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Effect of Essential Oils of some Indigenous Plants on Settling and Oviposition Responses of Peach Fruit Fly, *Bactrocera zonata* (Diptera: Tephritidae)

Ayesha Ilyas[1], Hafiz Azhar Ali Khan[2,*] and Abdul Qadir[1,*]

[1]*College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan*

[2]*Institute of Agricultural Sciences, University of the Punjab, Lahore, Pakistan*

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AI performed the experiments and collected data. AI, HAAK, AQ convinced and designed the experiments, analyzed the data and wrote the paper. All the authors approved the final version of the manuscript.

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Botanicals, Toxicity, Biorational insecticides, Ecotoxicology, Fruit flies.

ABSTRACT

The experiments were set up to investigate the settling and ovipositional deterrent effects of crude leaf extracts of six indigenous plants *viz*., amaltas (*Cassia fistula*), datura (*Datura alba*), neem (*Azadirachta indica*), niazboo (*Ocimum basilicum*), yellow kaner (*Thevetia peruviana*) and safeda (*Eucalyptus camaldulensis*) against the peach fruit fly, *Bactrocera zonata* (Saunders), at 2% concentration in a free choice bioassays. Acetone, chloroform, petroleum ether and ethanol were used for oil extraction from leaves. Amongst the various treatments applied, the acetone extract of *D. alba* showed the highest repellency of 84.14%, whereas, the lowest repellency of 10.73% was observed by the chloroform extract of *T. peruviana*. Significant ovipositional deterrent effects of the extracts applied have been observed. Maximum oviposition inhibition was shown by petroleum ether extract of *A. indica* (57.14%), while the lowest ovipositon deterrence of 5.71 % was exhibted by the petroleum ether extract of *C. fistula*. However, in case of the petroleum ether extract of *O. basilicum* and the acetonic extract of *Eucalyptus* more pupae were developed in treated fruits as compared to their untreated guavas. The acetonic extracts of *T. peruviana* showed overall less settlings on both treated and untreated guavas resulting in less number of pupae developed. The results suggested that the extracts of plants tested in the present study could be considered in the management plans for the peach fruit fly.

INTRODUCTION

Pakistan is as an agricultural country where the fruits are grown with annual production of approximately 6.3 million tons covering the area of 0.64 million hectares. However, there has been a decline in the production over the last few years due to the attack of different insect pests (Anonymous, 2014). The most important economical insect pests which attack fruits are fruit flies (Diptera: Tephritidae) (Rehman *et al*., 2009). Fruit flies cause significant damage to the fruits and vegetable productions all over the world (Allwood *et al*., 2001). One of the most damaging fruit fly is the peach fruit fly, *Bactrocera zonata* (Saunders), (White and Elsan-Haarris, 1999) which cause significant losses to the fruit crops. Infestation of fruit flies not only cause post-harvest losses but the free trade of fresh horticultural produce to large profitable markets like the United States of America and Japan is also restricted in these countries which considered fruit flies as quarantine pests. *Bactrocera zonata* has been a serious pest of guava, citrus and mango orchards causing 50-55% infestation only in guava fruits in Pakistan (Chauhan *et al*., 2011).

Fruit flies are usually control with conventional insecticides like contact poisonsor baits (Rehman *et al*., 2009), however, these insecticides have negative effects on the environment and on-target beneficial organisms. Moreover, the export of insecticide treated fruits is in danger because of the occurrence of fruit flies larvae and insecticide residues applied for their control (Rehman *et al*., 2009). Therefore, there is a need to explore environmental friendly approaches for fruit flies control.

Recently the use of botanicals for protecting field crops from the attack of insect pests has gained much importance (Chauhan *et al*., 2011). Botanicals area source of numerous bioactive constituents such as secondary plant metabolites which play a role in the defense mechanism against herbivores. Secondary metabolites such as alkaloids, terpenes, phenolics, steroids, tannins *etc*. (Orozco *et al*., 2006; Mazid *et al*., 2011) cause toxicity or change in behavior in insects. Plant extracts have been used to manage different insect including fruit flies worldwide. For example, Isman (2006) reported that more than 400 insect pest species have been found susceptible

* Corresponding authors: azhar_naturalist@yahoo.com
qadir.qau@gmail.com
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to neem plant (*A. indica*). Similarly, the extracts of *Acoruscalamus*, *A. indica* and *Curcuma longa* have shown their strong growth inhibitory, repellent and toxic effects against fruit flies (Akhtar *et al*., 2004). However, the work on plant extracts for the management of fruit flies is still lacking at Pakistan level.

In the present study, we evaluated the settling and oviposition responses of the fruit fly, *B. zonata*, against six indigenous plant extracts in free choice bioassays.

MATERIALS AND METHODS

Rearing of fruit flies

Infested mango fruits purchased from fruit markets of Lahore (31.5546° N, 74.3572° E), and placed in large plastic jars having sand at the base for pupation in the laboratory. Pupae were sieved and transferred to cages (180×120×120 cm) for adult emergence. Flies were offered fresh guava fruits at their ovipositional age for infestation in the laboratory. The culture of *B.zonata* was maintained under controlled conditions at a constant photoperiod (10L: 14D), temperature (28±2˚C) and relative humidity (70-80 %).The adults were provided an artificial diet consisting of two banana, six egg yolks, four spoons of honey, eight spoons of sugar, half spoon of brewer's yeast and one spoon of multivitamin syrup (Akhtar *et al*., 2004; Siddiqui *et al*., 2006) along with a supplement of protein hydrolysate and the colony was maintained.

Plant material and extract preparation

Young and older leaves of six indigenous plants *viz*., amaltas (*Cassia fistula*), datura (*Datura alba*), neem (*Azadirachta indica*), niazboo (*Ocimum basilicum*), yellow kaner (*Thevetia peruviana*) and safeda (*Eucalyptus camaldulensis*) were collected from Lahore with no pesticide treatments applied. Leaves were shade dried for 14 days and ground to a fine powder and then stored in air tight jars (30×30×90 cm). Four solvents namely petroleum ether, acetone, chloroform and ethanol were used for the extraction of essential oils.

One hundred grams of each plant leaf powder were soaked in 200 ml of the solvent in the ratio of 1:2 (w/v) in a conical flask for about a week and shaken at intervals. After a week the supernatant was filtered with a double layer of Whatman filter paper no. 42. The mentioned procedure was repeated thrice to gain maximum extractable. All the filtrates were combined together and allowed to evaporate at rotary evaporator (Ahmed *et al*., 2006)

For preparation of the test solution, two grams of each plant extract was weighed separately in a beaker for preparation of 2 % solution then added 4 ml of distilled water with the addition of some granules of detergent (commercial product Surf) and was continuously stirred to make thick homogeneous paste. In this mixture add another 96 ml of water to make the required concentration (Akhtar *et al*., 2004; Siddiqui *et al*., 2006). Fresh clean guava fruits were dipped in prepared solution for 10 seconds and air dried at room temperature for an hour. The treated fruits were given to flies to observe the settling and ovipositional response of the flies in the next 48 h.

Settling activity and ovipositional response

Treated and untreated guava fruits were given to 10 pairs of almost 15 days old flies in the cage of (180 × 70 × 40 cm) in free choice test. For settling and ovipositional response fruit flies settled on treated and untreated fruits were counted every one hour from 10:00 am to 3: 00 pm for two days. After 48 h both treated and untreated guava fruits for each extract were separately kept in plastic jars (30 × 30 × 90 cm) having sand at the base for pupation and covered with muslin cloth. After about a week sand was sieved to collect pupae which were then placed in plastic cages for adult emergence. The number of pupae recovered was analyzed to evaluate the effect of plant extract on fecundity.

Percent repellency was calculated by using the following formula (Rehman *et al*., 2009):

Repellency (%) = Half of the number of flies settled on both treated and untreated guavas – Number of flies settled on treated guavas / Half of the number of eggs laid on both treated and untreated guavas × 100

Oviposition deterrence (%) = Half of the number of eggs laid on both treated and untreated guavas – Number of eggs laid on treated guavas / Half of the number of eggs laid on both treated and untreated guava × 100

Statistical analysis

Percent mortality in different treatments were analyzed using a one-way analysis of variance (ANOVA) with Statistix 8.1 software (Analytical Software, 2005). Means were compared by LSD test, at 0.05 probability level.

RESULTS

Settling response

The mean number of flies settled on different treatment combinations is presented in Table I. Significant differences were observed among the various extracts applied compared to the control treatments. Among the treatments applied, acetone extract of *D. alba* showed the highest repellency of 84.14% with the mean number of flies settled on treated guava was 2.3 as compared to 26.7 visits of untreated fruit followed by 83.08% repellency shown by *E. camaldulensis* in chloroform with 15.33 flies visit treated as compared to 35.7 settlings on untreated fruit. Next to these were the acetone extract of *E. camaldulensis* with 79.80% (3 flies settled on treated in comparison with 26.7 on untreated guava) and *T. peruviana* with 71.25% (with 1.67 on treated as against 13.7 settlings in control respectively. *C. fistula* in ethanol, *A. indica* in chloroform, Acetonic extract of *A. indica*, petroleum ether extract of *C. fistula* and *E. camaldulensis* have shown better results with 68.82%, 66.17%, 65.00%, 64.71% and 63.85% repellency, respectively. Not very good but satisfactory repellencies of 53.87%, 44.14%, 41.59%, 40.30% and 36.99% were shown by *O. basilicum* in chloroform, *E. camaldulensis* and *T. peruviana* in ethanol, *O. basilicum* and *T. peruviana* in ethanol and *T. peruviana* in petroleum ether, respectively. Petroleum ether extract of *D. alba*, *C. fistula* in acetone, *C. fistula* and *D. alba*in chloroform, ethanolic extract of *A. indica*, *O. basilicum* in acetone and *T. peruviana* in chloroform have also suppress settlings of flies on treated guava as compared to control with 30.84% , 29.03, 19.31%, 17.60%, 11.56%, 11.33% and 10.73% of repellencies, respectively.

Oviposition deterrence

It was observed that irrespective of treated or untreated fruits, overall oviposition was inhibited in fruits treated with various solvent extracts as compared to control where all fruits placed were untreated. Concluding that extract applied has some ovipositional deterrent effects. Oviposition deterrence by the flies on treated or untreated fruits are shown in Table I. Out of all the plant extracts tested 53.85% oviposition inhibition was shown in petroleum extract of *D. alba* where there recovered just 5.33 pupae in treated as compared to 27.33 pupae

Table I.- Mean number (± SE) of *B. zonata* settled and pupae recovered by *B. zonata* adults settled on untreated guava fruits and those treated with different plant extracts in three solvents at 2% concentration in a free choice test.

Plant	Solvent	Mean No. of flies settled		Repellency (%)	Mean No. of pupae recovered		Oviposition deterrence (%)
		Treated (Mean± SD)	Untreated (Mean± SD)		Treated (Mean± SD)	Untreated (Mean± SD)	
Amaltas	Petroleum ether	3 ± 0.27^{kl}	33.33 ± 1.55^{bc}	64.71	4 ± 1.5^{fg}	3.67 ± 0.42^{ij}	5.71
	Acetone	3.33 ± 0.16^{kl}	6.33 ± 0.42^{no}	29.03	1.5 ± 0.6^{fg}	3.33± 0.41^{ij}	43.48
	Chloroform	9.33 ± 0.42^{fghijkl}	13.67 ± 0.42^{jklm}	19.13	1.5 ± 0.58^{fg}	2.33 ± 0.16^{hij}	15.00
	Ethanol	5.67± 0.41^{hijkl}	28.67 ± 1.81^{cd}	68.82	2 ± 0.5^{fg}	4 ± 0.27^{hij}	33.33
Kaner	Petroleum ether	2.33 ± 0.83^{kl}	5 ± 0.27^{o}	36.99	1.33 ± 0.5^{ab}	3.33 ± 0.16^{b}	43.48
	Acetone	1.67 ± 0.5^{i}	13.67 ± 0.41^{jklm}	71.25	1.67 ± 0.5^{fg}	3.67 ± 0.15^{ij}	37.04
	Chloroform	19.67 ± 5.16^{abcd}	22.67 ± 0.56^{efg}	10.73	21 ± 8.33^{fg}	35.67 ± 1.1^{ij}	15.72
	Ethanol	12 ± 0.83^{defghij}	8 ± 0.27^{no}	41.59	1.33 ± 0.15^{bc}	2.33 ± 0.15^{c}	27.78
Datura	Petroleum ether	7.33 ± 1.59^{ghijkl}	7 ± 0.27^{no}	30.84	5.33 ± 0.57^{fg}	27.33 ± 1.64^{ij}	53.85
	Acetone	2.33 ± 0.15^{kl}	26.67 ± 1.1^{de}	84.5	1.67 ± 0.16^{fg}	2.67 ± 0.16^{ij}	22.73
	Chloroform	10.33 ± 0.42^{efghijk}	14.67 ± 0.41^{ijkl}	17.60	20.33 ± 0.08^{bcde}	49.33 ± 1.09^{e}	41.67
	Ethanol	19± 0.27^{abcd}	8.33 ± 0.42^{no}	-39.86	2 ± 0.27^{g}	3 ± 0.27^{j}	20.00
Neem	Petroleum ether	9 ± 0.27^{ghijkl}	15± 0.27^{ijk}	25.00	3 ± 0.27^{efg}	11 ± 0.27^{efg}	57.14
	Acetone	8 ± 0.27^{ghijkl}	39.33 ± 1.03^{a}	65.00	4 ± 0.27^{fg}	2 ± 0.27^{j}	29.82
	Chloroform	0.7 ± 0.54^{ghijkl}	33 ± 1.52^{bc}	66.17	2 ± 0.27^{fg}	3.67 ± 0.41^{ij}	-33.33
	Ethanol	15.33 ± 0.68^{cdefg}	19.33 ± 0.16^{ghi}	11.56	3 ± 0.27^{fg}	0.81 ± 0.27^{ij}	14.29
Niazboo	Petroleum ether	10± 0.27^{efghijkl}	22.33 ± 1.03^{a}	38.08	16.67 ± 0.56^{cdefg}	8.33 ± 0.57^{gh}	-31.69
	Acetone	13.33 ± 0.41^{defghi}	28.33 ± 1.77^{bc}	11.33	2 ± 0.27^{fg}	3 ± 0.27^{ij}	20.00
	Chloroform	14 ± 0.27^{cdefgh}	46.67 ± 0.41^{lmno}	53.87	2 ± 0.27^{g}	2 ± 0.27^{j}	0.00
	Ethanol	18 ± 0.27^{cde}	42.33 ± 1.03^{ijk}	40.30	3 ± 0.27^{fg}	4 ± 0.27^{ij}	14.29
Safeda	Petroleum ether	4.67 ± 0.16^{jkl}	21.33± 0.42^{fgh}	63.85	15.67 ± 1.34^{efg}	29 ± 0.72^{gh}	29.75
	Acetone	3 ± 0.27^{kl}	26.67 ± 0.42^{de}	79.80	10.33± 1.67^{defg}	7.67 ± 0.41^{fg}	-7.69
	Chloroform	15.33 ± 5.35^{cdefg}	35.67 ± 0.83^{ab}	83.08	4 ± 0.27^{bc}	8.33 ± 0.42^{c}	34.96
	Ethanol	15 ± 2.37^{cdefg}	24 ± 0.27^{defg}	44.14	3.67± 0.31^{efg}	6 ± 0.27^{ef}	37.93
Control		15.78 ± 6.81	4.89 ± 2.45	52.69	31.00 ± 14.60	12.17 ± 8.25	43.63

Means followed by different letters within treatments are significantly different at $p < 0.05$; LSD Test (STATISTIX SOFTWARE). Significance at $p < 0.05$ is between different superscripts.

recovered from untreated control, petroleum ether extract of *A. indica* has shown 57.14% oviposition deterrence with 3 pupae recovered from treated fruits in comparison from untreated guava fruits with 11 pupae. *C. fistula* in acetone showing 43.48%, *T. peruviana* in petroleum ether with 43.48% again oviposition deterrence. Better oviposition deterrence of 41.67% has shown by *D. alba* in chloroform. *E. camaldulensis* in ethanol, *T. peruviana* in acetone, *E. camaldulensis* in chloroform and *C. fistula* in ethanol have shown 37.94%, 37.04%, 34.96% and 33.33% inhibition of pupae. *C. fistula* in petroleum ether, *T. peruviana* in ethanol, *D. alba* in acetone, *D. alba* in ethanol, *T. peruviana* in the acetone extract of *A. indica*, *O. basilicum* in ethanol and the acetone extract of *D. alba*, *A. indica* and *O. basilicum* in chloroform, *A. indica* in ethanol are all the extracts which have shown minimum oviposition as the mean number of pupae produced were very less in both treated or untreated guavas. Some of the extracts such as those of *O. basilicum* in petroleum ether and *A. indica* in chloroform as well as *E. camaldulensis* in acetone did not show any effect on oviposition of flies rather they allowed more oviposition in treated fruits as against their respective untreated guavas. Ovipositional responses of plant based products applied have shown significant differences.

DISCUSSION

Farmers presently rely chiefly on the use of insecticides for controlling fruit flies population. In an estimate about 10% of insecticides used in the country are utilized for control of fruit flies (Stonehouse *et al*., 1998). This state of affairs is most concerning from the ecological point of view as well as the issue of insecticide residues in exportable fruits and vegetables. Pakistan's export of fruits and vegetables faces serious threat to the use of insecticides. Sri Lanka refused to accept onion from Pakistan in 2002 because of insecticide residues and required certification that the imported citrus fruit was from the fruit fly free area. Similarly, Mauritius needs certification forth import of the persimmon. Korea, Japan and Jordan have already banned the import of fruits from Pakistan. Under such circumstances massive thrust to increase export of fruits by Pakistan to new and existing markets may suffer a serious setback unless solutions to pest attack are found other than pesticides. Under WTO regulations, the international standards of exportable fruits and vegetables have to be followed especially under sanitary and phytosanitary measures under which these must be free of pest and pesticide residues. Plant derivatives appear to be a good source of safe and environment friendly chemicals which can be used as alternatives to insecticides. Studies by Shivendra and Singh (1998), Shakuntala and Thomas (2001a), (b), Tewari (2001) and present research indicated great potential of some indigenous plants for controlling fruit flies. Being medicinal and having traditional uses, these plants are not expected to leave any harmful residues in treated commodities. Plant extracts contain enormous, unexploited pool of chemical compounds offering countless potential uses. One of these uses is in agriculture to deal with insect pests with fewer risks. Several studies consuming plant extracts in human and animal health protection, agronomy and domestic pest management have been predominantly encouraging (Pascual-Villabbos and Robledo, 1999; Scott *et al*., 2004). The toxic effects of crude plant extracts on insect pests are demonstrated in several ways, including growth retardation, lengthened developmental time, suppression of calling behavior, increased mortality rate, oviposition deterrence and feeding inhibition (Rehman *et al*., 2009). Botanical insecticides fulfill the requirements to shelter particular crops while suppressing harm to non-target organisms, so their potential worth is enormous. In actual, synthetic insecticides are known, through many reports, to induce quick resistance in insects, trigger health problems, and leave residues in the environment (Khan *et al*., 2016, 2017). In contrast, the use of botanical pesticides for plant protection has assumed greater importance due to environmental deterioration and health hazard associated with the use of synthetic insecticides. It is hoped that the extensive use of botanical insecticides in integrated pest management will help in conserving environmental quality. The botanical insecticides do not rapidly induce insect resistance and they produce no residues in the environment or on agricultural products because they are highly bio-degradable (Bullangpoti *et al*., 2007; Dhaliwal and Koul, 2007). Therefore, the use of and research on botanical insecticides can decrease problems faced by synthetic insecticides. Moreover, the use of secondary plant metabolites is similar to the natural defense of plants to herbivores. Consequently, this natural defense that promotes co-evolution is safe to the environment and can exhibit many deterrent effects on pest organisms. Therefore, secondary metabolites as a self- defense approach of the plants can be effectively used as shown in a number of studies on non- azadirachtin and some limonoid inhibitors (Koul *et al*., 2004a) non-azadirachtin and some limonoid inhibitors (Koul *et al*., 2004b) Non-azadirachtin limonoids have explicitly two different modes of action, feeding deterrence and physiological toxicity, that play significant roles in their potential effects. Many plant species have insecticidal activity, but most have not been seriously promoted or studied. We still have little information on their active structures and modes of action in insect pests.

The results obtained from the different treatments of experiments under laboratory conditions revealed significant effects of plant extracts on both settling and ovipositional deterrence activity of *B. zonata*. Among the different extracts of *C. fistula, D. alba, T. peruviana,* each extracted in petroleum ether, chloroform, acetone as well as in ethanol. Overall, the highest % repellency is shown by the acetonic extract of *T. peruviana* with only 1 fly visited treated fruit as compared to 13 flies settled on untreated guava with 71% repellency and showing good results of the medium polarity solvent of *T. peruviana* supported by the work of (Suresh *et al*., 2013) in which they determined the effects of leaf extracts of *T. peruviana* extracted in solvents of different polarities against larvae of *Anopheles stephensi* and *Aedes aegypti*. In the study, the acetonic extract of yellow kaner was most effective, while its chloroform extract was least effective which is in agreement with the results of present study. Agarwal and Dev (2013) tested the aqueous extract of six plants: cuscuta (*Cuscutareflexa*), kaner (*Thevetia nerefolia*), parthenium (*Parthenium histrophorus)*, karanj (*Pangamapinnata*), Dhatura (*Datura latifolia*) and neem seed kernel extract (*Azadirachta indica)* at 2% and 5% concentration observed the effects of pupal dipping in 2% and 5% plant extracts in the laboratory and observed the adult emergence and % pupal mortality of *B. cucurbitae*. Their results on total emergence revealed that kaner at 5% were the best in reducing adult emergence. In our study petroleum ether extract of yellow kaner has shown the highest oviposition deterrence of 43% among its other solvent extracts with 1 pupae recovered from treated guava as compared to 3 pupae from untreated guava fruits and showing that components extracted in the lower polar solvent are having good oviposition deterrent property. In our study we have observed satisfactory repellent activities of *T. peruviana* in its higher polarity solvents as in ethanol with 41% repellency and 27.78 % oviposition inhibition may shows its higher molecular weight compounds fails to inhibit oviposition of flies satisfactory. When we studied the effects of *C. fistula* in different polarity solvents against the repellent and ovipositional behaviour of flies, it was observed that petroleum extract of *C. fistula* have shown maximum repellency of 64% with 3 flies visited that treated fruits as compared to 33 flies settled on untreated guava. Its low polarity solvent extracts are good repellent as compared to other solvent extracts but they are not good oviposition inhibitors rather more pupae were recovered from treated guava as compared to untreated guava in case of petroleum ether extract of *C. fistula* . However, in our findings, in case of ethanol extract of *C. fistula* 5 flies visited treated guava as compared to 28 flies settled on untreated guava showing 68.82% repellency, satisfactory oviposition inhibition of 33% was shown by ethanolic extract of *C. fistula*. Our findings with various solvent extracts of *C. fistula* showed that its low molecular weight extracts as in case of petroleum ether has shown the best repellency of 64% and its medium polar acetonic extract as well as high molecular weight ethanolic extracts as in ethanol has shown better oiviposition inhibition among its all solvent extracts. *Cassia fistula* commonly known as amaltas or golden shower is an intermediate sized tree and its derivatives are used in ayurvedic prescriptions as well as home remedies against ants. Duraipandiyan *et al*. (2011) studied the larvicidal as well as antifeedant actions of rhein (1,8- dihydroxyanthraquinone-3-carboxylic acid) derived from C. fistula flowers extracted in ethyl acetate and studied against lepidopteron pests *Spodopteralitura* and *Helicoverpa armigera*. Significant antifeedant activity was observed against *H. armigera* (76.13%) at 1000 ppm concentration. The plant is extensively used by tribal people to deal with various ailments as that of ringworm and other fungal skin infections (Rajan *et al*., 2001).

Datura alba leaves extracts in our study with different polarity solvents revealed that the low polarity solvent extract of *D. alba* as in case of petroleum ether extract maximum oviposition deterrence of 53% with only 5 pupae recovered from treated guava as compared to 27 from untreated fruit and also satisfactory percent repellency of 30% as compared to its other solvent extracts has shown, While Chloroform extract of this plant has also shown good oviposition inhibition of 41 % where 20 pupae were recovered from treated fruits as compared to 49 from untreated guava fruits and in case of repellent activity of chloroform extract of *D. alba* the lesser number of flies settled on treated guava as compared to the fruit not treated with any solvent extract. Acetonic extract of *D. alba* in our study has shown promising repellency of 84.5% with 22.73% oviposition inhibition. High polarity solvent extracts of *D. alba* has shown negative impact rather in case of treated fruits as in case of ethanol more flies settled on treated guava as compared to untreated guava fruits in case of ethanolic extracts of *Datura alba*. Khan *et al*. (2011) reported that the effect of crude leaf extract of *D. alba* was evaluated against the American cockroach, *Periplaneta americana*. The efficacy of leaf extract of *D. alba* in disturbing the normal metabolic and physiological processes was determined in the cockroach midgut and concluded this plant could be used as an effective botanical insecticide in the Integrated Pest Management (IPM) Programmed for *P. americana* and other insect pests.

In the present study, extracts of niazboo *(O. basilicum*) study have shown better repellent action in low polarity solvents than its medium polarity acetonic extract. However, the ethanol extract of niazboo in our experiments has also shown satisfactory repellent action. As far as concerned with its oviposition inhibition, *O. basilicum* in low polarity petrolem ether has shown more oviposition in treated as compared to untreated fruits. The work of Lohar (2001) also supports our findings regarding the effect of *O. basilicum*, *C. fistula* and *A. indica*on repellency and oviposition deterrence of flies. They usedsome of the plant extracts *viz*., arandi (*Ricinus communis*), neem (*A. indica*), karanj (*Derris indica*), marva (*O.basilicum*), pilu (*Salvadora oleoides*), dhatura (*Datura metel*), amaltas (*C. fistula*), guava (*Psidiumpyriferum*), bluegum (*Eucalyptus camaldulensis*) and bougainvillea (*Bougainvillea* sp.), against *Tribolium castaneum* (a stored grain insect pest). In general, all the treatments applied had significantly reduced the oviposition of *T. castaneum*. Our study revealed that *A. indica* has shown better repellencies in low and medium polarity solvents while its higher polarity ethanol extract has not shown satisfactory repellent effects. Various extracts of *E. camaldulensis* in the present study have all shown promising repellencies with satisfactory oviposition inhibition. The development of insect resistance in response to plant extracts is particularly slow in contrast to resistance to pure components which progresses rapidly. It was recommended that the cause underlying the severely slow evolution of resistance to the plant extracts is because it is more problematic for an insect to develop numerous alterations simultaneously (Branttstem *et al*., 1986). Furthermore, the environmental burden of individual constituents is reduced and also the yields of crude extracts are economical as well as cheaper to prepare. Also the plant extracts subjected to simple chemical fractionation processes may have a great potential for insect control (Weaver *et al*., 1997; Siskos *et al*., 2009).

CONCLUSION

Plants used in this study have shown satisfactory repellent and oviposition inhibiting results against fruit flies. The plants studied could provide suitable alternatives into IPM programmes. Further investigations are necessary to separate active compounds present in the promising extracts through partitioning these extracts by chromatographic techniques and to study their chemosterilant, neurotoxic and genotoxic effects. Such compounds may also have effects on hormonal imbalance and reproductive physiology of insects. This information can be helpful in developing environment friendly effective formulations for commercial use against insects.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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