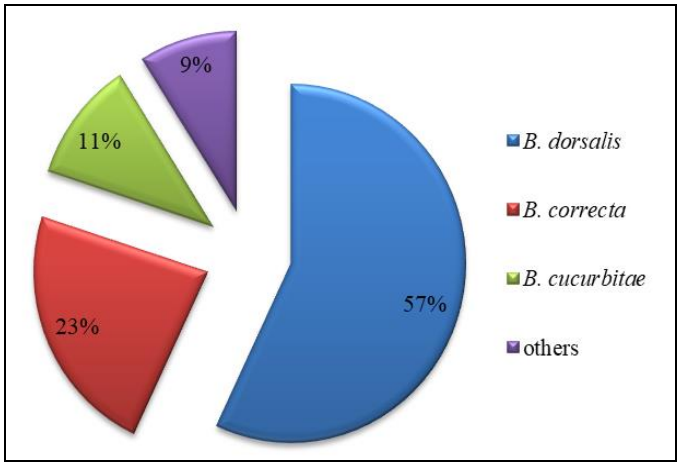

Fig 1: Abundance of fruit flies in Myanmar's tropical region during 2016, 2017 and 2018 (a) 57% blue color represent *B. dorsalis,* (b) 23% red color illustrate *B. correcta,* (c) 11% green color mention *B. cucurbitae* (d) 9% purple color represent other fruit flies listed as *B. latifrons, Carpomya vesuvina, B. cilifera, B. tau, B. carambolae, B arecae, B. zonata, B. latilineola, B. diversa, B. rubigina, B. neocognata, B. lateritaenia, B. caudate, B. kandiensis, B. malaysiensis, B. raiensis, B. verbascifoliae and B. nigrofemoralis* in tropical region, Myanmar in 2016, 2017 and 2018.

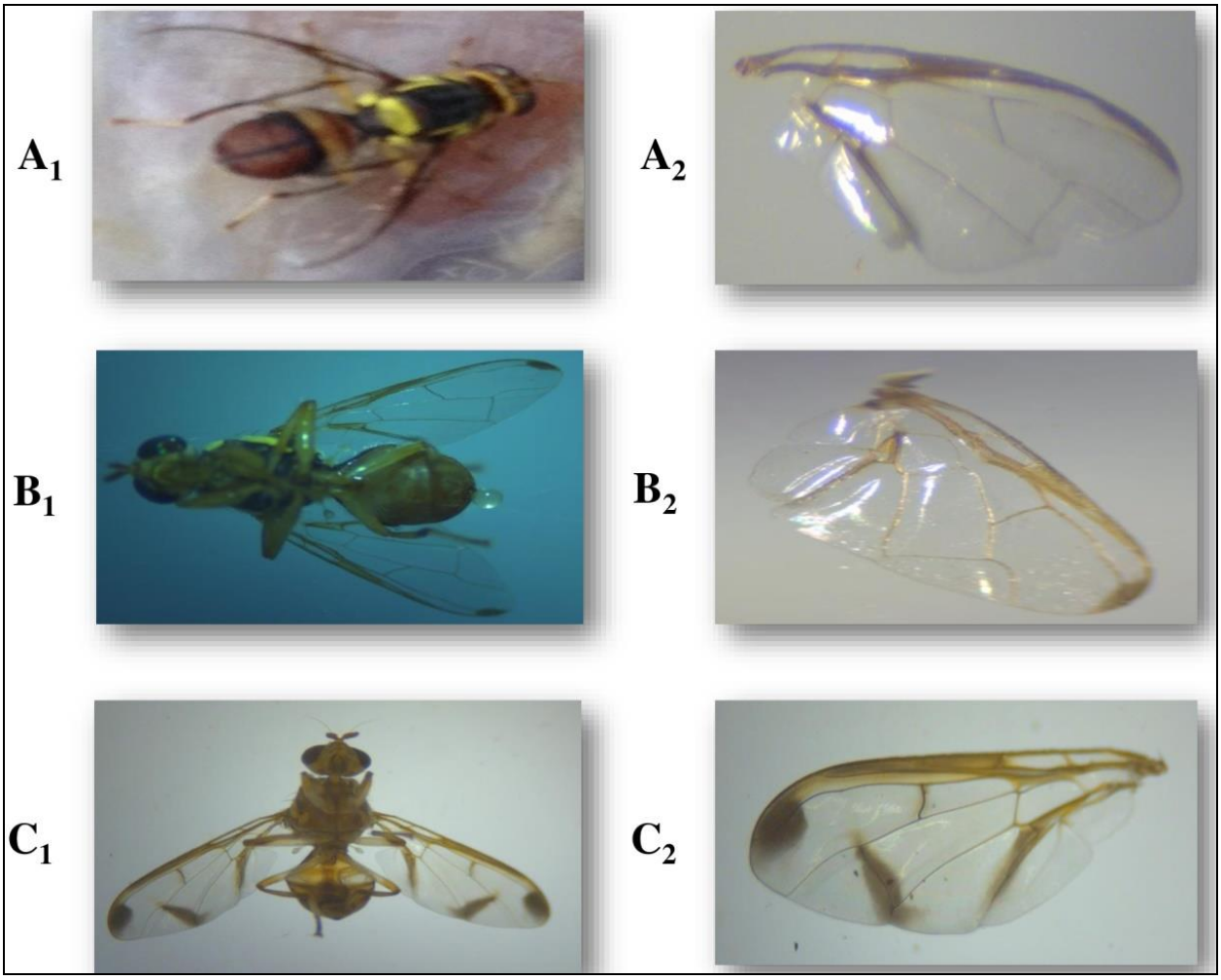

Fig 2: Morphological identification of economically important fruit flies in Myanmar (A1) *B. dorsalis* adult, (A2) *B.dorsalis* wing, (B1) *B. correcta* adult, (B2) *B. correcta* wing, (C1) *B. cucurbitae* adult, (C2) *B. cucurbitae* wing.

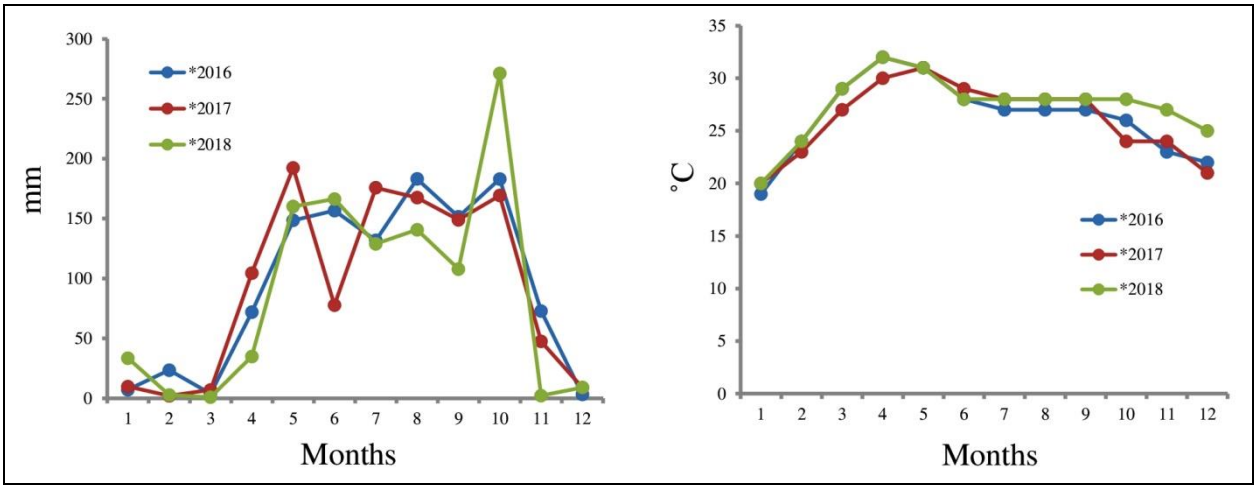

Fig 3: Metrological data with rainfall (mm) and temperature (ºC) in tropical region, Myanmar during 2016, 2017 and 2018.

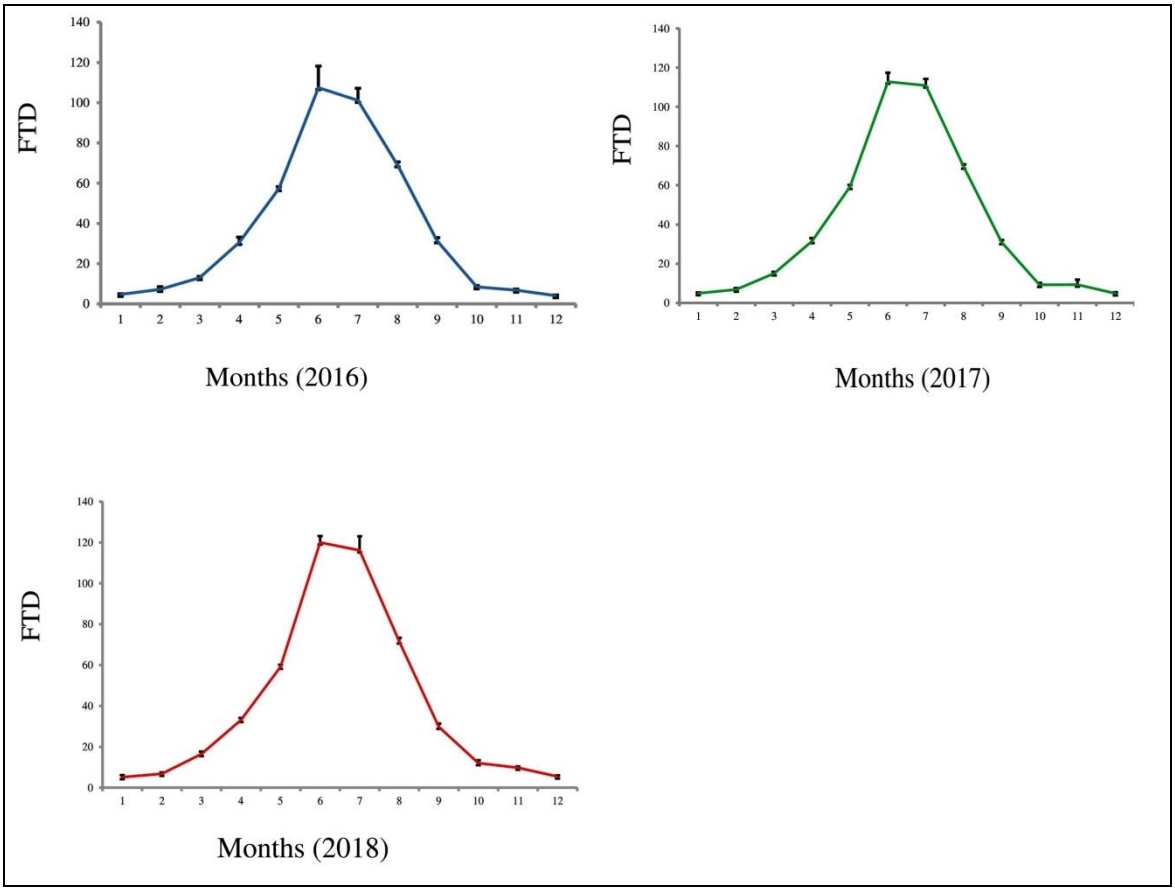

Fig 4: Population dynamic of the oriental fruit fly, *B. dorsalis* in tropical region of Myanmar during 2016, 2017 and 2018.

6. Conclusion

In eventually, we discovered that traditional control, orchard-by-orchard approach of insecticide application show that it might be the cause of high infestation in tropical region of Myanmar and so, high infestation might be increased year by year. We also find that the individual control program of orchard-by-orchard approach insecticide application by growers related to the current market price. On the other hand, insecticide application method is very harmful to human's health. Our results reveal that *B. dorsalis* dominate on tropical region of Myanmar and fruit fly infestation percentages are very high. Thus, AWIPM by government system should be established and cooperated with growers in order to create for the world fine ecosystem especially for Myanmar and neighbor countries.

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