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Prediction of Annual Generation and Seasonal Fluctuation of Two Fruit Flies, *Ceratitis Capitata* and *Bactrocera Zonata* in Mango Orchard During Two Fruiting Seasons

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ABSTRACT

Degree-day (DD) and thermal developmental thresholds (T0) constants for immature and mature stages of *Ceratitis capitata* (Weidenmann) and *Bactrocera zonata* (Saunders) were estimated. The threshold of immature stages (embryonic development, larval duration and pupal duration) which being 7.44, 5.01 and 3.18°C in *C. capitata* & 5.83, 3.54 and 6.65°C in *B. zonata;* respectively. The threshold temperature (t_0) for the mature stages (pre-oviposition period) recorded 7.08 &7.23°C in *C. capitata* and *B zonata;* respectively. The (t_0) of the duration generation were 8.96 &5.14°C in *C. capitata* and *B. zonata;* respectively. The temperature from 20 to 30°C was the optimum effective zone for *C. capitata* and *B. zonata* stages. The results of laboratory experments were used in a DD model for *C. capitata and B. zonata stages* and correlated them with field fly activity data collected from pheromone traps during two fruiting seasons 2022 and 2023. to predict the peaks of adult emergence according to the DD model patterns. we recorded four peaks each season for each species of the two fruit flies in June, July, August and September. *B. zonata* had higher peaks than those observed in *C. capitata* during the two fruiting seasons. These results helpful in timing fly activity and in IPM program pest control.

KEYWORDS: *Ceratitis capitata, Bactrocera zonata,* development, forecasting, thermal threshold, peaks.

1. INTRODUCTION

Mango considered the most important popular tropical fruits. It has a strong antioxidant, antilipid, peroxidation, cardio tonic, hypotensive wound healing, antidegenerative and antidiabetic activities (Shah K. A., *et al* 2010). Mango fruiting area about 265509 feddan founded mostly in Ismailia and Sharkia. Produce about 145913 ton and 313357 ton in Ismailia (C. A. P& S 2021). It is a very important exporting fruit. The tephritid fruit flies, the Medfly (*C. capitata*) and the peach fruit fly (*B. zonata*) are very dangerous pests attacking numerous species of horticultural plants as mango. They cause a huge damage in mango and other horticultural fruits (White & Elson-Harris, 1992 and Hashem *et al*., 2001). The economic damage of fruit flies appears in qualitative as well as quantitative yield losses. Temperature is the most affecting environmental factor which enhance the developmental rate of many pests as fruit flies. This factor is important for studying economic insects to obtain good information for the prediction of insect population. The world wide spread of this pest is due to its ability for adapting with various climatic changes, the wide range of hosts, highest fertility and the resistance to the used insecticides.

Degree-day (DD) and thermal developmental thresholds (t_0) used to determine the generations of pest and time of pest applied control. Monitoring based on degree-days accumulations is a valuable tool for predicting population pest occurrence. Insecticide is a common effective control method. The number of insecticidal applications markedly reduced at the economic threshold level.

This work aimed to study the relation between temperature and the developmental rate of the two fruit flies using thermal summation. The prediction of development and emergence as effective step for pest management. Monitoring based on degree-days accumulation is a valuable tool to predict population pest occurrence.

2. MATERIALS AND METHODS

2.1. Test insects: -

All stages of the two fruit flies (*B. zonata* and *C. capitata*) used in this study were obtained from a laboratory strains reared in the Horticultural Insects Research Department (HIRD), Plant Protection Institute (PPRI) , Agricultural Research Center (ARC), Dokki, Giza under constant conditions (30±1ºC and 70±5 % R. H.) according to Shehata *et al*. (2008). Small card (1×1 cm) of black filter paper were used. Fifty newly deposited eggs laid within 2hours were inspected to avoid cracked, crashed, damaged or unhealthy eggs then arranged in rows and transferred on wetted black filter papers with distilled water.

2.2.Tested fruits: -

Mango fruits devoted for experimentation washed with tap water then immersed in a disinfectant solution for 1 minute to kill pathogens and left to dry. Afterward, at a sterilized atmosphere (inside laminar flow hood cabinet), small cut in mango peels were made by cutters that sterilized before and cavities measured 1.5x1.5x0.5cm (length, width and depth) were formed by spatulas in fruit flesh.

The black card loaded with eggs which transferred by forceps and inserted into cavities of mango fruit then covered by the peel of mango and rapped thoroughly with adhesive tape.

Four mango fruits (replicated three times) infected artificially with *C. capitata* eggs. The infested mango were placed in plastic boxes (10.0 x10.0 x8.0 cm) contain about 100grams of dried fine sand for pupation then transferred to 5 different incubators adjusted temperature at 20, 25, 30, 35and 40±1℃ El-Abbassi *et al.,* (2017). The same experiment was repeated with *B. zonata* eggs at the same conditions.

The infested mango fruits were examined every 12hrs. to record the incubation period (eclosion), larval duration for development, and pupation period as accurately as possible. Pupae were collected from the fine sand, and kept under the same conditions till adult emergence. The emerged adults were copulated in pairs of each fly species. Every10 pairs kept in wooden cage (10 × 10 × 15cm) provided with (10g sugar: 1g protein hydrolyzed) and a cup of a water-saturated cotton piece for hydration. The pre-oviposition period of the two fruit flies were recorded, till the first ovi-position observed.

2.3.Collected males of the two species fruit flies: -

The field experiments were conducted at orchard in Sharkia governorate, Egypt from June to September in 2022 and 2023 during the fruiting season. An area of 25 feddans of cultivated with mango trees used in this investigation. Jackson traps provided with male six phermone methyl eugenol 98% purity for *B. zonata* adult and trimedlure 98% purity for *C.*

capitata adult (Harris *et al*., 1971). Cotton dispensers were loaded with lures and hanged in the Jackson traps which provided with sticky cards to catch the adult males of two flies. Five replicates traps of each attractant were distributed throughout mango trees, with the rate of one trap/feddan for each species. The traps were hung in the south of mango trees. Trapped males were counted and recorded. Every week the sticky cards of Jackson traps were changed, also the cotton dispensers of two types of pheromones were replaced every two weeks. Fly population was estimated by (FTD) which mean the number of flies counted / trap/ day.

In insects the regression relationship between temperature and developmental rates expressed by the formula $Y= K (T-t_0)$ according to Kajanshikov (1946) where Y is the rate of development determined as the inverse of the duration, T is the given temperature, t_0 expresse the slope value of the regression line of developmental rate. K is the number of heat units required to complete life stage development for about 50% of individuals, expressed as $K = D (T - t_0)$; where T is the temperature required for complete development (Arnold, 1960). According to t_0 estimated for the two fruit flies, *B. zonata* & *C. capitata*, and the daily (T_{max}) & (T_{min}) temperatures which obtained from Central Laboratory for Agricultural Climate (CLAC), the number of heat units (H) acquired by an individual fly under field conditions estimated by Richmond *et al*. (1983) equations, as follows:

$H = \sum Hj$, where: H = the heat units number required for complete development

$Hj = (T_{max.}+T_{min.}) / 2 - t_0$, if $T_{max.} > t_0$ and $T_{min.} > t_0$

$Hj = (T_{max.}-t_0)^2 / 2 (T_{max.} - T_{min.})$, if $T_{max.} > t_0$ and $T_{min.} < t_0$

$Hj = 0$ if $T_{max.} < t_0$ and $T_{min.} < t_0$

2.4.Statistical analyses

All data were analyzed by statistical program by one-way ANOVA according to Snedecor and Cochran (1972)

3. Results

The environmental factor, temperature has important effects on the rate of development in all insect stages. In this study a positive relationship observed between temperatures and rates of development from egg to adult stage for the two fruit flies *C. capitata* and *B. zonata*. Data clarified in Table (1, 2, 3 and 4) and illustrated in Fig. (1and 2) showed lower development threshold temperature (t_0) for each insect developmental stage in the two fruit flies. The threshold of immature stages (embryonic development, larval duration and pupal duration) which being 7.44, 5.01 and 3.18°C in *C. capitata* & 5.83, 3.54 and 6.65°C in *B. zonata;* respectively. Threshold temperature (t_0) for the mature stages (pre-oviposition period) recorded 7.08 &7.23°C in *C. capitata* and *B. zonata;* respectively. The threshold (t_0) of duration of generation were 8.96 &5.14°C in *C. capitata* and *B. zonata;* respectively.

Temperature degrees from 20 to 30°C was the optimum effective zone for two species of fruit flies stages. The rate of development increase with increasing temperatures in all mature and immature stages of the two fruit flies. The rate of development of all *C. capitata* stages was faster than that found in *B. zonata* stages at 20, 25 and 30°C. All deposited eggs of *C. capitata* failed to hatch at 35°C while all mature and immature stages of *B. zonata* completing their development at the same temperature. However, there was a significant decrease in the incubation period, larval and pupal duration as well as pre-oviposition periods and the duration of generation by increasing temperature. We used laboratory results to determine a DD model for *C. capitata and B. zonata stages* and corelated with field fly activity data collected from pheromone traps during two fruiting seasons to predicted peakof adult emerged according to fly activity by the DD model patterns. As illustrated in Table (5, 6) as well as Fig. 3 and 4, the obtained results indicated that the peaks of *C. capitata* population density in season 2022 were slightly higher than that recorded during the season 2023. The peak values during seasons 2022 recorded 19.3, 23.67, 32.33, 39.33 and 40 at thermal units equal 233.85, 652.31, 1112.09, 1423.67 and 2040.94 respectively; whereas, the peak values recorded 14.33, 17.33, 24.33, 31.33 and 26.33 at thermal units 393.11, 722.76, 1369.45, 1900.9 and 2269.95 during seasons 2023. The accumulative daily-degrees in the generations ranged from 311.57 to 617.27 during season 2022 and from 329.65 to 531.45

Table 1. Developmental rates of immature stages of *C. capitata* in Mango at different constant temperature

Temperature	Incubation period	Rate of development	Thermal units	larval duration	Rate of Development	Thermal units	Pupal duration	Rate of development	Thermal units
20	3.3a	30.3	41.45	10.3a	9.71	154.4	11.3a	8.85	190.07
25	2.12b	47.17	37.23	7.9b	12.66	157.9	8.82b	11.34	192.45
30	1.8b	55.56	40.61	6.2c	16.13	154.94	7.1c	14.08	190.4
35	-	-	-	-	-	-	-	-	-
F	17.32	-		224.6			89.27		
LSD	0.65	-		0.048			0.774		
t_0	-	-	7.44	-	-	5.01	-	-	3.18

Table 2. Developmental rates of pre-oviposition period and duration of generation of *C. capitata* in Mango at different constant temperature

Temperature	Preoviposition	Rate of development	Thermal units	Duration of generation	Rate of development	Thermal units
20	6.3a	15.87	81.4	31.2a	3.21	463.6
25	4.1b	24.39	75.26	22.94b	4.36	455.6
30	3.5c	28.57	80.22	18.6c	5.37	462.4
35	-	-	-	-	-	-
F	88.91			146.28		
L.S.D	0.54			1.78		
t_0	-	-	7.08	-	-	5.14

Table 3. Developmental rates of immature stages of *B. zonata* in Mango at different constant temperature

Temp	Incubation period	Rate of development	Thermal units	larval duration	Rate of Development	Thermal units	Pupal duration	Rate of development	Thermal units
20	3.9a	25.64	55.26	10.6a	9.43	174.5	13.95a	7.17	186.23
25	2.5b	40	47.93	8.7b	11.49	186.7	9.94b	10.06	182.4
30	2.1bc	47.61	50.76	7.4c	13.51	195.8	7.97bc	12.55	186.1
35	1.8c	55.55	52.51	5.6d	17.86	176.18	6.51c	15.36	184.56
F	49.3			113.6			10.3		
L.S.D	0.43			0.65			3.28		
t_0			5.83			3.54			6.65

Table 4. Developmental rates of pre-oviposition period and duration of generation of *B. zonata* in Mango at different constant temperature

Temperature	Preoviposition	Rate of development	Thermal units	Duration of generation	Rate of development	Thermal units
20	24.3a	4.12	268.27	52.75a	1.89	673.62
25	14.6b	6.85	234.18	35.74b	2.8	635.1
30	11.4bc	8.77	239.9	28.87c	3.46	657.37
35	9.8c	10.2	255.19	23.71d	4.28	658.43
F	20.5	-	-	106.1	-	
L.S.D.	4.2	-	-	3.9	-	
t_0			8.96			7.23

Table 5. Differences between the estimated peaks using the accumulative thermal units for the revealed generation of *C. capitata* adult during two fruiting seasons.

Series of peaks	Peaks of captured flies			DD's		Differences of (DD's)between peaks		
	2022	**2023**	**Mean±S.E.**	**2022**	**2023**	**2022**	**2023**	**Mean of DD's of peaks**
1st	19.3	14.33	16.81	233.85	393.11	233.85	393.11	313.48
2nd	23.67	17.33	20.5	652.31	722.76	418.45	329.65	374.05
3rd	32.33	24.33	28.33	1112.09	1369.45	459.78	459.78	459.78
4th	39.33	31.33	35.33	1423.67	1900.90	311.57	531.45	421.51
5th	40	26.33	32.83	2040.94	2269.55	617.27	368.65	492.96
Mean±S.E.	30.792	22.73		1092.57	1331.16	408.19	416.53	412.36

Table 6. Differences between the estimated peaks using the accumulative thermal units for the revealed generation of *B. zonata* adult during two fruiting seasons.

Series of peaks	Peaks of captured flies			DD's		Differences of (DD's)between peaks		
	2022	**2023**	**Mean±S.E.**	**2022**	**2023**	**2022**	**2023**	**Mean of DD's of peaks**
1st	27.67	35	31.33	208.38	349.22	208.38	349.22	278.80
2nd	49	46.33	47.66	740.46	1392.8	532.08	1043.6	787.82
3rd	56.67	51	53.83	1149.7	1725.3	409.28	332.56	370.92
4th	53.67	54	53.83	1719.4	2064.7	569.69	339.39	454.54
5th	53	54	53.5	2150.6	2369	431.12	304.22	367.67
Mean±S.	48.002	48.06	-	1193.7	1580.2	430.11	473.79	-

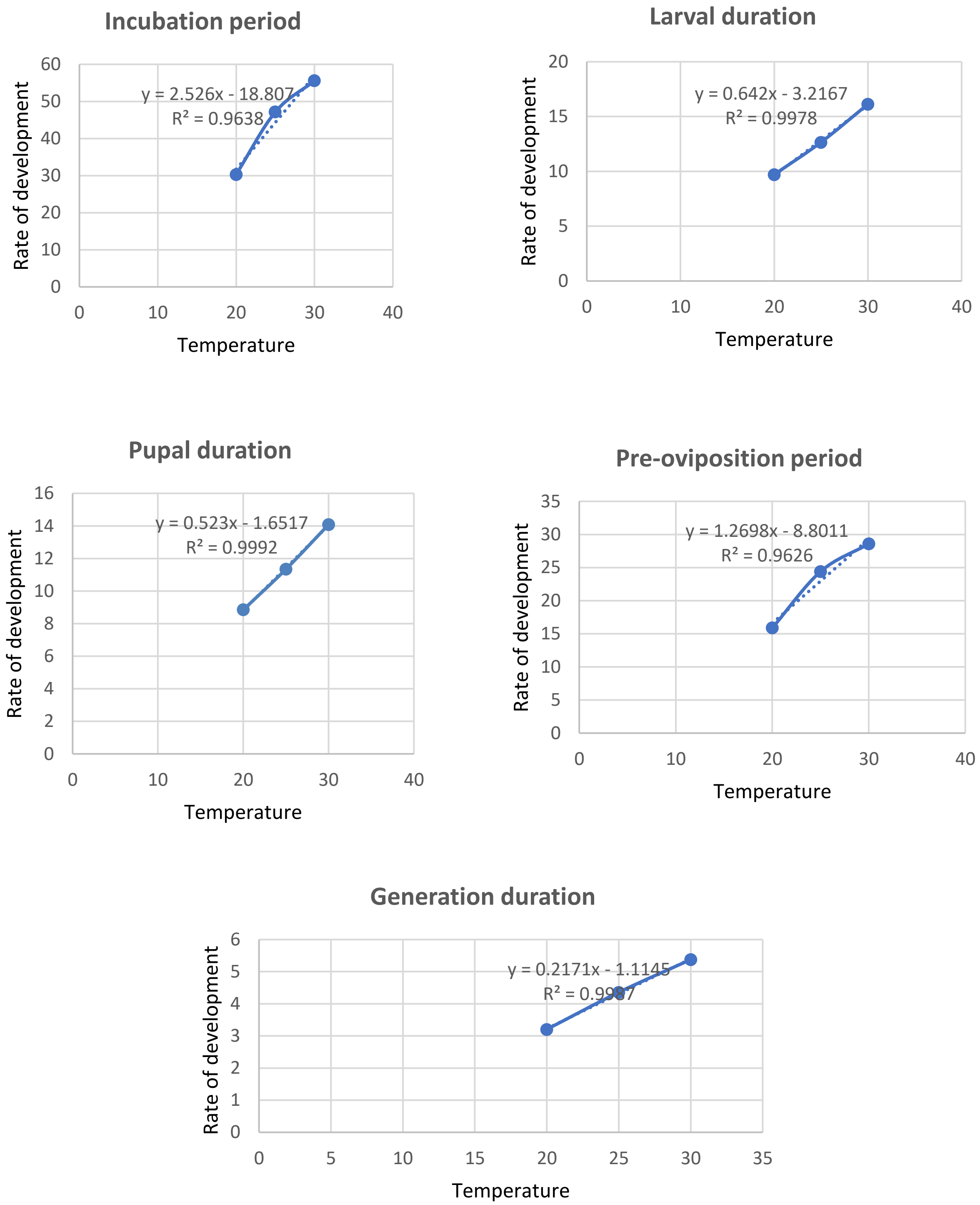


Figure 1. The regression line of immature, mature stages and generations of *Ceratitis capitata* at constant temperature.

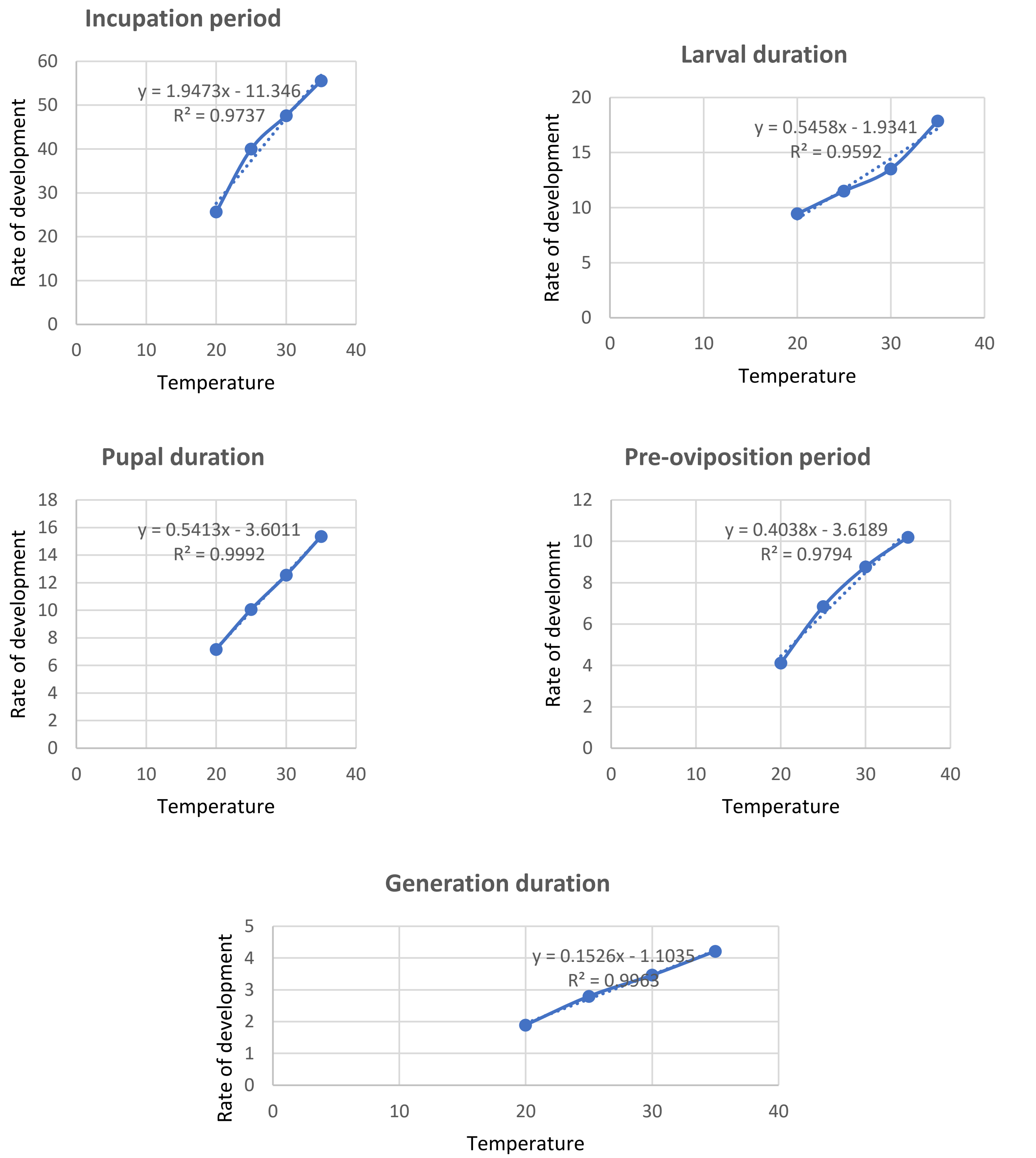
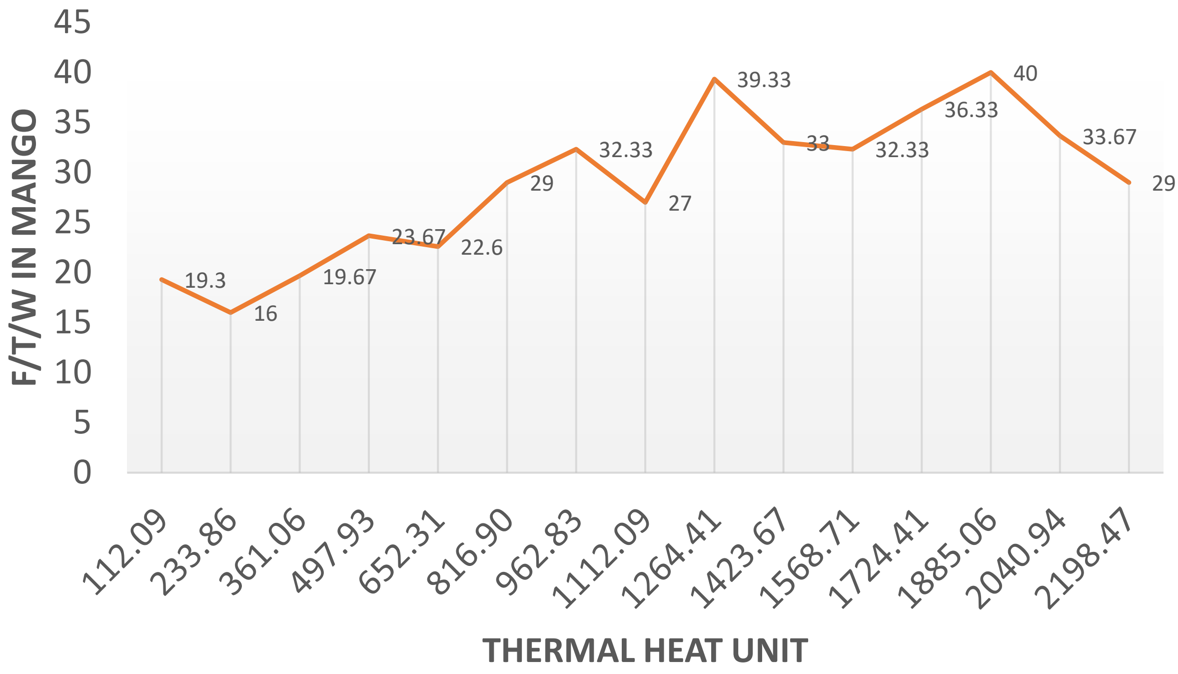


Figure 2. The regression line of immature, mature stages and generations of *Bactrocera zonata* at constant temperature.



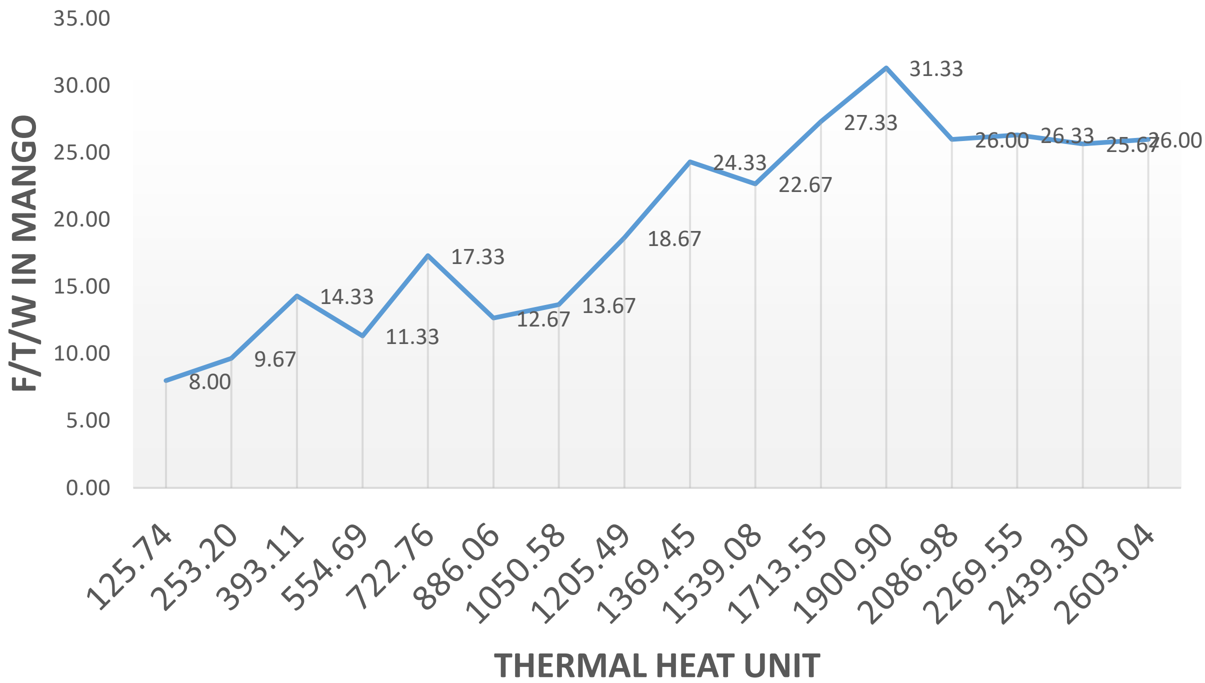


Figure 3. Population density of trapped *Ceratitis capitata* adult males during two fruiting seasons in mango orchard

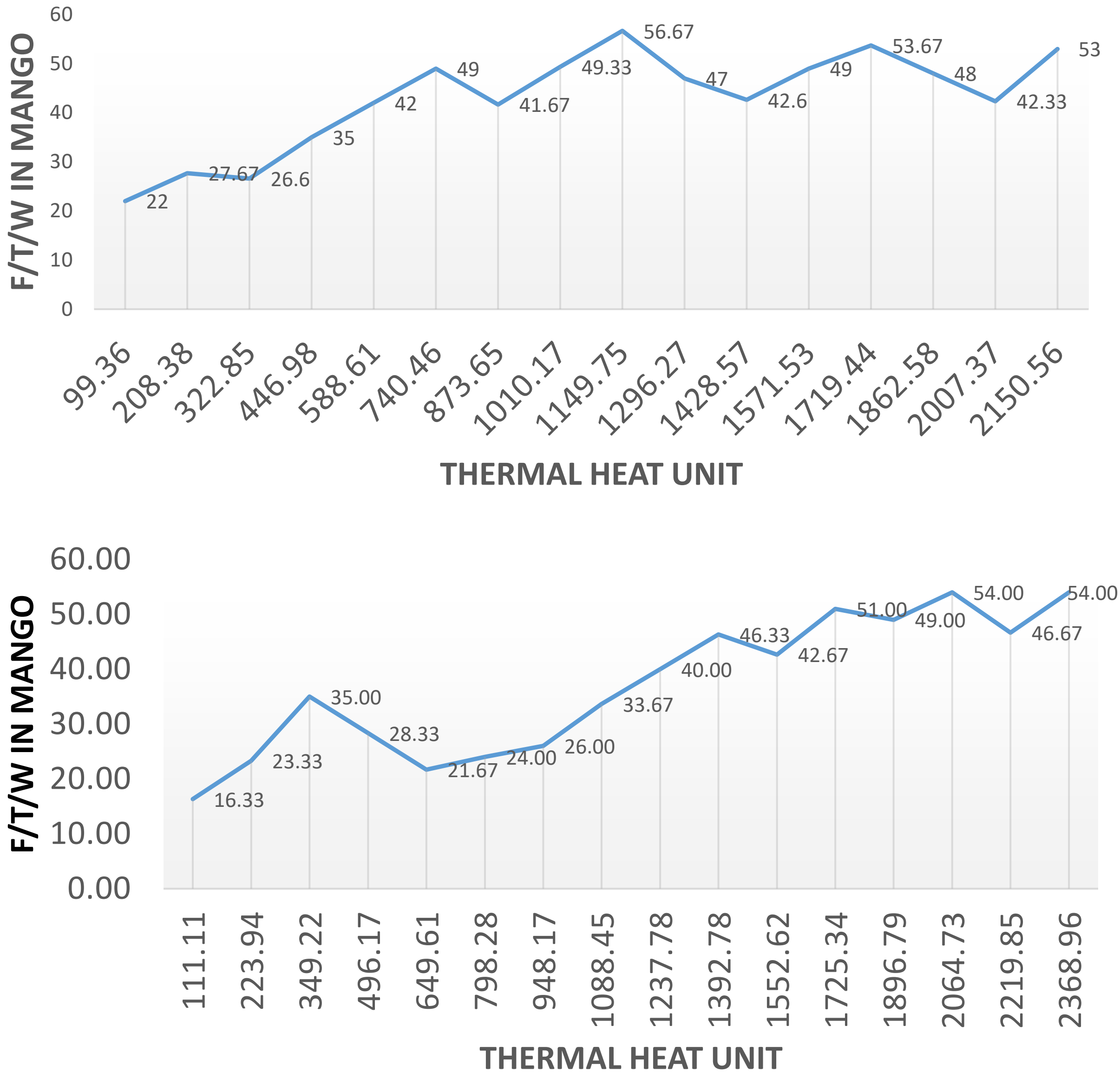


Figure 4. Population density of trapped *Bactrocera zonata* adult males during two fruiting seasons in mango orchard

during season 2023. The peaks of captured B. zonata flies observed higher in season 2023 than that recorded in season 2022. The peaks values were 35, 46.33, 51, 54 and 54 at the thermal unite 349.22, 1392.8, 1725.3, 2064.7and 2369 during season 2023.Whereas the peak values recorded 27.67, 49, 56.67, 53.67and 53 at the thermal units which being 208.38, 740.46, 1149.7, 1719.4 and 2150.6 during season 2022. The accumulative daily- degree in the generations ranged from1392.8 to 2369 and from 740.46 to 2150.6 during season 2023 and 2022; respectively. results detected in tables (7and 8) illustrated the peaks of adult emergence according to the DD model patterns of the two fruit flies during two fruiting seasons 2022 and 2023.The results recorded high fly activities increase gradually during four months from June to August. Average of male flies/trap/week ranged btween16.99 and 34 during season 2022 & ranged from10.83 and 26.33 during season 20.33 in case of *C. capitata*. Average of male flies/trap/week ranged between 27.81 and 47.77 during season 2022 & ranged from 25.74 and 51.55 during season20.33 in case of *B. zonata.* we recorded four peaks each season for each species of the two fruit flies in June, July, August and September. *B. zonata* had higher peaks than those observed in *C. capitata* during the two fruiting seasons.

Table 7. Monthly population density of *Ceratitis capitata* trapped males and accumulative heat units in degree-days (DD's) during two seasons

Month	Average of male flies/trap/week			Average accumulative heat units in daily-degrees		
	2022	2023	Mean	2022	2023	Mean
June	16.99	10.83	13.91	301.24	331.68	316.46
July	26.9	15.58	21.24	886.03	966.22	926.12
August	33.59	26.33	29.96	1573.25	1721.99	1647.62
September	34	26	30	2197.93	2437.29	2317.61

Table 8. Monthly population density of *Bactrocera zonata* trapped males and accumulative heat units in degree-days (DD's) during two seasons

Month	Average of male flies/trap/week			Average accumulative heat units in daily-degrees		
	2022	2023	Mean	2022	2023	Mean
June	27.81	25.74	26.78	269.4	295.1	282.25
July	45.5	26.33	35.91	803.2	871.1	837.17
August	49.78	45.8	47.79	1433	1561	1497.08
September	47.77	51.55	49.66	2007	2218	2112.34

4. DISCUSSION

Developmental times of *B. zonata* was lower at 35 °C than at 30 °C, as previously discussed by Duyck *et al*. (2004). The durations values observed for peach fruit flylife stage at different temperatures were closed to those recorded by (Younes & Akel, 2010; Adly, 2016). The developmental time require to complete the life stages of medfly were shorter than that observed in B. *zonata* stages at temperatures between (20 and25 °C), but they were quite similar at higher temperatures (30°C), which indicate highly adaptation in *B. zonata*, and a reduced efficiency for development under low temperatures (Agarwal *et al*., 1999). The obtained results are agreement with those discussed by Yones *et al*. (2011) they recorded that the developmental rates in all different stages of *P. gossypiella* increase with increasing temperatures. The efficiency of DD models patterns for insect developmental prediction ranges from very accurate to poor, depending on the insect and the model used (Lischke *et al*., 1997). The current results are agree with those recorded by Abdel-Galil *et al*. (2010), he recorded peak of the fruit fly populations in September, during ripening time of guava and mango fruits. The current results are supported by (Bjeliš & Pelicarić, 2002), they observed about five in Croatia which is mostly supported our results. Generally, insects life activities were low in June and July so, populations decreased in June and July and return to increase in August, (Ghanim, 2017), observed four peaks for *Ceratitis capitata* populations in peach orchards. This work also supported by *Bayoumy et al (*2020) they recorded four generations for the two species of fruit flies per season.

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الملخص العربي

التنبؤ بالتقلب الموسمي والاجيال السنوية لذبابة فاكهة البحر الابيض المتوسط *Ceratitis capitata* و ذبابة الخوخ *Bactrocera zonata* في بساتين المانجوا خلال موسمين اثمار

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اشتملت هذه الدراسة على تقدير الوحدات الحرارية التراكمية للاطوار الغير كاملة النمو (t_0) لذبابة الفاكهة وذبابة الخوخ معمليا عند درجات حرارة ٢٠،٢٥،٣٠،٣٥ . وكذلك تم تقدير تعداد ذكور ذبابة الفاكهة والخوخ باستخدام المصائد الفرمونية فى فترات التزهير والاثمار بمزرعة مانجو خلال موسم ٢٠٢٢،٢٠٢٣ على التوالى ومقارنتها بالقمم المتوقعة باستخدام درجات الحرارة اليومية استنادًا إلى بيانات الطقس المحلية. أوضحت النتائج ان معدلات النمو لاطوار ذبابتى الفاكهة والخوخ تتزايد بازدياد درجات الحرارة. وكان صفر النمو (t_0) للجيل يساوى ٥.١٤, ٧.٢٣ وحده حرارية لذبابتى الفاكهة والخوخ على التوالى. كما اظهرت النتائج تباين واضح فى درجات الحرارة اليومية المتراكمة الفعلية للجيل تراوحت بين ٢٣٣.٨٥ و ٦١٧.٢٧ ، ٣٩٣.١١و ٥٣١.٤٥ لذبابة الفاكهة خلال موسم ٢٠٢٢،٢٠٢٣ على التوالى. بينما تراوحت هذه القيم بين ٢٠٨.٣٨و٥٦٩.٦٩ ،٣٤٩.٢٢و١٠٤٣.٦ لذبابة الخوخ خلال موسم ٢٠٢٢،٢٠٢٣ على التوالى. واظهرت النتائج خمس قمم نشاط لذبابة الفاكهة والخوخ خلال الموسمين كما اظهرت النشاط التزايدى الواضح للحشرتين ابتداء من شهر يونية وحتى سبتمبر. لذلك فان التنبؤ بظهور اجيال جديدة للحشرة يلزم لتحديد الوقت الامثل للمكافحة ويقلل استخدام المبيدات الحشرية.