Pak. J. Agri. Sci., Vol. 57(2), 451-456; 2020
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/19.9310
http://www.pakjas.com.pk

LOSS ASSESSMENT AND MANAGEMENT OF *Bactrocera zonata* (DIPTERA: TEPHRITIDAE) IN CITRUS ORCHARDS

Muhammad Ashfaq[1,*], Muhammad Ahsan Khan[1], Muhammad Dildar Gogi[1] and Abdul Rehman[2]

[1]Department of Entomology, University of Agriculture, Faisalabad, Pakistan; [2]Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan
***Corresponding author's e-mail: mashfaqm786@yahoo.com**

Bactrocera zonata (Saunders) is among the most devastating species of Tephritidae, causing severe damage to fruits in Asian countries including Pakistan. The management of this particular species is very challenging because of its complex biology, mode of adaptation and wide range of hosts. Citrus occupies the prominent position in fruit industry of Pakistan in terms of its area, production and export. No systematic information is available on the losses of citrus caused by *B. zonata*, and its management. This study was conducted at Faisalabad and Sargodha districts. Data were collected at fortnight intervals started at early maturity of fruits and continued for 60 days to assess the losses of fruit in three citrus varieties from four different locations of each research site during 2015-16. Male Annilation Technique (MAT) and Bait Application Technique (BAT) with insecticides and sanitation measures (Collection of infested fruit and buried deep in soil) were applied in the form of three IPM models to monitor the infestation rate. The results show that maximum loss of fruit (14.95%) was computed after 60 days of observation among three citrus varieties whereas the minimum fruit loss (6.87%) was measured at 15 days interval. Among varieties, maximum loss (18.92%) was observed in *Citrus reticulata* during both years followed by *C. sinensis* and *C. paradisi* with the highest loss in district Faisalabad (14.66% & 12.26%) as compared to district Sargodha (8.91% & 7.67%), respectively. Among IPM models, the highest infestation was observed in IPM-1 (6.90%), followed by IPM-2 (4.31%). Minimum infestation was recorded by IPM-3 (3.10%). The above findings indicated that the integrated management of *B. zonata* using MAT and BAT techniques has significant effect over control on the fruit fly infestation in the citrus orchards of the study area.

Keywords: *B. zonata,* loss assessment, *C. reticulata,* MAT, BAT and management.

INTRODUCTION

Fruit flies are considered as one of the most damaging agricultural pest around the globe and cause huge threats to horticultural crops, both fruits and vegetables (Hasyim *et al*., 2008; Clarke *et al*., 2011; Hendrichs *et al*., 2015). There are about 4,000 species of fruit flies in the family of Tephritidae throughout the world, out of which around 350 species have great importance (Asian Fruit Fly IPM Project, 2011). Tephritid fruit flies cause 90 to 100 % yield loss in fruits and vegetables depending upon several factors such as area, season, variety and their population (Sapkota *et al*., 2010). Fruit fly caused direct loss in the form of yield and indirect loss such as reduction in trade and export prospect (Sharma *et al*., 2015).

Several Bactrocera species have been established outside of their native Asian range including Pakistan, triggering serious losses at the farm level (Sarwar *et al*., 2013; Khan and Akram, 2018). The estimated annual losses caused by fruit flies in Pakistan are around US$ 200 million (Hussain *et al*., 2010). *Bactrocera zonata* is one of the most important polyphagous fruit flies which is widely distributed in several regions of Pakistan (Sarwar, 2006). The species is vastly distributed along coastal, sub coastal, northern plains and semi desert regions of the country (Marwat *et al*., 1992; Sarwar *et al*., 2013), leading to severe damage to fruits followed by high economic loss (Sarwar *et al*., 2013).

Because of its high economic value and multiple uses, citrus is cultivated on an area of 206,569 hectares of Pakistan, producing 2.36 million tons annually (Memon, 2017). The majority of citrus orchards are located in Punjab province with 95% of the total area (Altaf and Khan, 2008). Citrus production has been reduced throughout the world because of various biotic and abiotic factors (Farnsworth *et al*., 2014). Among biotic factors; the major citrus production loss is caused by arthropod pests (Kilalo *et al*., 2009) such as fruit fly. *Bactrocera zonata*has been considered as one of the major threats to citrus industry causing severe direct and indirect losses throughout the country (Mahmood *et al*., 2014).

The integrated pest management (IPM) is a well-recognized technique and has recently been used for the management of fruit fly throughout the world (Ekesi and Billah, 2007; Ekesi *et al.,* 2009). In citrus orchards, fruit fly pests are currently controlled mainly through the use of proteinaceous bait sprays and bait stations (Manrakhan and Grout, 2010). Fruit fly invasions can also be prevented by using the traps of various

sizes around the perimeter of medium as well as large orchards which not only shows the promising results but also act as ecofriendly (Epsky*et al.,* 2014). Without broadcasting of insecticide, toxic baits are considered as pest management means to diminish the fruit fly population (Navarro-Llopis *et al.,* 2013; Hafsi *et al.,* 2015).

The efficacy of crop protection methods, systems sustainability and making decisions for better integrated pest management quantitative information on crop losses and its management is quite necessary (Savary and Willocquet, 2014; Avelino *et al*., 2015; Allinne *et al*., 2016). In Pakistan, the fruit fly is an economic pest towards citrus which is causing production loss at greater extent. Therefore, the current study was conducted to assess the losses caused by fruit fly (*B. zonata*) and its management to avoid the losses in citrus orchards for more production of yield in two districts of Punjab, Pakistan.

MATERIALS AND METHODS

***Study sites*:** The current study was carried out in major citrus growing areas of Punjab: Sargodha and Faisalabad located between the longitudes 73.07º& 72.67 º East and latitude 31.5º& 32.08 º of North, respectively. The summer season start from April and continues till October with June and July as the hottest months whereas the winter season starts from November and continues till March with December and January as coldest months. The average annual rainfall ranged from 346 mm to 400 mm with half of the annual precipitation received in the months of July and August across the both districts. The mean maximum and minimum temperatures in summer are 39ºC and 27ºC in Sargodha and 40.7ºC and 27.4ºC in Faisalabad, respectively, whereas the mean maximum and minimum temperatures in winter are 20ºC and 8ºC in Sargodha and 19.4ºC and 4.4ºC in Faisalabad district.

***Loss assessment of fruit fly in citrus varieties*:** Fruit loss in citrus orchards was assessed in the study districts for consecutive two years viz., 2015and 2016, during fruiting seasons. Four different locations (Replications) each comprising of three different varieties of citrus viz., mandarin (*Citrus reticulata*), sweet orange (*Citrus sinensis*) and grape fruit (*Citrus paradisi*) from each district were selected for survey. The distance from location was 5 ± 1 Km. The age of each tree was more than five years. The data were collected at fortnightly intervals (15, 30, 45 and 60 days) for two months when the fruit got maximum size. One square meter iron ring was used to collect the dropped fruits from underneath the canopy of each selected tree. In each orchard, four different trees were selected randomly for each citrus variety. Fruits were classified and packed in separate polythene bags. The collected fruits were tagged, brought into the laboratory, counted and separated into total number of fruits and infested fruits showing sign of ovipositor by naked eyes. The percent fruit loss for each variety and districts was calculated by following formula (Khan *et al*., 2005).

$$\text{Fruit loss (\%)} = \frac{\text{No. of infested fruits}}{\text{Total number of fruits}} \times 100$$

The experiment was performed following factorial arrangement under Randomized Complete Block Design (RCBD). The collected data were analyzed following two-way Analysis of Variance (ANOVA) using the Statistix 8.1 software and means were compared by Tukey's Honestly Significant Difference (HSD) test at probability level of 5%.

***Procedure for assessment of IPM models*:** Integrated Pest Management (IPM) module was applied to monitor the infestation by using MAT (Male Annilation Technique), BAT (Bait Application Technique), soft insecticides and sanitation measure. These techniques were applied in the form of three IPM models. IPM-1 consisted of; (I: Pheromone trap five per acre which was refreshed fifteen days intervals. II: BAT application of GF-120 was done after week intervals). IPM-2 consisted of; (I: Insecticide spinosad was spray at fifteen days intervals. II: Sanitation twice a week (Collection of infested fruit and buried deep in soil). IPM-3 consisted of; (I: MAT technique, II: BAT application technique, III: Soft insecticides (abamectin and spinosad) at rate of fifteen days intervals and IV: Sanitation). One orchard treated with water was used as control treatment. Four experimental unit (1st for IPM-1, 2nd for IPM-2, 3rd for IPM-3 and 4th for control one) at a distance of 5 Km from each other were selected in Faisalabad and Sargodha district for application of treatments. Randomly one hundred fruits from each experimental unit were collected and dissected to observe the larval presence in fruits. These infested fruits were identified, separated and counted. The data were then transformed into fruit infestation.

RESULTS

***Fruit infestation*:** The results showed significant results with respect to years, districts, varieties (Table 1). Among study years, the maximum fruit loss (11.79%) was observed during 2015 and minimum loss (9.96%) during 2016. Among verities significant variation regarding loss was observed (f =3034.09, d f= 2, p = 0.00), infestations in *C. reticulata* (18.92%), *C. sinensis* (9.70%) and *C. paradisi* (4.01%) were recorded. Fruit loss in Faisalabad (14.66% & 12.26%) and in district Sargodha (8.91% & 7.67%) was observed during 2015 and 2016. Similarly, when compared the loss among districts, varieties and study years fruit loss of25.42% & 21.52% in *C. reticulata* in Faisalabad and 3.75% and 2.95%was recorded in *C. paradisi* in district Sargodha during 2015 and 2016.

The fruit loss on the basis of observation intervals was in the order of 60> 45> 30>15 days. The infestation after 60 days was14.96% and fruit loss after 15 days intervalwas6.87%. With respect to, the fruit loss among citrus varieties and study sites the maximum loss was observed for *C. reticulata* minimum for *C. paradisi* for both study districts. The loss assessed in *C. reticulata* was higher in district Faisalabad

Table 1. Citrus fruit losses (%) in different years, districts and citrus varieties.

Years	Districts	Percent loss between districts and citrus varieties during study years HSD≤0.05=1.26			Means based on Y × D HSD≤0.05=0.57	Means based on years HSD≤0.05=0.31
		C. reticulata (A)	*C. sinensis* (B)	*C. paradisi* (C)	(D)	(E)
2015	Faisalabad	25.42 ± 1.64^{A}	13.50 ± 0.95^{D}	5.07 ± 0.47^{H}	14.66 ± 1.37^{A}	11.79 ± 0.85^{A}
	Sargodha	15.17 ± 0.93^{C}	7.78 ± 0.78^{F}	3.76 ± 0.47^{IJ}	8.91 ± 0.81^{C}	
2016	Faisalabad	21.52 ± 1.37^{B}	11.01 ± 0.85^{E}	4.26 ± 0.38^{HI}	12.26 ± 1.17^{B}	9.96 ± 0.73^{B}
	Sargodha	13.55 ± 0.83^{D}	6.49 ± 0.67^{G}	2.95 ± 0.39^{J}	7.67 ± 0.74^{D}	
Means based on citrus varieties HSD≤0.05=0.45		18.92 ± 0.86^{A}	9.70 ± 0.53^{B}	4.01 ± 0.23^{C}		

Means within the columns A, B and C showing different letters are significantly different at probability level of 5%. Represent means (Y × D) different letters in column D are also different at probability level of 5%. Column E exhibited the means value of years at probability level of 5%. Means values showing different letters in last row within the columns are also different at probability level of 5%. Y = years, D= district

(15.64% to 30.91%) than (10% to 18.93%) for Sargodha for all observation intervals followed by *C. sinensis*. Minimum loss was measured in *C. paradisi* after 60 (6.60% & 5.74%), 45 (5.23% & 3.68%), 30 (4.19% & 2.60) and 15 days interval (2.63% &1.41%), for district Faisalabad and Sargodha (Table 2).

***Impact of IPM models on fruit infestation in citrus*:** The data showed significant difference (F = 49.46, df= 6, p = 0.00) among IPM models and data recording intervals (Table 3). The highest infestation of fruit fly in citrus orchards was recorded for control after 45 days of interval (36.72%) and was non-significant when compared with 30 days interval

Table 2. Citrus fruit losses (%) in different districts, citrus varieties and observation intervals.

Districts	Varieties	Percent loss between citrus varieties and observation intervals HSD≤0.05=1.99				Means based on varieties HSD≤0.05=0.78	Means based on Districts HSD≤0.05=0.31
		15 Days (A)	30 Days (B)	45 Days (C)	60 Days (D)	(E)	(F)
Faisalabad	*C. reticulate*	15.64±0.81^{EF}	21.50±0.73^{C}	25.83±0.68^{B}	30.91±1.45^{A}	23.47 ± 1.11^{A}	13.46 ± 0.91^{A}
	C. sinensis	7.79±0.44^{I}	10.74±0.59^{H}	13.90±0.71^{FG}	16.59±0.73^{E}	12.26 ± 0.66^{C}	
	C. paradisi	2.63±0.21^{NO}	4.19±0.24^{L-N}	5.23±0.36^{K-M}	6.60±0.47^{I-K}	4.66 ± 0.31^{E}	
Sargodha	*C. reticulate*	10.00±0.33^{H}	13.13±0.49^{G}	15.40±0.52^{EF}	18.93±0.58^{D}	14.36 ± 0.63^{B}	8.29 ± 0.55^{B}
	C. sinensis	3.74±0.36^{MN}	6.13±0.39^{I-L}	7.69±0.46^{IJ}	11.00±0.54^{H}	7.14 ± 0.52^{D}	
	C. paradisi	1.41±0.10^{O}	2.60±0.20^{NO}	3.68±0.29^{MN}	5.74±0.3^{J-L}	3.36 ± 0.29^{F}	
Means based on observation intervals. HSD≤0.05=0.57 (A)		6.87 ± 0.74^{D}	9.71±0.95^{C}	11.95±1.12^{B}	14.96±1.29^{A}		

Means within the columns A, B, C and D showing different letters are significantly different at probability level of 5%. Means values showing different letters in columns E and F are also different at probability level of 5%. Means values showing different letters in rows A are different at probability level of 5%.

Table 3. Comparison of IPM models against fruit fly infestation in citrus orchards.

IPM model	Infestation of fruit fly between IPM models and data recording intervals HSD≤0.05=1.08			Means based on IPM models HSD≤0.05=0.48
	15 days (A)	30 days (B)	45 days (C)	(D)
IPM-1	8.36 ± 0.23^{C}	6.91 ± 0.22^{D}	5.43 ± 0.21^{E}	6.90 ± 0.34^{B}
IPM-2	5.68 ± 0.30^{E}	4.13 ± 0.25^{FG}	3.12 ± 0.23^{G}	4.31 ± 0.31^{C}
IPM-3	4.69 ± 0.25^{EF}	3.13 ± 0.35^{G}	1.49 ± 0.11^{H}	3.10 ± 0.29^{D}
Control	33.47 ± 0.33^{B}	35.68 ± 0.25^{A}	36.72 ± 0.36^{A}	35.29 ± 0.37^{A}
Means base on application intervals (A). HSD≤0.05=0.38	13.05 ± 2.48^{A}	12.46 ±2.81^{B}	11.69 ± 3.03^{C}	

Means within the columns A, B and C showing different letters are significantly different at probability level of 5%. Means values showing different letters in columns D are also different at probability level of 5%. Means values showing different letters in row A are also different at probability level of 5%.

data (35.68%), whereas the lowest infestation was computed after 15 days of interval for control. Among IPM models the highest infestation was observed in IPM-1 (6.90%), followed by IPM-2 (4.31%) while the minimum infestation was recorded at IPM-3 (3.10%) which was significantly different ($p < 0.05$) from IPM-1 and IPM-2. With respect to observation intervals, the maximum infestation of fruit fly was recorded after 15 days interval (13.05%) and the minimum infestation of fruit in citrus orchards was observed after 45 days of interval as depicted in (Table 3).

DISCUSSION

Currently, peach fruit fly is considered as the major pest of fruit and vegetables in Pakistan because of its polyphagous nature, prevalence and predominance in all hosts, its rapid spread in South Asia, invasiveness and destructive nature (Sarwar *et al*., 2014). It is well established under tropical and subtropical conditions resulting in large amounts of damage in Asia (Butani and Verma, 1977; Agarwal *et al*., 1999). Moreover, the losses caused by fruit flies are responsible for reduced crop productivity around the world resulting in severe food security (Cooke, 2006;Oerke, 2006; Avelino *et al*., 2012). Therefore, for sustainable crop production and better pest management, information relevant to crop losses are of prime importance (Savary and Willocquet, 2014; Avelino *et al*., 2015; Allinne *et al*., 2016; Iqbal *et al*., 2018).
This current study confirms that the *B. zonata*, is well established in the studied areas where it occurs at high densities and is becoming the most abundant fruit pest species. The current experiment was carried out to assess the losses caused by *B. zonata* in citrus crop of two districts of Punjab, Pakistan. *B. zonata* is responsible for considerable losses to citrus in major growing areas during 2015-16. Results indicated that among the selected varieties maximum loss was recorded in *C. reticulata* followed by *C. sinensis* and *C. paradisi* during both study years. This might be due to the peel of *C. reticulata* that is more susceptible to *B. zonata*. Our results were supported by those of Rwomushana *et al*. (2008) who found that the loss was more in *C. reticulata* as compared to *C. sinensis* and *C. limon*. The result showed that infestation rate in *C. reticulata* was 5.6 per kg compared to *C. sinensis* (4.6 per kg) and *C. limon* (0.00). Moreover, the findings showed that the loss was higher in district Faisalabad as compared to district Sargodha during both studied years. This is due to the multiple cropping pattern and combination practiced in Faisalabad as compared to Sargodha. Results also verified by Vayssieres *et al*. (2009) who has reported similar infestation level of fruit fly on citrus species. Dorji *et al.* (2006) determined that the fruit fly caused more than 50 percent loss in *C. reticulata*. According to results by Sarwar *et al*. (2014) high density of fruit fly was recorded in the *C. reticulata* (79.58 per trap per week). Similarly, considerable losses due to fruit fly infestation with and without effective control measures were also reported by other authors (Naqvi, 2005; Paiva and Parra, 2013; Awad *et al*., 2014). Similarly, high infestation of fruit fly observed on *C. reticulata* and *C. sinensis* as compared to *C. limon* in Tanzania (Mwatawala *et al*. 2006) was in agreement to our findings, suggesting the pest may be adapted to a wide range of fruit characteristics.
Integrated pest management (IPM) is the combination of all effective and ecofriendly approaches for the control of insect pest. Many pests require IPM for their control as single method is not viable to control them (Alalouni *et al*., 2013; Bulman *et al*., 2016). Therefore, in present study evaluation of different IPM models was done to control the fruit fly infestation in citrus orchards. Results showed that maximum infestation was recorded in control treatment and minimum in the IPM-3. Our results are in line with those of Lloyd *et al*. (2010) who conducted the experiment to control the fruit fly by area-wide management (AWM) program and found a reduction of 21.8% fruit fly infestation under AWM program compared to untreated plot. In present study, all IPM models resulted in 25.11% to 35.49% less infestation as compared to control. These findings are also in agreement to those reported by Kibira*et al*. (2015) that used IMP package for the control of fruit fly in mango orchards and revealed that the application of IPM results in 46.3% less infestation and 22.4% more income when compared to control. Farman *et al*. (2015) also used IPM models and showed that no population was seen in baited trap experiment with a percent decrease ranged from 61.38% to 76.84%. Our results are similar to those reported by Muriithi *et al*. (2016); Khan *et al*. (2017) and Stringer *et al*. (2017) who evaluated the impact of IPM strategy and found less infestation percentage as compared to control for the management of fruit fly in different fruit orchards around the globe.

***Conclusion*:** Based on the finding of the present study it can be concluded that fruit losses caused by peach fruit fly in citrus varying for area (Districts), season (Year) and citrus varieties. *Citrus paradisi* exhibited comparatively less fruit infestation and is recommended for cultivation in fruit fly host-spot area. Application IPM program, specially IPM-3 model (MAT technique, Bait application technique, Soft insecticides and sanitation) is recommended for citrus growing area as significant reduction in fruit infestation was recorded all IPM modules especially in IPM-3.

***Acknowledgement*:** The authors acknowledge the financial support of the Office of Research, Innovation and Commercialization (ORIC), University of Agriculture, Faisalabad, Pakistan under Ph.D. Fellowship Program and Higher Education Commission (HEC) for the Project No. 6343 under National Research Program for Universities (NRPU) to complete this research work.

REFERENCES

Agarwal, M.L., P. Kumar and V. Kumar. 1999. Population suppression of *Bactrocera dorsalis* (Hendel) by *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) in North Bihar. Shashpa. 6:189-191.

Alalouni, U., M. Schadler and R. Brandl. 2013. Natural enemies and environmental factors affecting the population dynamics of the gypsy moth. J. Appl. Entomol. 137:721-738.

Allinne, C., S. Savary and J. Avelino. 2016. Delicate balance between pest and disease injuries, yield performance, and other ecosystem services in the complex coffee-based systems of Costa Rica. Agr. Ecosyst. Environ. 222:1-12.

Altaf, N. and A.R. Khan. 2008. Variation within kinnow (*Citrus reticulata*) and rough lemon (*Citrus jambheri*). Pak. J. Bot. 40:589-598.

Asian Fruit Fly IPM Project. 2011. Field exercise guide on fruit flies integrated pest management. Area-wide integrated pest management of fruit flies in South and Southeast Asia. Bangkok, Thailand. pp. 1-63.

Avelino, J., M. Cristancho, S. Georgiou, P. Imbach, L. Aguilar, G. Bornemann, P. Laderach, F. Anzueto, A.J. Hruska and C. Morales. 2015. The coffee rust crises in Colombia and Central America (2008-2013): impacts, plausible causes and proposed solutions. Food Secur. 7: 303-321.

Avelino, J., M.T. Hoopen and F. De Clerck. 2012. Ecological mechanisms for pest and disease control in coffee and cacao agroecosystems of the Neotropics. In: Rapidel B., L.C.J. Francois, B. John (Eds). Ecosystem services from agriculture and agroforestry measurement and payment. Routledge. pp. 125-152.

Awad, A.A., N.A. Ali and H.O. Mohamed. 2014. Ultrastructure of the antennal sensillae of male and female peach fruit fly, *Bactrocera zonata*. J. Insect Sci. 14:1-15.

Bulman, L.S., R.E. Bradshaw, S. Fraser, J. Martín-Garcia, I. Barnes, D.L. Musolin, and R. Drenkhan. 2016. A worldwide perspective on the management and control of Dothistroma needle blight. Forest Pathol. 46:472-488.

Butani, D.K. and S. Verma. 1977. Pests of vegetables and their control: cucurbits. Pesticides. 11: 37-41.

Clarke, A.R., K.S. Powell, C. Weldon and P.W. Taylor. 2011. The ecology of *Bactrocera tryoni* (Diptera: Tephritdae): what do we know to assist pest management? Ann. Appl. Biol. 158:26-54.

Cooke, B.M. 2006. Disease assessment and yield loss. In: Cooke B.M., D.G. Jones, B. Kaye (Eds). The epidemiology of plant diseases: Springer Netherlands. pp. 43-80.

Dorji, C., A.R. Clarke, R.A.I. Drew, B.S. Fletcher, P. Loday, K. Mahat, S. Raghu and M.C. Romig. 2006. Seasonal phenology of *Bactrocera minax* (Diptera: Tephritidae) in western Bhutan. Bull. Entomol. Res. 96:531-538.

Ekesi, S. and M.K. Billah. 2007. A field guide to the management of economically important Tephritid fruit flies in Africa, second ed. ICIPE Science Press, Nairobi. ISBN. 92:9064 209.

Ekesi, S., M.K. Billah, P.W. Nderitu, S. Lux andI. Rwomushana. 2009. Evidence for competitive displacement of *Ceratitis cosyra*by de Invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae) on mango and mechenisms contributing to the displacement. J. Econ. Entomol.102:981-991.

Epsky, N.D., P.E. Kendra and E.Q. Schnell. 2014. History and development of food-based attractants. In: Shelly T, Epsky N., E.B. Jang, J. Reyes-Flores, R. Vargas (Eds). Trapping and the detection, control, and regulation of tephritid fruit flies. Springer, Germany. pp.75-118.

Farman, U., H. Wardak, H. Badshah, A. Ahmad and M.Q. Kakar. 2015. Response of male fruit fly (Diptera: Tephritidae) to various food essences in methyl eugenol and cue-lure baited traps. J. Entomol. Zool. Stud. 3:239-245.

Farnsworth, D., K. Grogan, A. van Bruggen, and C.B. Moss. 2014. "The potential economic cost and response to greening in Florida citrus." Choices. 29:1-6.

Hafsi, A., A. Harbi, R. Rahmouni and B. Chermiti. 2015. Evaluation of the efficiency of mass trapping of *Ceratitis capitate* (Wiedemann) (Diptera: Tephritidae) in Tunisian citrus orchards using two types of traps: Ceratrap® and Tripack®. Acta Hort (ISHS). 1065: 1049-1056.

Hasyim, A., M. Muryati and W.J. De Kogel. 2008. Population fluctuation of adult males of the fruit fly, *Bactrocera tau* Walker (Diptera: Tephritidae) in passion fruit orchards in relation to abiotic factors and sanitation. Indones. J. Agric. Sci. 9:29-33.

Hendrichs, J., M.V. Teresa, M.D. Meye and A.R. Clarke. 2015. Resolving cryptic species complexes of major tephritid pests. ZooKeys. 540:5-39.

Hussain, A., A. Sajjad and J. Salim. 2010. Efficacy of different control methods against oriental fruit fly, *Bactrocera zonata* (Saunders). J. Agric. Biol. Sci. 5:1-3.

Iqbal, M., M. Hussain, R. Amjad, Q. Ali, N.A. Anjum and M.U. Qasim. 2018. Efficacy of different insecticides against citrus leaf miner, *Phyllocnistis citrella* Stainton, on citrus orchard at Bahawalnagar, Pakistan. J. Glob. Innov. Agric. Soc. Sci. 6:32-34.

Khan, H.A.A. and W. Akram. 2018. Trichlorfon and spinosad resistance survey and preliminary determination of the resistance mechanism in Pakistani field strains of *Bactrocera dorsalis*. Sci. Rep. 8:11223.

Khan, M.A., M. Ashfaq, W. Akram and J.J. Lee. 2005. Management of fruit flies (Diptera: Tephritidae) of the most perishable fruits. Entomol. Res. 35:79-84.

Khan, M.M., S.W.H. Shah, I. Akhter and H. Malik. 2017. Integrated pest management of fruit flies in guava Orchids. J. Ent. Zoo. Stud. 5:135-138.

Kibira, M., H. Affognon, B. Njehia, B. Muriithi, S. Mohamed and S. Ekesi. 2015. Economic evaluation of integrated management of fruit fly in mango production in Embu County, Kenya. Afric. J. Agric. Resour. Econo. 10:343-353.

Kilalo, D., F. Olubayo, S. Obukosia and S. I.Shibairo. 2009. Farmer management practices of citrus insect pests in Kenya. Afric. J. Hort. Sci. 2:168-176.

Lloyd, A., E. Hamacek, R.A. Kopittke, T. Peek, P.M. Wyatt, C.J. Neale, M. Eelkema and H. Gu. 2010. Area-wide management of fruit flies (Diptera: Tephritidae) in the Central Burnett district of Queensland, Australia. Crop Prot. 29:462-469.

Mahmood, R., A. Rehman and M. Ahmad. 2014. Prospects of biological control of citrus insect pests in Pakistan. J. Agric. Res. 52:229-244.

Manrakhan, A. and T.G. Grout. 2010. Fruit fly, integrated production guidelines for export citrus. In: TG Grout (Ed.). Integrated pest and disease management citrus research international, Nelspruit, South Africa. pp. 1-7.

Marwat, N.K., N. Hussain and A. Khan. 1992. Suppression of population and infestation of *Dacus* spp. by male annihilation in guava orchard. Pak. J. Zool. 24:82-84.

Memon, N.A. 2017.Citrus fruit (Kino): Punjab produced 98% of production. Exclusive on Kino. pp. 29-31.

Muriithi, B.W., H.D. Affognon, G.M. Diiro, S.W. Kingori, C.M. Tanga, P.W. Nderitu, S.A. Mohamed and S. Ekesi. 2016. Impact assessment of integrated pest management (IPM) strategy for suppression of mango-infesting fruit flies in Kenya. Crop Prot. 81:20-29.

Mwatawala, M.W., M. De Meyer, R.H. Makundi and A.P. Maerere. 2006. Seasonality and host utilization of the invasive fruit fly, *Bactrocera invadens* (Diptera: Tephritidae) in central Tanzania. J. Appl. Entomol. 130:530-537.

Naqvi, M.H. 2005. Management and quality assurance of fruits and vegetables for export needs for product to market approach. In: Use of Irradiation for quarantine treatment of fresh fruits and vegetables, 19 September 2005, Dhaka, Bangladesh. pp. 14-24.

Navarro-Llopis, V., J. Primo and S. Vacas. 2013. Efficacy of attract-and-kill devices for the control of *Ceratitis capitata*. Pest Manag. Sci. 69:478-482.

Oerke, E.C. 2006. Crop losses to pests. J. Agr. Sci. 144:31-43.

Paiva, P.E.B. and J.R.P. Parra. 2013. Hydrogen ionic potential (pH) of the attractant, trap density and control threshold for *Ceratitis capitata* (Diptera: Tephritidae) on Hamlin oranges in Sao Paulo central region, Brazil. Rev. Bras. Frutic. 35:464-470.

Rwomushana, I., S. Ekesi, I. Gordon and C.K.P.O. Ogol. 2008. Host plants and host plant preference studies for *Bactrocerainvadens* (Diptera: Tephritidae) in Kenya, a new invasive fruit fly species in Africa. Annu. Entomol. Soc. Am. 101:331-340.

Sapkota, R., K.C. Dahal and R.B. Thapa. 2010. Damage assessment and management of cucurbit fruit flies in spring-summer squash. J. Entomol. Nemato. 2:007-012.

Sarwar, M. 2006. Occurrence of insect pests on guava (*Psidium guajava*) tree. Pak. J. Zoo. 38: 197- 200.

Sarwar, M., M. Hamed, B. Rasool, M. Yousaf and M. Hussain. 2013. Host preference and performance of fruit flies *Bactrocera szonata* (Saunders) and *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) for various fruits and vegetables. Int. J. Sci. Res. Environ. Sci. 1:188-194.

Sarwar, M., M. Hamed, M. Yousaf and M. Hussain. 2014. Monitoring of population density and fruit infestation intensity of Tephritid fruit flies (Diptera: Tephritidae) in *citrus reticulata* Blanco orchard. J. Zool. Sci. 2:1-5.

Savary, S. and L. Willocquet. 2014. Simulation modeling in botanical epidemiology and crop loss analysis. The plant health instructor. pp. 1-173.

Sharma, D.R., D. Adhika and D.B. Tiwari. 2015. Fruit fly surveillance in Nepal. Agri. Biolo. Sci. J. 1:121-125.

Stringer, L.D., JM. Kean, J.R. Beggs and D.M. Suckling. 2017. Management and eradication options for Queensland fruit fly. Popul. Ecol. 59:259-273.

Vayssieres, J.F., A. Sinzogan, S. Korie, I. Ouagoussounon and A. Thomas-Odjo. 2009. Effectiveness of spinosad bait sprays (GF-120) in controlling mango infesting fruit flies (Diptera: Tephritidae) in Benin. J. Econ. Entomol. 102:515-521.

[Received 11 July 2019: Accepted 03 Dec- 2019
Published 8 Feb. 2020]