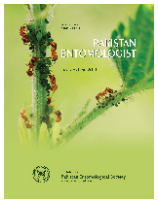
Pakistan Entomologist

Journal homepage: www.pakentomol.com



LABORATORY BIOASSAY FOR INVESTIGATING THE REPELLENT AND OVIPOSITION-DETERRENT IMPACTS OF VARIOUS IGRS ON GUAVA FRUIT FLY, *BACTROCERA CORRECTA* (DIPTERA: TEPHRITIDAE)

[*]Muhammad Jalal Arif, Muhammad Dildar Gogi, Wajeeh-Ud-Din, Muhammad Arshad, Zain-ul-Abdin and Waqas Wakil

Department of Entomology, University of Agriculture, Faisalabad, Pakistan

ARTICLE INFORMATION

Received: December 5, 2013

Received in revised form: June 2, 2014

Accepted: June 20, 2014

***Corresponding Author**:

Muhammad Jalal Arif

Email: jalalarif807@yahoo.com

ABSTRACT

A laboratory bioassay was carried out to assess the repellent impacts of various IGRs on guava fruit fly, *Bactrocera correcta* (Diptera: Tephritidae). The results reveal that settling response of adult guava fruit fly, percent repellency and percent oviposition-deterrence to treated fruit increased with increasing concentration of all evaluated IGRs. Less number of adult fruit flies settled on fruits treated with Silent® [12 (60%)] followed by Sitara® [13(65%)], Admiral® [13(65%)] and Runner® [13.7(69%)] at their highest concentration used in present study. Repellency test revealed that Silent® explained comparatively maximum repellency (22.3%) followed by Admiral® (19.7%), Sitara® (19%) and Runner® (18%) at their highest concentration used in present study. Probit analysis also demonstrated that Silent® proved highly effective repellent for adult guava fruit flies as it revealed the minimum RC_{50} value (0.61%) followed by Admiral®, Sitara® and Runner® which exhibited 0.86, 0.97 and 1.06% RC_{50} values, respectively. Similarly, Silent® proved highly effective oviposition-deterrent for adult guava fruit flies as it revealed the minimum ODC_{50} value (0.59%) followed by Admiral®, Sitara® and Runner® which exhibited 0.6, 0.66 and 1.2% ODC_{50} values, respectively. However, a comparison of FRD with RC_{50} and ODC_{50} values of IGRs expounded that none of the evaluated IGRs would be effective repellent or oviposition-deterrent because RC_{50} and ODC_{50} values of Silent®, Admiral®, Sitara® and Runner® were many times higher than their FRD. In conclusion, these IGRs can be used as repellent or oviposition-deterrent for fruit flies at higher dose rates; but it would be better to apply these IGRs for impregnation in impregnated-bagging-technique than foliar application.

Keywords: Bioassay, Guava fruit fly, Insect growth regulators, Repellence and deterrence

INTRODUCTION

Among fruit flies, the guava fruit fly, *Bactrocera correcta*, is found one of the most severe pest in the genus *Bactrocera* (Wang, 1996) and found in countries like Pakistan, Burma, India, Nepal, Sri Lanka, Vietnam, China and Thailand (Wang, 1996; Drew and Raghu, 2002). This fly is polyphagous with a wide host range of more than 30 plant families of tropical and subtropical fruits (Maynard *et al.,* 2004) but it is often referred as "guava fruit fly" (White and Elson-Harris, 1994) . Guava fruit fly cause severe quantitative and qualitative losses directly as well as indirectly to guava fruits (Alyokhin *et al*., 2001; Armstrong, 2003; Follett and Armstrong, 2004; Sarwar, 2006; Ekesi and Billah, 2007), rose-apple (*Syzygium jambos*), mango (*Mangifera indica*), sapodilla *(Manilkara zapota)*, peach (*Prunus persica*) (Fletcher, 1919; Clausen *et al*., 1965; Shah and Vora, 1975; Satoh *et al*., 1985), apricot (*Prunus armeniaca*) and suriname cherry (*Eugenia uniflora*) (Kapoor, 1993). Great losses were caused by this pest in fruit and vegetable production (Drew and Raghu, 2002) and is registered as a quarantine pest by most countries worldwide. *Bactrocera correcta*, severely infests summer crop of guava which is totally lost due to this pest. Fruit flies cause damage by puncturing the fruit skin through ovipositor and laying eggs (Hollingsworth and Allwood, 2000). The newly hatched larvae start feeding inside the fruit (Dhillon *et al.*, 2005) which is destroyed completely (Ye and Liu, 2005).

In Pakistan, synthetic insecticides such as deltamethrin,

Cite this article as: Arif, M.J., M.D. Gogi, Wajeeh-Ud-Din, M. Arshad, Zain-ul-Abdin and W. Wakil, 2014. Laboratory bioassay for investigating the repellent and oviposition-deterrent impacts of various IGRs on guava fruit fly, *Bactrocera correcta* (Diptera: Tephritidae). Pak. Entomol., 36(1):39-44.

fenthion and dimethioate are used as foliar spray on guava for management of fruit flies pest. The application of these insecticides cause very low level of reduction in fruit fly infestation but render high level of toxic residues in guava fruits. According to Patel *et al.* (1990), 14.95%, 11.865%, 8.83% and 21.5% reduction in guava infestation was observed when deltamethrin, fenthion, dimethioate and endosulfan were applied, respectively. There are many other biorational insecticides like IGRs which are considered comparative ecofriendly as well as effective against insect pests. Insect pest control by the help of IGRs has been developed in last few years (Alam *et al.,* 2001). IGRs affect the developmental stage, metamorphosis and reproduction of the insect pest (Riddiford and Truman, 1978; Magoc *et al.,* 2005). Cyromazine is chitin synthesis inhibitor used for control of Mediterranean fruit fly (Jemaa and Boushih, 2010) and the most effective larvicide against various dipteran and lepidopteran species (Hall and Foehse, 1980). Similarly, lufineuron has been investigated for its chemosterilant effects against various species of fruit flies (Chang *et al*., 2012). There are so many IGRs which have not been evaluated for their repellent and chemosterilant effects against fruit fly species, specifically against *B. correcta*.

Fruit flies are specific to type of odor emitted from plant parts as well as of synthetic chemicals for attraction and repellence (Cornelius *et al.,* 2000; Muryati *et al.*, 2012). The formulation of IGRs do have odor due to various components of their formulation that may repel the fruit flies. That's why hypothesis was made and tested either the evaluated formulations of IGRs have any repellency effect to guava fruit fly.

MATERIALS AND METHODS

The present research experiment was conducted in the Integrated Pest Management (IPM) laboratory of Department of Entomology, University of Agriculture Faisalabad, Pakistan.

Rearing of guava fruit flies

Infested guava were collected from different orchard in Faisalabad. The infested fruits were brought into laboratory and kept in the card boxes already half-filled with sieved and sterilized sand. After a week, pupae were recovered by using a fine mesh sieve. The pupae were placed in the dome shaped rearing cages till the adult emergence. The cages were provided with the spongy strips soaked with adult diet containing honey, protein and sugar solution. The strips were suspended after soaking in diet solution. The fresh, properly cleaned and washed guava fruits were brought in lab and suspended inside the rearing cage for eggs collection. The fruits after three days were transferred from rearing cage to card boxes containing sterilized sand for obtaining the next progeny. This procedure was used to mass culture fruit fly.

Preparation of pesticides dilutions

The plastic jar to be used in the trial were cleaned thoroughly with a detergent, rinsed with distilled water and then air dried. A stock solution (D-1) of the highest concentration was prepared for IGRs and the serial dilutions were made by taking half of the stock solution and diluting it with distilled water to the original volume in another measuring cylinder to make D-2. Successive dilutions were made until last dilution for each of the IGR was achieved. The formulations and concentration of IGRs used for studying their repellence and oviposition deterrence effects on guava fruit fly are given in Table 1.

Evaluation of repellency of pesticides dilutions

Five concentration of each IGRs were prepared in water and evaluated by fruit dip and free choice method.

Fruit dip method

Two guava fruits of almost similar size and shape were dipped in each concentration of every IGR for one minute and dried for ten minutes at room temperature. Similarly two guava fruits were dipped in water for one minute and dried for ten minutes.

Free choice method

Overall, two (2) guava fruits were treated with each concentration of each IGR (total 40 fruit were treated with five concentrations of four IGRs); whereas, two fruit were treated with water. These forty two (42) fruits treated with IGRs and water were labelled for respective treatments and suspended randomly inside the dome shaped cages at same height. Twenty female fruit flies approximately of two weeks old were released inside the cage. The number of fruit flies visiting treated fruits were observed and counted after every 60 minutes for 10 hours. Average numbers of fruit flies visiting fruits were calculated. After 24 hours, the old fruit flies were aspirated from each cage and new set of fruit flies was released. This practice was repeated after every 24 hours for 7 days. After 7 days, fruits were taken out and number of ovipunctures were counted. Each fruits was examined for ovipunctures under microscope. The fruits exhibiting ovipunctures were considered as fruit preferred for oviposition. This experiment was repeated three times under the same set of condition (30±2ºC, 70±5% rh and 16:8 hrs L:D period). The data collected on fruit fly settling and oviposition preference were transformed into corrected percentage repellency and corrected percent oviposition-deterrence by following formula.

$$\text{Corrected Percent Repellency} = \frac{½(NF_{t+ut}) - NF_t}{½(NF_t + u_t)} \times 100 \text{----------(1)}$$

NF_{t+ut} = Number of fruit flies settled on treated and untreated guava

NF_t = Number of fruit flies settled on treated guava (Rehman *et al*., 2009)

$$\text{Corrected Percent oviposition deterrence} = \frac{½(NO_{t+ut}) - NO_t}{½(NO_{t+ut})} \times 100 \text{ --------(2)}$$

NO_{t+ut} = Number of ovipunctures on treated and untreated guava

No_t = Number of ovipunctures on treated guava (Rehman *et al*., 2009)

Table 1
Formulations of insecticides used for experimentation.

Trade Name	Chemical Name	Company	FRD	Concentrations (%)
Runner® 240 EC	Methoxyfenozide	Dow Agro-sciences	120 ml/acre)	0.003, 0.006, 0.012, 0.024, 0.048
Silent® 5 EC	Lufenuron	Ali Akbar Group	200 ml/acre)	0.005, 0.01, 0.02, 0.04, 0.08
Sitara® 25 WP	Buprofezin	Ali Akbar Group	500 g/acre)	0.0125, 0.025, 0.05, 0.1, 0.2
Admiral® 10 EC	Pyriproxifen	FMC	200 ml/acre)	0.005, 0.01, 0.02, 0.04, 0.08

FRD = field recommended dose

Statistical Analysis

All the data regarding repellency of fruit fly were subjected to ANOVA techniques and Tucky's HSD test for determining the effects of treatments and comparing the means of significant treatments, respectively. The data regarding percent repellency and oviposition-deterrence were also subjected to probit analysis (Finney, 1952) for the determining RC_{50} (concentration at which 50% flies were repelled) and ODC_{50} (concentration at which 50% flies showed oviposition-deterrent response) values.

RESULTS

Impact of various concentrations of different IGRs on the settling response of adult guava fruit flies

Significant variation in settling response of adult guava fruit flies was observed for various concentrations of each evaluated IGR ($P < 0.05$) (Table 2). Settling response of adult guava fruit fly to treated fruit increased with increasing concentration of all evaluated IGRs. On an average, 13.7-17.6 (69%-88%), 13.0-18.3 (65%-91.5%), 12.0-17.0 (60-%-85%) and 13-16.6 (65%-83%) adult fruit flies settles on treated fruits, being significantly lower at higher concentration and higher at lower concentration used for Runner®, Sitara®, Silent®, and Admiral® in present study, respectively. Comparatively, less number of adult fruit flies settled on fruits treated with Silent® [12 (60%)] followed by Sitara® [13(65%)], Admiral® [13(65%)] and Runner® [13.7(69%)] at their highest concentration used in present study. However, at highest concentration used in present study, similar settling response of adult fruit flies to fruits treated all evaluated IGRs was observed (Table 3).

Impact of various concentrations of different IGRs on repellent response of adult guava fruit flies

Percent repellency of each evaluated IGR varied significantly for different concentrations ($P < 0.05$) (Table 2). Percent repellency increased with an increase in concentration of each IGR. In control treatments, 0.0% repellency of adult guava fruit fly was observed. Runner® explained 5.0-18% repellency against adult guava fruit flies, being significantly higher at 0.048% and lower at 0.003% concentration. Sitara® exhibited 1.7-19% repellency against adult guava fruit flies, being significantly higher at 0.2% and lower at 0.0125% concentration. Similarly, Silent® and Admiral® demonstrated 5.3-22.3% and 8.0-19.7% repellency against adult guava fruit flies, being significantly higher at 0.08% and lower at 0.005% concentration, respectively. These results revealed that Silent® explained comparatively maximum repellency

Table 2
ANOVA parameters for independent variable (concentrations) of different insecticides against various dependent variables (Total df = 17 having three replications).

Dependent variables	Insecticides	Concentrations (source of variation)				
		df	SS	MSS	F	P
Number of fruit flies settled	Runner®	$5^{+}/12^{++}$	85.5	17.3	8.65	0.001^{**}
	Sitara®	$5^{+}/12^{++}$	102.2	20.4	9.20	0.0009^{**}
	Silent®	$5^{+}/12^{++}$	108.9	21.8	26.1	0.0000^{**}
	Admiral®	$5^{+}/12^{++}$	95.6	19.1	11.5	0.0003^{**}
Percentage Repellency	Runner®	$5^{+}/12^{++}$	805.7	161.1	5.98	0.005^{**}
	Sitara®	$5^{+}/12^{++}$	1032	206.4	7.12	0.002^{**}
	Silent®	$5^{+}/12^{++}$	1128.9	225.7	12.0	0.0003^{**}
	Admiral®	$5^{+}/12^{++}$	916.9	183.9	7.50	0.002^{**}
Percentage Oviposition-deterrence	Runner®	$5^{+}/12^{++}$	1033.1	206.6	5.76	0.006^{**}
	Sitara®	$5^{+}/12^{++}$	1351.6	270.3	6.51	0.003^{**}
	Silent®	$5^{+}/12^{++}$	1509.8	301.9	13.4	0.0001^{**}
	Admiral®	$5^{+}/12^{++}$	1185.7	237.6	7.57	0.002^{**}

df = degree of freedom, SS = sum of square, MSS = mean sum of square, P = probability value, F = F-test value, ** = Highly significant at < 0.01 probability level, $^{+}$ = degree of freedom of treatment, $^{++}$ = degree of freedom of error

(22.3%) followed by Admiral® (19.7%), Sitara® (19%) and Runner® (18%) at their highest concentration used in present study (Table 3). The results of Probit analysis revealed that all the evaluated IGRs demonstrated different repellent effects on adult guava fruit flies as none of the fiducial limits against each IGR overlap each other. Silent® proved highly effective repellent for adult guava fruit flies as it revealed the minimum RC_{50} value (0.61%) followed by Admiral®, Sitara® and Runner® which exhibited 0.86, 0.97 and 1.06% RC_{50} values, respectively. None of the evaluated IGRs would be effective repellent at field recommended doses (FRD) because RC_{50} values of Silent®, Admiral®, Sitara® and Runner® were approximately 3, 4, 2 and 10 times higher than their FRD (Table 4).

Impact of various concentrations of different IGRs on oviposition-deterrent response of adult guava fruit flies

For each IGR, concentrations had significant effect on oviposition-deterrent response of adult guava fruit flies ($P < 0.05$) (Table 2). Percent oviposition-deterrence increased with an increase in concentration of each IGR. In control treatments, 0.0% oviposition-deterrence against adult guava fruit fly was observed. Runner® explained 6.3-20.7% oviposition-deterrence against adult guava fruit flies, being significantly higher at 0.048% and lower at 0.003% concentration. Sitara® exhibited 5.3-21.7% oviposition-deterrence against adult guava fruit flies, being significantly higher at 0.2% and lower at 0.0125% concentration. Similarly, Silent® and Admiral® demonstrated 6.0-25.7% and 8.6-22.3% oviposition-deterrence against adult guava fruit flies, being significantly higher at 0.08% and lower at 0.005% concentration, respectively. These results revealed that Silent® explained comparatively maximum oviposition-deterrence (25.7%) followed by Admiral® (22.3%), Sitara® (21.7%) and Runner® (20.7%) at their highest concentration used in present study (Table 3). The Probit analysis explained that oviposition-deterrent effects of the evaluated IGRs on adult guava fruit flies varied significantly as none of the fiducial limits against each IGR overlap each other. Silent® proved highly effective oviposition-deterrent for adult guava fruit flies as it revealed the minimum ODC_{50} value (0.59%) followed by Admiral®, Sitara® and Runner® which exhibited 0.6, 0.66 and 1.2% ODC_{50} values, respectively. However, a

Table 3
Number of fruit flies settles, percent repellency and percent oviposition-deterrence of different IGRs at their various concentrations against adult guava fruit flies (* values in bracket indicate the percent of total adult guava fruit flies released that were attracted to treated fruits).

Insecticides	Concentrations (%)	Number of fruit flies settled*	CPR (%)	CPOD (%)
	0.048	13. 7±1.5^{c} (69%)	18.0±5.1^{A}	20.7±4.9^{A}
	0.024	13.6±1.0^{C} (68%)	18.0±4.2^{A}	20.7±4.6^{A}
	0.012	14.5±1.3^{BC} (72.5%)	14.7±4.7^{A}	16.7±5.5^{A}
Runner®	0.006	15.6±1.5^{BC} (78%)	11.6±5.2^{AB}	13.0±4.4^{AB}
	0.003	17.6±2.1^{AB} (88%)	5.0±4.8^{AB}	6.3±4.7^{AB}
	0.0 (control)	19.7±1.7^{A} (98.5%)	0.00±0.0^{B}	0.00±0.0^{B}
	0.2	13.0±1.2^{D} (65%)	19.0±4.9^{A}	21.7±5.1^{A}
	0.1	13.3±1.3^{CD} (66.5%)	17.7±4.2^{A}	20.3±5.0^{A}
Sitara®	0.05	14.7±2.1^{BCD} (73.5%)	13±5.1^{AB}	15.0±5.3^{AB}
	0.025	17.3±1.4^{ABC} (86.5%)	4.6±4.3^{AB}	5.3±4.8^{AB}
	0.0125	18.3±1.1^{AB} (91.5%)	1.7±4.2^{B}	2±5.2^{B}
	0.0 (control)	19^{A} ± 1.6(95%)	0.00±0.0^{B}	0.00±0.0^{B}
	0.08	12.0±1.1^{D} (60%)	22.3±3.5^{A}	25.7±3.9^{A}
	0.04	12.3±0.7^{CD} (61.5%)	21±3.3^{A}	24.3±4.0^{A}
Silent®	0.02	14.7±0.6^{BC} (73.5%)	12.6±4.1^{AB}	14.7±3.6^{AB}
	0.01	14.7±0.8^{BC} (73.5%)	12.3±3.4^{AB}	14.3±3.8^{AB}
	0.005	17.0±1.2^{AB} (85%)	5.3±4.2^{BC}	6.0±3.7^{BC}
	0.0 (control)	19.0±0.9^{A} (95%)	0.00±0.0^{C}	0.00±0.0^{C}
	0.08	13±1.1^{C} (65%)	19.7±4.3^{A}	22.3±5.1^{A}
	0.04	13±1.2^{C} (65%)	19.7±4.5^{A}	22±4.7^{A}
Admiral®	0.02	16±2.1^{ABC} (80%)	17±5.1^{A}	19.3±4.5^{A}
	0.01	16±2.2^{ABC} (80%)	10±4.4^{AB}	11±4.6^{AB}
	0.005	16.6±1.3^{AB} (83%)	8±4.6^{AB}	8.6±4.4^{AB}
	0.0 (control)	19.3±1.5^{A} (96.5%)	0.00±0.0^{B}	0.00±0.0^{B}

CPR = Corrected Percentage Repellency; CPOD = Corrected Percentage Oviposition-deterrence

Table 4

Rc_{50} values for the percentage repellency as compared to control for free choice method of fruit dip technique of different concentrations of Runner®, Sitara®, Silent® and Admiral® for adults of guava fruit fly (*Bactrocera correcta*) at C.I. 95%.

Insecticide	FRD (ml/acre)	RC_{50}	95% FL	Slope ± SE	χ^2 (*d.f,* P)
Runner®	120	1.06% (1060 ml/acre)	0.18-6.64	0.43 ± 0.15	2.14 (3, 0.52)
Sitara®	500	0.97% (970 ml/acre)	0.37-7.74	0.50 ± 0.11	3.74 (3, 0.29)
Silent®	200	0.61% (610 ml/acre)	0.21-9.27	0.33 ± 0.11	2.49 (3, 0.47)
Admiral®	200	0.86% (860 ml/acre)	0.19-21.47	0.47 ± 0.13	6.98 (3, 0.07)

FRD= Field recommended dose, RC_{50} = Concentration of IGR at which 50% of fruit flies were repelled from treated fruits, FL = Fiducial limit, SE = standard error, χ^2 = Chi square value, *d.f,* = degree of freedom, P = probability value i.e. 5%

comparison between FRD and ODC_{50} expounded that none of the evaluated IGRs would be effective oviposition-deterrent because ODC_{50} values of Silent®, Admiral®, Sitara® and Runner® were approximately 3, 3, 1 and 13 times higher than their FRD (Table 5).

DISCUSSION

Fruit flies are specific to type of odor emitted from plant parts as well as of synthetic chemicals for attraction and repellence (Cornelius *et al.,* 2000; Muryati *et al.*, 2012). The formulation of insecticides do have odor due to various components of their formulation that may repel the fruit flies. A laboratory bioassay was carried out to assess the repellent impacts of various IGRs on adult guava fruit fly, *B. correcta.* The results reveal that settling response of adult guava fruit fly, percent repellency and percent oviposition-deterrence to treated fruit increased with increasing concentration of all evaluated IGRs. This concentration dependent variation in repellence and deterrence may be attributed to more concentrated solution of formulation and solvent used for fruit dipping, because odor is more persistent in more concentrated form as compared to diluted form. Less number of adult fruit flies settled on fruits treated with Silent® (60%) followed by Sitara® (65%), Admiral® (65%) and Runner® (69%) at their highest concentration used in present study. Repellency test revealed that Silent® explained comparatively maximum repellency (22.3%) followed by Admiral® (19.7%), Sitara® (19%) and Runner® (18%) at their highest concentration used in present study. These variation in the repellence of IGRs can be ascribed to the variation in the chemical constituents of their formulation as different pesticide company use different types of chemicals as carrier/inner materials for the formulation of active ingredients at their pesticide formulation plants. The statistical parameters of Probit analysis of present study also proved these results. According to the results of Probit analysis, Silent® proved highly effective repellent for adult guava fruit flies as it revealed the minimum RC_{50} value (0.61%) followed by Admiral®, Sitara® and Runner® which exhibited 0.86, 0.97 and 1.06% RC_{50} values, respectively. These result cannot be compared or contradicted with other researchers no information was found in the reviewed literature. Similarly, Fruit flies are very sensitive in selecting fruits for oviposition to ensure the survival and development of next progeny. The selection of suitable fruits progeny development is achieved with the help of different types of chemoreceptors present on their different body parts, especially, on antennal, mouthparts, tarsi etc. The fruits found contaminated with toxicant are rejects by fruit flies for oviposition. But the degree of deterrence varies from species to species as well as from chemical to chemical (Eisemann and Rice, 1985; McInnis, 1989; Oi and Mau, 1989; Messina, 1990; Kostal, 1993). The results of present research confirmed these facts. A significant variation in the oviposition deterrence was demonstrated by different IGRs. Silent® proved highly effective oviposition-deterrent for adult guava fruit flies as it revealed the minimum ODC_{50} value (0.59%) followed by Admiral®, Sitara® and Runner® which exhibited 0.6, 0.66 and 1.2% ODC_{50} values, respectively. Unlikely, the results described by El-Mahasen *et al.* (2010) are not in confirmation with the results of present studies. They carried out an experiment to evaluate the biological effects of five IGRs (Applaud®, Match®, Mimic®, Admiral® and Consult®) on house fly and documented significantly increased oviposition-deterrence by Applaud®, Match®, Mimic®, Admiral® and Consult® exhibiting 58.88%, 56.90%,

Table 5

ODC_{50} values for the percentage oviposition deterrence as compared to control for free choice method of fruit dip technique of different concentrations of Runner®, Sitara®, Silent® and Admiral® for adults of guava fruit fly (*Bactrocera correcta*) at C.I. 95%.

Insecticides	FRD (ml/acre)	ODC_{50}	95% FL	Slope ± SE	χ2 (d.f, P-value)
Runner®	120	1.37% (13.7 ml/L)	0.15-21.7	0.45 ± 0.14	3.07 (3, 0.38)
Sitara®	500	0.66% (6.6 ml/L)	0.29-3.04	0.51 ± 0.11	4.18 (3, 0.24)
Silent®	200	0.59% (5.9 ml/L)	0.16-17.1	0.33 ± 0.10	1.95 (3, 0.58)
Admiral®	200	0.60% (6.0 ml/L)	0.24-27.7	0.30 ± 0.10	1.83 (3, 0.60)

FRD= Field recommended dose, ODC_{50} = Concentration of IGR at which 50% of fruit flies showed oviposition-deterrence for treated fruits, FL = Fiducial limit, SE = standard error, χ^2 = Chi square value, *d.f,* = degree of freedom, P = probability value i.e. 5%

60.47%, 64.98% and 55.79% oviposition deterrence, respectively at 100 ppm concentration. The variation and contradiction in these results is attributed to difference in target fly and method of IGR application as they used house fly and diet-impregnation method while guava fruit fly and fruit-dipping method was used in present study. Similarly, variation in concentration, used in present study and by El-Mahasen *et al.* (2010), is another factor that justify the difference in results. However, a comparison of FRD with RC_{50} and ODC_{50} values of IGRs expounded that none of the evaluated IGRs would be effective repellent or oviposition-deterrent at FRD because RC_{50} and ODC_{50} values of Silent®, Admiral®, Sitara® and Runner® were many times higher than their FRD. These results cannot be compared or contradicted as no information on such aspects are available in the reviewed literature. The results also demonstrate that dose rate higher than FRD of these IGRs should be used to get 50% repellency or oviposition-deterrence against guava fruit flies. In conclusion, these IGRs can be used as repellent or oviposition-deterrent for fruit flies at higher dose rates; but it would be better to apply these IGRs for impregnation in impregnated-bagging-technique than foliar application. There also need to investigate their repellent and oviposition-deterrent effects in the field conditions.

REFERENCES

Alam, M.J., Y. Funaki, and N. Motoyama, 2001. Distribution and incorporation of orally ingested cyromazine into house fly eggs. Pestic. Biochem. Physiol., 70: 108-117.

Alyokhin, A.V., C. Mille and R.H. Messing, 2001. Selection of pupation habitats by oriental fruit fly larvae in the laboratory. J. Insect Behav., 14: 57-67.

Armstrong, J.W., 2003. Quarantine security of bananas at harvest maturity against mediterranean and oriental fruit flies (Diptera: Tephritidae) in Hawaii. J. Econ. Entomol., 94: 302-314.

Chang, C. L., I. K. Cho and Q. X. Li, 2012. Laboratory evaluation of the chemosterilant lufenuron against the fruit flies *Ceratitis capitata, Bactrocera dorsalis, Bactrocera cucurbitae* and *Bactrocera latifrons*. J. Asia Pac. Entomol., 15, 13-16.

Clausen, C.P., D.W. Clancy and Q.C. Chock, 1965. Biological control of the oriental fruit fly (*Dacus dorsalis* Hendel) and other fruit flies in Hawaii. United States Department of Agriculture, Tech. Bull., 1322: 1-102.

Cornelius, M.L., J.J. Duan and R.H. Messing, 2000. Volatile host food odors as attractants for the oriental fruit fly (Diptera: Tephritidae). J. Econ. Entomol., 93 (1): 93-100.

Dhillon, M., K.R. Singh, J.S. Naresh and H.C. Sharma, 2005. The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. J. Insect Sci., 5: 40-60.

Drew, R.A.I. and S. Raghu, 2002. The fruit fly fauna (Diptera: Tephritidae: Dacinae) of the rainforest habitat of the Western Chats, India. Raffles Bull. Zool., 20: 327-352.

Eisemann, C.H. and M.J. Rice, 1985. Oviposition behaviour of *Dacus tryoni*: the effects of some sugars and salts. Entomologia Exp. Appl., 39:61-71.

Ekesi, S. and M.K. Billah, 2007. A field guide to the management of economically important tephritidae fruit flies in Africa. ICIPE, Nairobi, Kenya.

El-Mahasen, A.M.M., A.A. Assar, M.E. Khalil and S.H. Mahmoud, 2010. Biological effects of some insect growth regulators on the house fly, *Musca domestica* (diptera: muscidae). Egypt. Acad.J. Biolog. Sci., 3 (2): 95-105.

Finney, D.J.Ed., 1952. Probit Analysis. Cambridge. England, Cambridge University Press.

Fletcher, T.B., 1919. Second hundred notes on Indian insects. Bull. Agric. Res. Inst, Pusa, 89: 1-102.

Follett, P.A. and J.W. Armstrong, 2004. Revised irradiation doses to control melon fly, mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae) and a generic dose for tephritid fruit flies. J. Econ. Entomol., 97: 1254-1262.

Hall, R. and M.C. Foehse, 1980. Laboratory and field tests of CGA7262 for the control of house and face fly in poultry, bovine and swine manure. J. Econ. Entomol., 73: 564-569.

Hollingsworth, R., A.J. Allwood, 2000. Melon fly. SPC Pest Advisory Leaflet. Draft. 2pp.

Jemaa, J.M. and E. Boushih, 2010. Cyromazine induced effects on larvae and adults of laboratory Tunisian strain of the Mediterranean fruit fly Ceratitis capitata. Tunisian J. Pl. Protect., 5: 213-222.

Kapoor, V.C., 1993. Indian fruit flies. International Science Publisher, New York. 228 p.

Kostal, V., 1993. Physical and chemical factors influencing landing and oviposition by the cabbage root fly on host-plant models. Entomologia Exp. Appl., 66:109-11.

Magoc, L., J.L. Yen, A. Hill-Williams, J.A. McKenzie, P. Batterham and P.J. Daborn, 2005. Cross-resistance to dicyclanil in cyromazine-resistant mutants of *Drosophila melanogaster* and *Lucilia cuprina*. Pestic. Biochem. Physiol., 81: 129-135.

Maynard, G.V., J.G. Hamilton and J.F. Grimshaw, 2004. Quarantine-Phytosanitary, sanitary and incursion management: an Australian entomological perspective. Aust. J. Entomol., 43: 318-328.

McInnis, D.O., 1989. Artificial oviposition sphere for Mediterranean fruit flies (Diptera: Teprhitidae) in field cages. J. Econ. Entomol., 82(5):1382-1385.

Messina, F.J., 1990. Components of host choice by two *Rhagoletis* species (Diptera: Tephritidae) in Utah. J. Kans. Soc., 63(1):80-87.

Muryati, Y.A. Trisyono, Witjaksono and Wahyono, 2012. Effects of citronella grass extract on oviposition behavior of carambola fruit fly (*Bactrocera carambolae*) in mango. ARPN J. Agric. Bio. Sci., 7 (9): 674-679.

Oi, D.H. and R.F.L. Mau, 1989. Relationship of fruit ripeness to infestation in"Sharwil" avocados by the mediterranean fruit fly and oriental fruit fly (Diptera: Tephritidae). J. Econ. Entomol., 82(2):556-560.

Patel, I.S., V.R. Upadhyay, H.N. Vyas, A.T. Patel, 1990. Field bioefficacy of different insecticides for the contrl of ber fruit fly, *Carpomyia vesuviana* Costa (Tephritidae: Diptera). Gujrat Agri. Univ. Res. J., 16(1): 57-59.

Rehman, J.U., G. Jilani, M.A. Khan, R. Masih and S. Kanvil, 2009. Repellent and oviposition deterrent effects of indigenous plant extracts to Peach Fruit Fly, *Bactrocera zonata* Saunders (Diptera: Tephritidae). Pak. J. Zool., 41: 101-108.

Riddiford, L.M. and J.W. Truman. 1978. Biochemistry of Insect Hormones and Insect Growth Regulators, In: Biochemistry of Insects (Ed. M. Rockstein,). Acad. Press, New york. pp. 307- 357.

Sarwar, M., 2006. Occurrence of insect pests on guava (*Pisdium guajava)* tree, Pak. J. Zool., 38(3): 197-200.

Satoh, I., M. Yamabe, S. Satoh and A. Ohki, 1985. Study of the frequency of finding of the fruit flies infesting the fruit imported as air baggage. Res. Bull. Plant Prot., 21: 71-73.

Shah, A.H. and V.J. Vora, 1975. Occurrence of *Dacus correctus* Bezzi (Tephritidae: Diptera) on mango and chiku in south Gujarat. Indian J. Entomol., 36: 76.

Wang, X.J., 1996. The fruit flies (Diptera: Tephritidae) of the East Asian region. Acta Zool. Sinica, 21: 1-338.

White, I.M. and M.M. Elson-Harris, 1994. Fruit Flies of Economic Significance: Their Identification and Bionomics. CAB International Oxon, UK. pp. 601.

Ye, H. and J. Liu, 2005. Population dynamics of the oriental fruit fly, *Bactrocera dorsalis* (Diptera: Tephritidae) in the Kunming area, Southwestern China. J. Insect Sci., 12: 387-392.