Article

Population activity of peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephiritidae) at fruits orchards in Kafer El-Shikh Governorate, Egypt

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Abstract

Peach Fruit Fly (PFF) *Bactrocera zonata* (Saunders) is one of most dominant and destructive key pest in fruit orchards in different agro-ecosystem in Egypt, so monitoring adults' population fluctuation in orchards, through capturing adults, has been considered as main way to forecasting or management the pest. So current study aimed to assay the efficiency of Jackson traps baited with methyl eugenol (M.E.) on male capture, that were distributed in different fruit trees orchards, in different positions and hang levels in one of Egyptian agro-ecosystem (Kafer El-Shikh Governorate), from (May 2014 to April 2015). Moreover, adults capture in McPhail traps in navel orange orchards intercropping with Guava were exploded to detect abundant and rearing season of the pest studying impact of abiotic factors on population, and estimation number, time and duration of annual generation. Obtained results declared that the pest had 7-8 annually generation. Jackson traps that placed in center of orchard and hanged at 2 m height more efficient than others for male catches. Highest numbers of PFF male attack orchards of Navel orange intercropping with Guava, while the lowest were with Navel orange and Guava. Each of season and kind of orchard or intercropping system had combined and significant effect on mass trapping. In McPhail traps, highest mass trapping of adult was observed in autumn (20.353 adult/ trap/ week), while each of spring, summer and winter season were similar in mass trapping. Only Wind direction as climatic factors had negative significant effect on mass trapping of PFF adults in McPhail traps, while each of maximum and mean temperature of winter season had positive significant effect on mass trapping.

Keywords *Bactrocera zonata*; ecology; generations; population fluctuation; Kafer El-Shik; Egypt

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1 Introduction

Tephritid fruit flies are a group of dangerous insects, attack fruits of fruit trees and certain vegetable fruits in all over the world causing direct and indirect economic injury. Economic injury levels of these groups were studied by (Joomaye et al., 2000; Sarwar, 2006). The damage of genus *Bactrocera* has a wide host range of its species and the invasive power of some species within the genus (Clarke et al., 2005). Peach fruit fly (PFF), *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) is known as a most serious pest of tropical and subtropical fruits (Fletcher, 1987). It was recorded on more than 50 cultivated and wild plant species, mainly those with fleshy fruits including guavas, mangoes, peach, apricots, figs and citrus (White and Elson-Harris, 1992; EPPO, 2005; Ghanim, 2009). It originated in South and South-East Asia (Agarwal et al., 1999), and spread to other parts of the world. In December 1998, *B. zonata* was officially identified and recorded for the first time, on infested guavas collected in Agamy and Sabahia, near Alexandria. In 1999, the first traps were set up and showed high capture rates in Egypt (El-Minshawy et al., 1999). In October 2000, *B. zonata* was detected in North Sinai and different localities in Egypt such as Kalubia (Hashem et al., 2001) and El-Behera (Draz et al., 2002). Presence of the pest has now been confirmed from all areas of the Sinai, throughout the Nile Delta region and the entire Nile Valley (Cayol et al., 2002; EPPO, 2002). Distribution and infestation patterns of *B. zonata* in the New Valley Oases were also studied Abdel-Galil (2007).

B. zonata can be monitored by different kinds of traps (Jackson or Steiner traps, though Jackson traps are preferable) baited with the male lure methyl eugenol (O-methyl eugenol), which attracts male flies at very low concentrations (Qureshi et al., 1992). In 2001, Egypt initiated a project to monitor and control this pest in the Sinai, using the male annihilation technique (MAT). Many authors interested in monitoring and studying population fluctuation of PFF males such as Ishtiaq et al. (1999), Rai et al. (2008), Deepa et al. (2009), Dale and Patel (2010), El-Gendy (2012), Thakur et al. (2013),Venkatachalam et al. (2014), Sundar et al. (2015) and Darwish et al. (2015) by using of methyl eugenol (ME), while others such as Sarada et al. (2001), Rajitha and Viraktamath (2005), Rizk et al. (2014), Darwish et al. (2014) and Nagaraj et al. (2014) concerned monitoring both sexes by food attractant traps (Mcphail), seasonally or along year on different host plants to detect rearing and abundance period of PFF, best position of traps or study impact of physical environmental factors on trap capture on different host plants.

Current study aimed to through same light on seasonal population dynamics, activity, number and duration of annual generation of *B. zonata* adults in fruit orchard of Kafer El-Shikh governorate agro-ecosystem by using two different types of traps, in addition evaluating efficiency of Jackson traps in different hanging height levels and position in fruit orchards on PFF male capture, finally studying effect of surrounding fruit trees kind on PFF male capture.

2 Materials and Methods

To study annual activity of Peach Fruit Fly (PFF) *Bactrocera zonata* (Saunders) adults and level of fruit tree infestation in Kafer El-Shikh Governorate, current field study conducted for a whole year of study (from May, 2014 to April, 2015) in Fowa district at El-Dahab Island (located from N31^{o} 12' 30'' to N31^{o} 12' 4'' and from E 30^{o} 33' 37'' to E 30^{o} 33' 11''), with cultivated area 23 Feddan with different fruitful tress such as Navel orange, Mandarin, Guava and Peach. Numbers of captures adults of PFF in different types of traps were recorded weekly.

2.1 Traps types, position and distribution for adults capture

Population fluctuation of PFF adult were monitored by two different ways, the first method depended on using sex pheromone to attract adult males, and second main used traps baited with buminal lure to catch both sexes. Jackson traps baited with capsules of attractant, male sex pheromone (Methyl eugenol) that were gained from

Plant Protection Research Institute, Dokki, Giza, Egypt. Pheromone capsule of each trap was exchanged every 14 days, while sticky sheets were exchanged weekly. Jackson traps were distributed in area of 13 Feddan of navel orange intercropping with guava trees. In addition, weekly numbers of capture males' for each trap were recorded. On the other hand, McPhail traps as food attractant traps, baited with buminal, were used to attract both sexes, which was distributed in area of 5 Feddan of navel orange intercropping with guava trees and were also exchanged every 14 days.

To study best situation and hanging height level of traps and their impact on mass capture flies in different seasons of year, twenty Jackson traps were distributed in area of 10 Feddan in different cardinal directions and middle, with rates 4 traps at each direction (East, West, North, South, Middle), distance between traps was about 100 meter, on hanging level of 2 meters. In addition, 16 Jackson traps were also hanging on four different height levels (1, 1.5, 2 and 2.5 meters from earth surface) (four replicates for each treatment) and distributed in area of 3 Feddan with distance rate 100 meter between each trap. Numbers of capture males' for each trap were counted and recorded weekly.

To study seasonal fluctuation of PFF adults (Males and Females), five of McPhail traps distributed in area of 5 Feddans, that were hanging on 2 meters height from earth surface. Numbers of capture adults' form each trap were also counted and recorded weekly.

Weekly mean numbers of PFF males from Jackson traps distributed in different cardinal directions or hanging in different height levels were recorded. On the other hand, weekly means of climatic factors (maximum and minimum and mean temperature, maximum and minimum relative humidity, precipitation as well as wind speed and direction), calculated 7 days earlier from corresponding sampling dates, were obtained from Central Laboratory for Agricultural Climate (CLAC), Doki, Giza.

Weekly mean numbers of PFF males, captured by pheromones traps or PFF adults capture by buminal lure, graphically illustrated to detect periods of abundance and rearing of them along year, and were compared in the four seasons of year (Winter – Spring – Summer – Autumn), so obtained data subjected to ANOVA test analysis to detect population abundance and rearing seasons, as well as most attractant baits types traps. In addition, to detect ideal and best situation or hang heights of Jackson pheromone traps, obtained data subjected seasonally and annually to ANOVA test analysis.

To clarify the simultaneous effects of those climatic factors on PFF Adult activity, all obtained data subjected to statistical analysis by applying simple correlation analysis as correlation coefficient value (r) and applying partial regression formula (C-multiplier, Fisher, 1950) to clarify the combined effect of the four factors as a group on the population dynamic of PFF adults as possible. All statistical analyses of obtained data were conducted by using COSTAT (2008) statistical software computer program.

2.2 Number and duration of annual generations of PFF

Two different ways of PFF adults annual generation calculation were concerned during current study as follows:

2.2.1 Estimation annual generations according to Audemard and milaire (1975) and Iacob (1977)

The first main suggested by Audemard and Millaire (1975) and emended by Iacob (1977), which depended on weekly mean captured numbers of PFF adults by McPhail traps baited with buminal lure. Those mean numbers of PFF adults were accumulated along the year and arranged, and then illustrated graphically on semigaussian paper (scale gausses). Whether, the number and duration of annual field generations could be detected.

2.2.2 Estimation of annual generation depending on thermal constant and day degree unites

The second way depend on determination accumulated daily thermal units for *B. zonata* development by transforming recorded daily maximum, minimum temperature and threshold of development (zero of development) of PFF to Daily Degree Units (DDU) by applying following formula of Richmond et al. (1983).

DDU = (Max. Temp. + Min. Temp.)/2 – Threshold of Development Temp (t_0). If Max. t > Min. t > to

DDU = (Max. Temp. - t_0)^2/2(Max. Temp. - Min. Temp.) If Max. t > to > Min. t

DDU = Zero If to > Max. t > Min. t

Then estimation number and duration of *B. zonata* annual generations could be possible in the field by using calculated value of Thermal constant of *B. zonata* developments (C) and applying following formula according to Jasic, 1975.

$$\text{Number of Generations} = \Sigma\,(\text{D.D.U}) / C$$

Estimated Values of development threshold (zero of development) (t_0) and Thermal constant (C) of *B. zonata* to develop from egg to adult were 11.84°C and 487.92 thermal units, respectively according to Sharaf El-Din et al. (2007).

2.3 Mass trapping of jackson traps placed in different fruit orchards

Designated fruit tree type that surrounded Jackson traps on mass trapping of Peach fruit fly males, twenty of Jackson trap were distributed in five different fruits orchards, that had been cultivated with Navel orange, Mandarin, Guava, Peach intercropping with Navel orange or Guava intercropping with Navel orange trees. Tested area of each fruit orchard (3 Feddans) was supplemented with 4 Jackson traps distributed in middle of orchard and hanging on 2m height from ground surface, distance between traps was about 100 meter. Numbers of capture males' for each trap were counted and recorded weekly for a whole year of investigation (from May 2014 to April 2015).

Weekly mass trapping of males were compared in the four seasons of year (winter – spring –summer – autumn) in each tested orchards, and among tested fruit orchards. So obtained data subjected to ANOVA test analysis to declare effect of fruit trees kind on mass trapping and detect mass trapping variation in different seasons of year for each tested hosts.

3 Results and Discussion

The Peach Fruit Fly (PFF) is one of the most destructive insect pests on commercial fruit trees and is considered as a major economic and quarantine pest in Egypt. So occurrence of PFF in orchards should be monitored constantly, to make management decision in right time and right place. Population fluctuation of adult were monitored by two different mains, the first main depended on using Jackson traps baited with male sex pheromone and second main used McPhail traps baited with buminal to catch both sexes.

3.1 Seasonal activity of peach fruit fly males and best position of Jackson traps

Weekly numbers of captured males in Jackson traps that were distributed in different main directions (East, West, North, South and Center) or hanging in different height levels (1, 1.5, 2, 2.5 meters) of Navel orange orchards in whole year of study (from May,2014 to April, 2015), are graphically illustrated in Figures (1, 2 and 3) respectively. The highest population density was observed in autumn that had seasonal mean number 7.723 males/ trap while numbers were noticed in spring and summer seasons with seasonal male mean numbers 3.93 and 3.43 males/ trap, respectively. Lowest population numbers were recorded in winter with mean value 2.86 males / trap. Results of statistical analysis confirmed presence significant difference among seasons (F= 49.069***, $LSD_{0.01}$ = 0.735). As shown in Fig. 1, populations of PFF males started with limited number 5.4 males / trap at beginning of May 2014 then decreased through June and July 2014. From the second week of August, numbers increased gradually to achieve highest peak (8.5 males / trap) in 30 August, that only highest peak in summer. Autumn season, characterized as season of males abundance and activity, three different increasing peaks were observed in months of the season (11th October, 8th November and 13th December 2014) with males numbers 8.3, 17.1 and 9.2 males / trap, respectively. Although winter season has lowest numbers of males, it harbored two peaks in beginning and near end of winter (31 January and 21 March 2015, respectively) with males' numbers 4.5 and 8.3 males / trap. Finally, males numbers increased gradually again from beginning of next spring to record a peak at end of April 2015.

Results of correlation analysis for studying impacts of maximum, minimum, mean temperature, maximum and minimum relative humidity, direction and speed of winds on males capture, declared that no significant effect of previous mentioned factors on PFF males mass trapping along a year. While maximum relative humidity % had negative significant effect (r = -0.766**) on mass trapping during spring season; maximum, minimum and mean temperature had positive significant effect (r = 0.558*, 0.654* and 0.685**, respectively) on males mass trapping in winter season, in addition wind direction had positive significant effect (r= 0.569*) on it.

Situation of Jackson traps showed significant difference (F = 21.406***, $LSD_{0.1}$ = 0.823) among tested trap situation in navel orange orchards along year of study. Traps located in center of the orchard harbored highest number of mass trapping 6.65 males / trap followed by North traps (5.69 males/ trap), while traps located in West and South of the orchards harbored moderated males numbers (3.79 and 3.58 males / trap, respectively). Finally traps located in East directions trapped lowest numbers of males (2.73 males / trap) along a year. As shown in Fig. 2, highest level of mass trapping was observed in November, 2014, especially in Center traps (67.5 males / trap). Same trend continued to April, 2015 and observed in May and September, 2014. In contrary, mass trapping from June to August and in October get out of this trend that traps located in West and North of orchard were more attractant for males than others.

Statistical analysis for seasonal effect of climatic factors on males mass trapping in different directions reflected that maximum, minimum, mean temperature of spring season had negative significant effect on male captures of traps located in South, East and Center of the orchard; in addition, minimum relative humidity% had also negative significant effect on males captures of all tested distributed traps, while mean relative humidity % had negative significant effect only on males capture of West traps. Minimum relative humidity % of summer had negative significant effect on males captures of traps located in Center, East traps. Maximum, minimum, mean temperature of autumn had only positive significant effect on males' capture of North traps while minimum and mean relative humidity% had negative significant effect on it. Finally, maximum, minimum, mean temperature of winter had positive significant effect on male captures of all distributed traps; wind direction had also positive significant effect on males' captures of North and East traps only.

Hanging height level of Jackson traps has also significant effect on males mass trapping, that significant difference (F = 20.982***, $LSD_{0.1}$ = 1.216) among tested trap heights in navel orange orchards was observed along year of study, that traps hanged at 2 meters height from ground surface harbored highest number of mass trapping 9.02 males / trap followed by traps at 1.5 and 2.5 meter height (5.23 and 4.50 males / trap, respectively), while traps were hanged at 1 meter height harbored lowest numbers of males (3.60 males / trap). As shown in Fig. 3, highest level of mass trapping at 2 meter height (17.4 male/ trap) was observed in May, 2014 then in November, 2014 (13.40 male/ trap). Results of seasonal specific statistical analysis reflected that no significant difference ($F = 2.751^{ns}$) among tested traps heights was observed in months of summer 2014, while it was graded from significant difference in winter season to high significant difference in spring and autumn seasons.

Statistical analysis reflected that each of maximum, minimum, mean temperature had negative significant effect on males capture of traps hanged at 1 meter (r = -0.323*, -0.373** and -0.353*, respectively) and 1.5 meter height (-0.288*, -0.335* and -0.314*, respectively) than others. Although wind speed had negative significant effect on males capture in most levels except 2 meters height, wind direction had positive significant effect on males capture in all tested levels (r = 0.342*, 0.466**, 0.423** and 0.304*, respectively).

Population fluctuation of captured PFF male using Jackson traps in harmony with other data, that were recorded in another Agro-ecosystem of Egypt i.e. In El-Behera Governorate, El-Gendy (2002) mentioned, that total captured males were varied from month to another and from host to another, the highest male activities were recorded for all tested hosts through October and November in both years (1999/2000) and (2000/2001). Moreover, in Sohag Governorate, Mohammed (2002) detected that caught highest numbers of flies at August, September and October, while fewer numbers of flies were recorded in other months. The prevailing weather factors varied in its significant during three years 1999, 2000 and 2011. While in East Asia, population takes different trend that in Tandojam, Pakistan, Qureshi et al. (1975) noticed that the monthly means of captured males were at their lowest in January-February and increased gradually to reach a peak in March-May. Population declined in June-July but increased again in August reaching another peak in September, in two orchards of guava near in 1970-1972; in BARI, Chakwal (Punjab), Mahmood and Mishkatullah (2007) observed low population level from November to February, and increased level from March to August. The population peak of capture flies appeared in July and August and maximum declined was observed in October depending on the level of maturity fruits, temperature and rainfall; in Sardarkrushinagar, Gujarat, India. Dale and Patel (2010) reported that highest number of fruit fly populations was observed in September and the lowest in May in the guava orchard. The fruit fly population in the guava orchard had a significant positive correlation with minimum temperature and relative humidity.

Although impact of some abiotic factors in current study differ from season to another and direction or hanging level to another, their general impacts were observed by Mohamed (2003) indicated a significant positive correlation between fly population and maximum and minimum temperature, and a significant negative correlation with R.H. % for two season (2000-2001) and (2001-2002) in Sohag Governorate; Meena et al. (2013) discovered that abiotic factors showed positive correlation with trap catch; Jitendra et al. (2014) that detected maximum temperature had non-significant on trap catches; while minimum temperature, relative humidity and rainfall had a significant positive correlation; and Sundar et al. (2015) that found each of minimum and maximum temperature had highly positive significant effect on density trapped *B. zonata* males. Effect of position and hanging levels of Jackson traps on PFF male catches differed from Agro-Ecosystem to another i.e. in Tirupati, Andhra Pradesh, India Sarada et al. (2001) traps placed on the ground caught significantly more number of flies than traps on 1.0 m, 2.0 m and 1.5 m, respectively. Traps in the periphery of the orchard attracted more number of flies compared to the traps in the center of mango trees orchard. Moreover, El-Gendy (2012) detected suitable height for hanging traps on the tree was 1.5 m, followed by 1.0, 2.5 and 2.0 m heights, respectively; the best position of trap on the tree was West direction of the tree, followed by North, East and South directions, respectively, In El- Behera Governorate.

3.2 Population fluctuation of peach fruit fly adults in fruit orchards

Weekly numbers of captured males in McPhail traps baited with buminal along year of study (from May 2014 to April 2015), graphically illustrated in Fig. 1, showed that mass trapping of Mcphail traps higher than Jackson traps in all seasons of year, where statistical analysis detected that high significant difference among them was observed during investigation period. Moreover population fluctuations of trapped adults in McPhail traps take the same activity trend of males fluctuation in Jackson traps along year of study, that high significant difference of adult mass trapping noticed among seasons of year ($F= 8.858^{***}$, $LSD_{0.1} = 3.821$). Highest mass trapping of adult was observed in autumn (20.353 adult/ trap/ week), while each of spring,

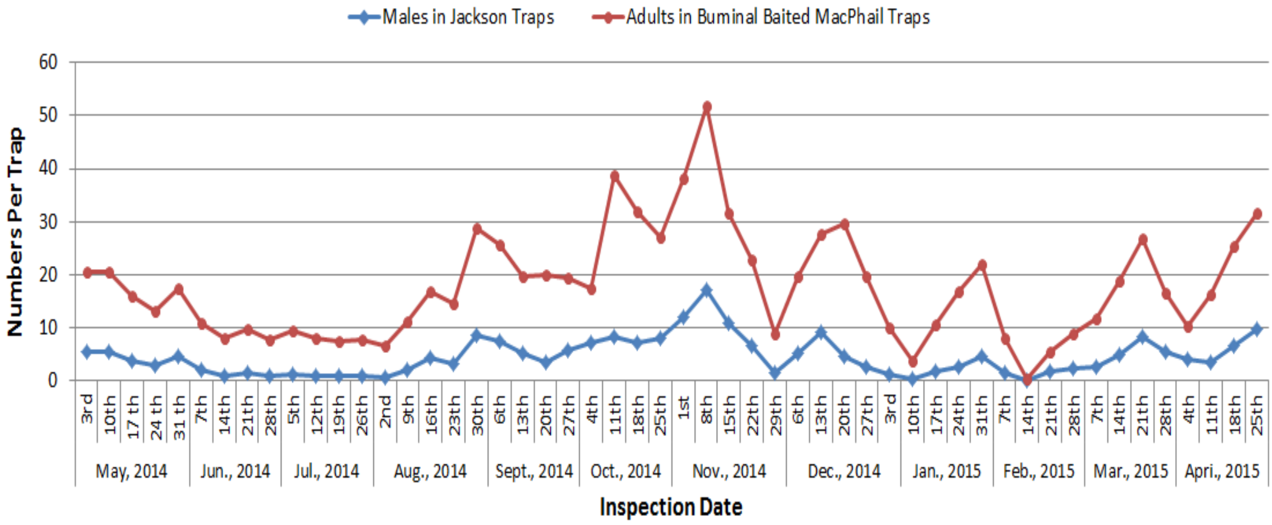

Fig. 1 Population fluctuation of PFF males in Jackson traps and both sexes in buminal baited McPhail traps at navel orange orchards in Kafer El-Shikh Governorate.

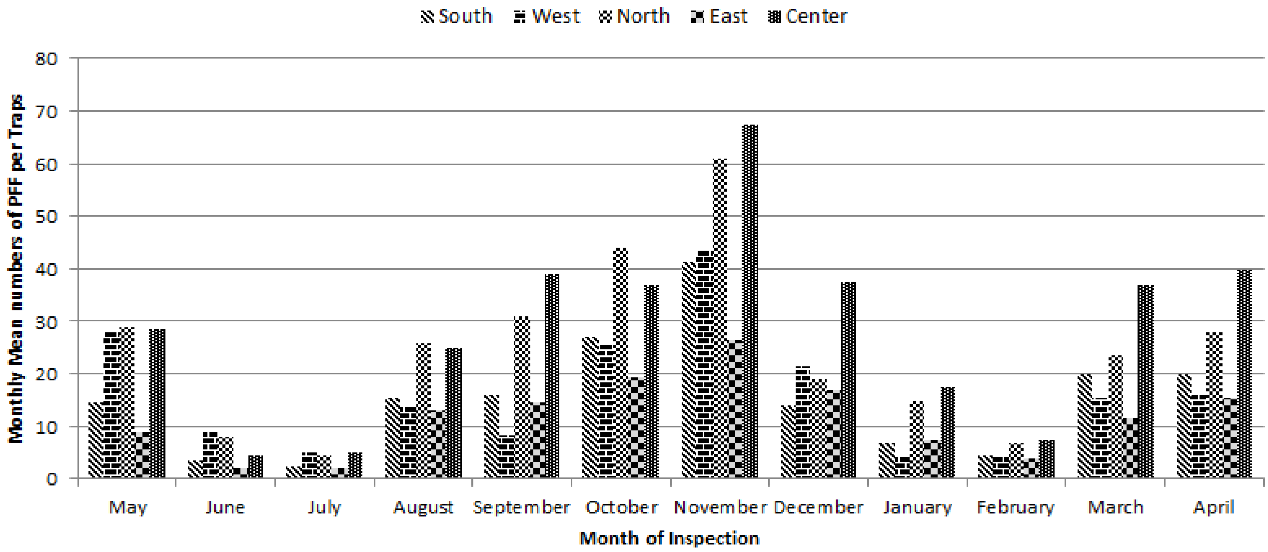

Fig. 2 Monthly numbers of PFF males in Jackson traps distributed in different directions of navel orange orchards in Kafer El-Shikh Governorate.

Fig. 3 Monthly numbers of PFF males in Jackson traps hanging in different height levels at navel orange orchards in Kafer El-Shikh Governorate.

Summer and winter season were similar in mass trapping that adults numbers were 12.062, 11.615 and 9.446 adult / trap/ week, respectively. Weekly numbers of PFF adults' populations started with limited number 15 adult/ trap at beginning of May 2014 then decreased along both June and July 2014. From the second week of August, numbers increased gradually again to achieve highest peak (20.2 Adult/ trap) in 30 August, that only highest peak in summer. Three different increasing peaks were observed in months of autumn season with adult population density 30.4, 34.6 and 25 adult/ trap, respectively. Winter peaks, which were in beginning and near end of winter, had adult population density 17.6 and 18.6 adult / traps.

Only wind direction as climatic factors had negative significant effect on mass trapping of PFF adults in McPhail traps (r =-0.386**), while the others hadn't any effect on mass trapping, along a year. On the other hand, minimum relative humidity % of spring season had negative significant effect on mass trapping (r = -0.657*), while each of maximum and mean temperature of winter season had positive significant effect on mass trapping (r = 0.579* and 0.570*, respectively).

Population fluctuation of captured PFF adults in McPhail traps are nearly in harmony with other related Agro-Ecosystem of Egypt i.e. in Fayoum Governorate, Saafan et al. (2005) mentioned that captured peach fruit fly adults per trap per day (CTD) ranged from 5.2 to 108.2 flies, with mean of 37.46 flies, and from 2.93 to 69.64 flies, with mean of 31.26 flies, during the two successive seasons of 2002/2003 and 2003/2004; in Kharga oases, and Abdel-Galil et al., (2010) detected two annual peaks of *B. zonata* throughout May and September and coincided with the ripening periods of apricot, mango and guava. While in Different Agro-ecosystem in India, population takes different trend that Khan and Khan (1987) found that the seasonal abundance of *B. zonata* was mostly occur from March to August, especially July-August summer monsoon; In mid-hill regions of Himachal Pradesh, Gupta et al. (1990) found weekly traps capture were correlated positively with the mean maximum temperature, minimum temperature and RH% during 1986 and 1987; in North Bihar, Agarwal and Kumar (1999) reported that Maximum fly population was observed during the third week of June. Fly population showed positive correlation with maximum and minimum temperature, rainfall and negative correlation with relative humidity; in Dharwad, Karnataka, India, Rajitha and Shashidhar-Viraktamath (2006) found that trap catches of *B. zonata* were significantly and positively correlated with maximum temperature in a guava orchard; in Jammu and Kashmir, Rai et al., (2008) observed a positive correlation between fruit fly and abiotic factors (temperature, humidity and rain), temperatures below 15 degrees was lethal for the growth and development of fruit flies and during this period (December and January), fruit fly populations were very low; and in Kanpur, Uttar Pradesh, Deepa and Agarwal (2010) stated that *B. zonata* was negatively correlated with temperature and rain, and positively correlated with relative humidity. Finally in Mauritius, Manrakhan and Price (2000) mentioned that the major peak of *B. zonata* was in January, 1999.

3.3 Annual generations of peach fruit flies

Number and duration of annually generations of PFF were estimated by two different methods of calculation, which shown in Tables 1 and 2 and graphically illustrated in Fig. 4. Data indicated that *B. zonata* has 7-8 generations along year. The longest generation duration observed in winter, while the shortest were in summer season.

3.3.1 Annual generation and Accumulated daily thermal units of *Bactrocera zonata*

Numbers and durations of *B. zonata* annual generation could be calculated and estimated by applying formula of Richmond et al. (1983) and exploded current recorded maximum and minimum daily temperature of Kafer El-Shikh Governorate from May 2014 to April 2015, estimated values development threshold (zero of development) (t_0) and Thermal constant (C) of *B. zonata* to develop from egg to adult were 11.84°C and 487.92 thermal units, respectively according to Sharaf El-Din et al. (2007).

Data in Table 1 revealed that *B. zonata* has 7 field generations on orchards of Navel orange mixed with Guava trees in Kafer El-Shikh Governorate. The first generation was in mid of spring (from 3 May to 8 June, 2014) with generation duration 37 days. Three of generations were observed in summer seasons (from the second to fourth generation) with lowest generation duration (33, 31 and 31 days, respectively), although the second one was overlapped between spring and summer season (9 June to 11 July 2014). While autumn season has two dominant generations (fifth and sixth generation) that fifth (from 12 September to 17 October 2014) (36 days) was shorter than the sixth (from 18 October to 26 December, 2014) that later had doubled generation duration (70 days). The seventh generation was extended along winter until beginning of spring, so it harbored highest generation duration (123 days) (27 December 2014 to 28 April 2015**).**

Table 1 Number and durations of annual generations for *B. zonata* in Kafer El-Shikh Governorate, depending on thermal constant and day degree unites according to Richmond et al., (1983).

Numbers and durations of annual generations of *B. zonata* adults			
No. Generation^{sea}	Approximated date of occurrence		Generation Duration (Days)
	From	To	
G1^{Sp}	3-May-2014	8-June-2014	37
G2$^{Sp\text{-}Su}$	9-June	11-July	33
G3^{Su}	12-July	11-August	31
G4^{Su}	12-August	11-September	31
G5^{Au}	12-September	17-October	36
G6^{Au}	18-October	26-December	70
G7$^{W\text{-}Sp}$	27-December	28-April-2015	123

3.3.2 Number of annual generations according to Audemard and milaire (1975) and Iacob (1977)

Annual generations of PFF could be estimated by applying the formula suggested by Audemard and Millaire (1975) and Iacob (1977) that depended on accumulated weekly mean numbers of catches PFF adults and avoiding consecutive and overlapping of generations from 3 May, 2014 to 28 April 2015.

Data presented in Table 2 and graphically illustrated in Fig. 4, revealed that number and duration of *B. zonata* generations were nearly related, coincide and agree with obtained results by applying day degree theory with exception that number of generations was more than that calculated by previous method, where eight generation were recorded along year of study.

First generation observed along May (from 3 May to 31 May 2014) with 28 days of generation duration that considered as the main generation of spring season, while two another generations of spring were overlapped with previous winter (eighth generation of current study which extended for 84 days from end of January to end of April 2015) and next summer season which considered as second generation of this study (extended for 35 days from first week of June to second week of July, 2014). While third and fourth generations are considered as main generations of summer that observed from third week of July to third week of August and from the fourth week of August to the first week of September, with duration of generations 28 and 21 days, respectively.

Three generations were recorded and observed in autumn season (generations from the fifth to the seventh). Each of first and second generation of autumn extended for 28 days from the third week of September to third week of October and fourth week of October to fourth week of November, 2014, while the third generation (from end of November, 2014 to fourth week of January 2015) overlapped with next winter, which had doubled generation durations (56 days) than the others. All of winter generations' were overlapped and longest generation.

Mean numbers of PFF adults for each generation were recorded, that highest values (19.08 and 23.4 adult / trap/ week) observed in fifth and sixth generation in autumn season, while lowest numbers (8.24 adults / trap/ week) were recorded during the third generation in summer season.

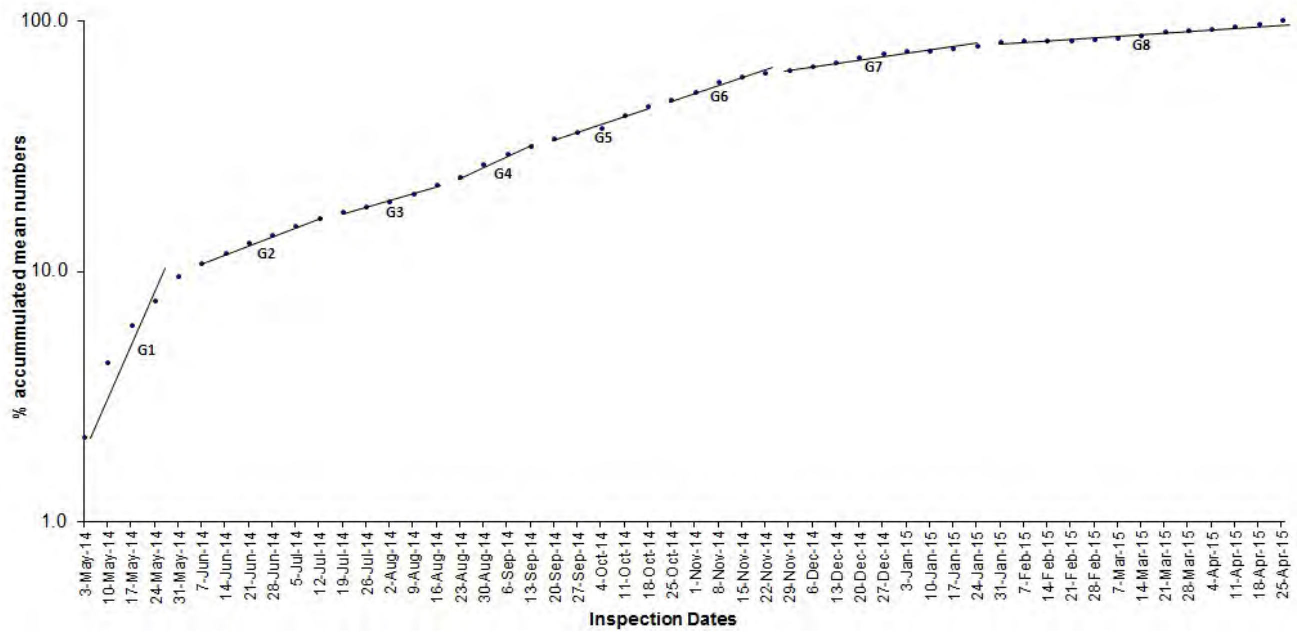

Fig. 4 Numbers of annual generations of PFF adults' *B. Zonata* along years (From 3 May, 2014 to 25 April, 2015) at fruit orchards in Kafer El-Shikh Governorate.

Table 2 Estimated numbers and durations of annual generations for *B. zonata* adults and associated average weekly mean numbers of adults in Kafer El-Shikh Governorate, according to Audemard and Milaire (1975) and Iacob (1977).

No. Generation^sea	Approximated date of occurrence		Generation	Average of weekly numbers in specific generation
	From *(- 0 : 6 days earlier)	To ** (+ 0 : 6 days later)	Duration ***(+ 0 : 12 days)	
G1^Sp	3-May-2014	31-May-2014	28	13.12
G2^Sp-Su	7-June	12-July	35	7.73
G3 ^Su	19-July	16-August	28	8.24
G4 ^Su	23-August	13-September	21	16.10
G5 ^Au	20-Setember	18-October	28	19.08
G6 ^Au	25-October	22-November	28	23.40
G7 ^Au-W	29-November	24-January-2015	56	13.11
G8 ^W-Sp	31-January-2015	25-April-2015	84	11.32

For avoiding time gapping among separated Generations.

* **:** Time of begging generation may be started earlier with 0 to 6 day.

** **:** Time of end generation may be extended for 0 to 6 day.

*** **:** 0 to 12 days may be added to all generation duration values.

In general, these results are in accordance with FAO/IAEA (2000), which recorded that the *B. zonata* in general had 6-10 overlapping generations per year; El-Aw et al. (2003) that estimated generation time (Gt) of PFF was 79.42 days on mandarin and 116.56 days on navel orange, respectively; Shehata et al. (2008) indicated that *B. zonata* completed 8 generations per year where the longest generation (56 days) was recorded during winter months and the shortest one (34 days) was recorded during summer months in Egypt; Khalil et al. (2010) that stated that PFF in Asyout have the highest number of possible generations as compared to other locations (North Sinai and EL-Behera) under current climate to be 8 compared with 6 and 7 for other locations, respectively; and Delrio and Cocco (2012) that stated *B. zonata* develops throughout the year when temperatures exceed 12 degrees C and can complete several generations per year in Egypt.

3.4 Mass trapping of Jackson traps and surrounding fruit trees type

Mass trapping of Peach fruit fly males was estimated by using Jackson traps distributed in Navel orange, Mandarin, Guava, Peach intercropping with Navel orange or Guava intercropping with Navel orange trees orchards. Obtained data were graphically illustrated in Fig. 5. The total captured males were varied from month to another and from host to another. Generally, highest mean numbers of PFF males occurred on November in most tested fruit orchards, while the lowest values were in July. Monthly population Fluctuation of PFF males in traps placed at Mandarin and Navel orange orchards were in harmony, that showed highly significant difference from month to another [(F=10.229***, $LSD_{0.1}$ = 2.161) and (F=12.472***, $LSD_{0.1}$ = 1.780), respectively]. The lowest numbers observed in July, 2014 (1 male/ trap) for both hosts then increased gradually and significantly through next months to achieve highest abundant numbers in November, 2014 (10.33 and 9.53 males/ trap, respectively) then decreased significantly in December (8.17 and 7.75 males/ trap, respectively), February (1.75 and 2.92 males/ trap) and then increased with high significant numbers in March, 2015 (5.33 and 5.25 males/ trap, respectively). The captured males was significantly different through experimental year (F=8.837***, $LSD_{0.1}$ = 1.735) in orchard of Guava. The highest mean number (8.07 males/ trap) was only occurred in November, 2014 then decreased significantly in December, 2014 to moderated numbers (6.08 males / trap).While numbers in rest months of the year were low significantly (ranged between 1 - 3.47 males / trap) then increased in March, 2015 (5.58 males / trap). In addition, in orchard of Navel orange inter cropping with peach showed different population fluctuation of capture PFF males. Lowest numbers of PFF males (1.58 males / trap) were recorded in February, 2015 then decreased accidently to higher significant number in March (8.17males / trap) to achieve highest peak in next April, 2015 (11.42 male / trap). Another significant and abundant numbers were recorded in November, 2014 (8.07 males / trap), which wasn't significantly different with same peak of capture that occurred in Navel orange orchard without intercropping. So intercropping hasn't effect on reduction or increasing population in months of abundant in case of intercropped Peach with Navel orange. On the other hand, orchard of Navel orange intercropping with Guava showed nearly similar results that occurred in navel orange or guava orchards. The lowest numbers of capture males were recorded in June and July (1.17 and 1.33 male / trap, respectively) then increased significantly in next September, 2014 to harbored highest numbers in November, 2014 (13.93 male / trap), then captures decreased gradually from December to next February 2015. So another peak observed in April with moderated numbers of catches (10 males / trap). Those two peaks had significantly higher capture than those of traps placed in separated Navel orange or Guava orchard (without intercropping) (F "for both peaks" = 3.784* and 16.625*** with $LSD_{0.1}$ = 2.161 and 2.062). So intercropping has significant effect on increasing population through months of abundant in case of Guava and Navel orange. Types and numbers of intercropping fruit trees system had obviously effect on trapped male density and population trend along a year.

Statistical analysis confirmed that traps that were placed in Navel orange intercropping with Guava, trapped significantly highest numbers of PFF male comparing with others during summer and autumn season (F= 5.137*** and 8.869***) followed by traps in orchards of Mandarin, Navel orange intercropping with Peach, Navel orange then Guava, respectively. While in winter season, no significant difference was detected among traps in tested orchards. Finally, in spring, traps that were placed in orchards of Navel orange intercropping with peach, captured significantly highest numbers of PFF males (F= 12.933)***, followed by traps in orchards of Navel orange intercropping with Peach, while those of Mandarin, Navel orange and Guava were the lowest. Moreover, general annual analysis indicated that highest numbers of PFF male attack orchard of Navel orange intercropping with Guava, while the lowest were with Navel orange and Guava. Each of season and type of orchard had combined and significant effect on mass trapping (F= 4.414***).

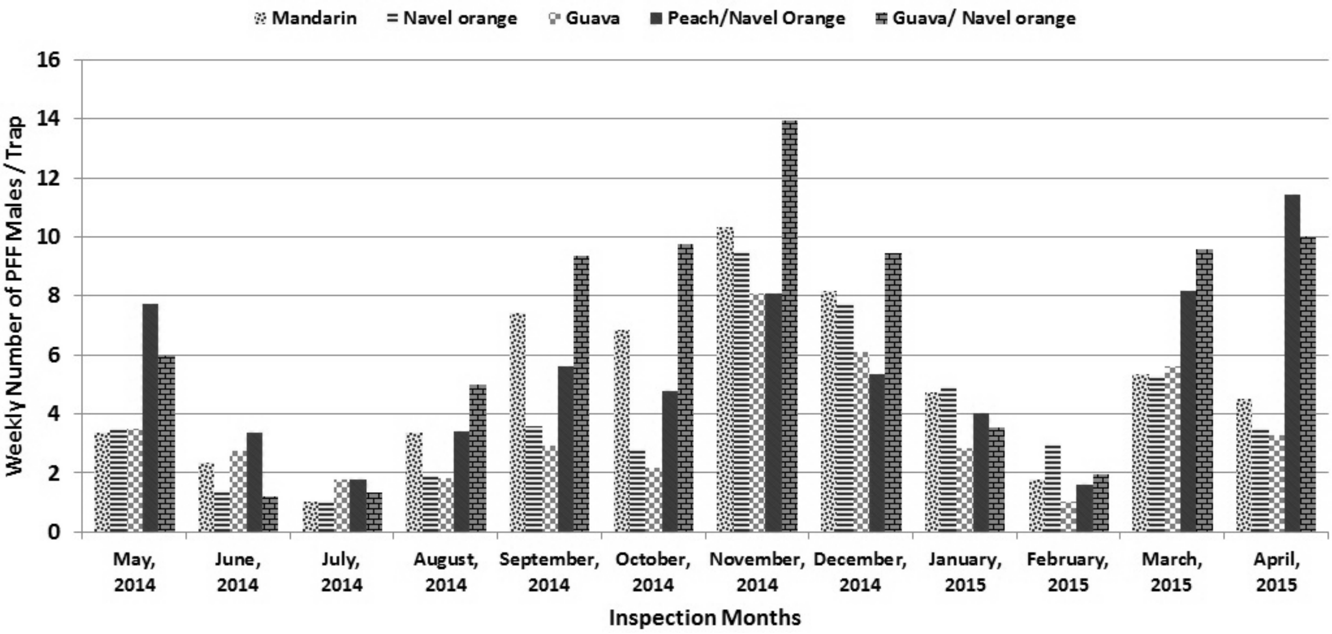

Fig. 5 Monthly mean numbers of PFF males in Jackson traps distributed in different fruits orchards in Kafer El-Shikh Governorate.

In Kharga oases, Egypt, Abdel-Galil et al. (2010) recorded two annual peaks of *B. zonata* throughout May and September and coincided with the ripening periods of apricot, mango and guava. One annual peak was recorded in September and/or October in both Moot and Bodkholow in Dakhla oases and coincided with the ripening period of mango, guava and citrus. Shehata et al. (2008) noted that the most favorite host to this fly was pear fruits followed by guava, peach, apple and finally apricot, in Egypt. In El- Behera governorate Darwish (2012) found that traps that were placed in Navel orange orchards received highest number PFF males in February 2009 and then decreased gradually from March, to June, and lowest with traps in peach orchard. From July until January 2010, the average captured number of males was higher in navel orange than peach orchard. In next season year (2010/2011) the numbers of *B. zonata* increased gradually through three successive months, February, March and April in navel orange and the same trend in peach orchard and began to decreased from May to September and raised up in October and then decreased to the end of the season on peach orchard to disappear completely in January 2011. As the navel orange orchard the monthly average numbers of males were fluctuated and raised up to the top most in October, 2010 and followed the gradually reduction the end of the season in February, 2011. In Assiut, Darwish et al. (2014) monitored that peach fruit fly population during 2011, increased gradually from July to the third week of September. Afterwards, the population declined from the third week of September up to the third week of October then increased to reach its second major peak during October. The greatest drop was observed in November until second week of December. North-western Himalayan region, India, Gupta et al. (1990) found that the seasonal fluctuation of *B. zonata* adult activity occurred during June on apricot and plum while in the second week of July on peach. The maximum capture on peach occurred during the third week of June. In Jammu and Kashmir, India, Rai et al. (2008) revealed that fruit flies occurred on guava, mango, citrus and phalsa, with peak populations of 1882.2, 1967.3 and 1069.3 adult male /trap, respectively. The population density was significantly higher in navel orange orchard than in peach orchard. In Sardarkrushinagar, Gujarat, India, Dale et al. (2010) Mentioned the highest number of fruit fly populations was observed in September and the lowest in May in the guava orchard. The peak fly population coincided with the fruiting season of guava.

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