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Repellent and Oviposition Deterrent Effects of Indigenous Plant Extracts to Peach Fruit Fly, *Bactrocera zonata* Saunders (Diptera: Tephritidae)

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Abstract.- Repellent and oviposition deterrent effects of sweetflag' *Acorus calamus* L. (*Acorales*:*Acoraceae),* 'tumba' *Citrullus colocynthis* L. (Cucurbitales: Cucurbitaceae), 'turmeric' *Curcuma longa* L. (Zingiberales: Zingiberaceae), 'kuth' *Saussurea lappa* (Decaisne) C. B. Clarke (Asperales: Asteraceae), 'balchar' *Valeriana jatamansi* Jones (Dipsacales: Valerianaceae), and 'harmal' *Peganum harmala* L. (Sapindales: Nitrariaceae) extracts each in petroleum ether, acetone and ethanol were evaluated at 2% concentration against peach fruit fly *Bactrocera zonata* in a free choice bioassay. Petroleum ether extract of *C. longa,* ethanol and acetone extracts of *P. harmala* were the most promising repellents against Peach fruit fly. Acetone extract of *P. harmala,* ethanol extract of *V. jatamansi* and petroleum ether extract of *S. lappa* also showed effective oviposition deterrence. *C. colocynthis* suppressed the overall egg laying.

Keywords: Peach fruit fly, *Acorus calamus*, *Curcuma longa*, *Valeriana jatamansi*, *Saussurea lappa*, *Peganum harmala*, *Citrullus colocynthis*, Repellent.

INTRODUCTION

The peach fruit fly, *Bactrocera zonata* (Saunders), is one of the most harmful species of Tephritidae. It causes heavy damage in Asia (Butani, 1976; Butani and Verma, 1977; Agarwal *et al.*, 1999) and is a serious pest of peach, *Prunus persica* (L.) Batsch (Rosales: Rosaceae) and custard apple, *Annona squamosa* L. (Magnoliales: Annonaceae) in India (Butani, 1976; Grewal and Malhi, 1987), as well as guava *Psidium guajava* L. (Myrtales: Myrtaceae) and mango *Mangifera indica* L. (Sapindales: Anacardiaceae) in Pakistan (Syed *et al.*, 1970). Peach fruit fly is native from India where it was first recorded in Bengal (Kapoor, 1993). It is present in numerous countries of tropical Asia: India, Indonesia (Sumatra, Moluccas), Laos, Sri Lanka, Vietnam, Thailand (White and Elson-Harris, 1992), Mayamar, Nepal, Bangladesh, and probably all of South-east Asia (Kapoor, 1993).

Direct fruit damage, fruit drop, and loss of export markets through quarantine restrictions are all means by which fruit fly infestation causes economic loss. With adult traits that include high mobility and dispersive powers, high fecundity, and in some species extreme polyphagy, dacines fruit flies such as *B. zonata* are well-documented invaders and rank high on quarantine target lists.

In Pakistan, the fruit fly complex may cause losses that range from 20 to 90 % in different areas of the country (Stonehouse, 1997). Fruits and vegetables suffer extensive damage due to impacts on yields and fruit quality. Citrus, mango, guava and peach industries on average suffer loss by 7.5, 15, 35 and 30%, respectively. In melons, levels of infestation of 50, 37 and 23% were found in Dera Ismail Khan, Rahim Yar Khan and Kulachi areas of Pakistan, respectively (Stonehouse *et al.*, 1998).

For the management of fruit flies, increasing applications of pesticides are facing resistance from environmentalists and the general public (Clark *et al.*, 1996). The situation is further complicated because biological and cultural control methods do not yield immediate results necessary for successful eradication programs (Baranowski *et al.*, 1993; Aliniazee and Croft, 1999). To prevent fruit flies from harboring in these areas and re-infesting surrounding areas, alternate strategies for managing these critically sensitive areas must be developed.

The search for lower risk eco-friendly alternative has resulted in renewed interest the use of plant extracts for reducing the impact of fruit flies on fruit yield and quality. The botanical insecticides

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are generally pest-specific and are relatively harmless to non-target organisms including humans. They are also biodegradable and harmless to the environment. Furthermore, unlike conventional insecticides that are based on a single active ingredient, plant-derived insecticides comprise an array of chemical compounds, which act concertedly on both behavioural and physiological processes. Thus the chances of pests developing resistance to such substances are less likely. One plant species may possess substances with a wide range of activities; for example, extracts from the neem tree *Azadirachta indica* are antifeedant, anti-oviposition, repellent and growth regulating. Monoterpenoids of essential oils provide effective lead molecules in the management of stored product insects and insect pests of public-health importance (Ignacimuthu, 2004). Of the numerous plants investigated in Pakistan, neem (*Azadirachta indica* A. Juss (Sapindales: Meliaceae) has shown the most promising results. More than 400 insect species, including many key pests of agriculture and households, are susceptible to various behavioural and physiological effects of *A. indica* extracts and concoctions (Isman, 2006). Akhtar *et al.* (2004) demonstrated repellent and growth inhibiting effects of *A. indica*, *Curcuma longa* L. (Zingiberales: Zingiberaceae), and *Acorus calamus* L. (Acorales: Acoraceae) against *Bactrocera zonata*. Yasmin, (2004) reported that of three plants, *Saussurea lappa* (Decaisne) C. B. Clarke (Asperales: Asteraceae), *Valeriana jatamansi* Jones (Dipsacales: Valerianaceae) and *Peganum harmala* L. (Sapindales: Nitrariaceae), extracted in petroleum ether (a mixture of C5-7 alkanes), *P. harmala* was the most effective oviposition deterrent for *B. zonata.* Among the petroleum ether, acetone and ethanol extracts of turmeric, acetone extract was the best repellent and growth inhibitor against *B. zonata* (Siddiqui *et al.,* 2006).

The plants used in the present studies are indigenous and abundantly available. These are locally used in ayurvedic medicines. Therefore, the extracts are not expected to leave any toxic residues in plants and fruits if commercially used. *A. calamus* and *Citrullus colocynthis* are used as folk medicinal plants. *A. calamus* acts as emetic, nauseant, antiseptic, aromatic, carminative, antiperiodic and nerve sedative. *C. Colocynthis* acts as hydrogogue, cathartic and arbortifacient, emetic, expectorant and diuretic. *C. longa* acts as aromatic, stimulant, carminative and anthelmintic (Ammon *et al.,* 1992). *S. lappa* is tonic, stomachic, stimulant, carminative, used for asthama, diuretic, antiseptic, cough, cholera, aphrodisiac, and anthelmintic. The rhizomes are highly aromatic used in perfumeries. Rhizomes are also used for skin diseases. *V. jatamansi* is useful in hysteria, insomnia, habitual constipation, neurosis, cholera and in scorpion sting and also used for perfumery. Locally the dry roots are used to remove foul odour of mouth caused by tooth trouble (Morazzoni and Bombardelli, 1995). *P. harmala* is used to treat depression, dermatosis (Iwu *et al.,* 1994) and it is anti-cancerous.

In the current study chemical profile of the test plants obtained through extraction with organic solvents of different polarities were tested for repellent and oviposition deterrent effects on peach fruit fly, *Bactrocera zonata* by offering treated and untreated guava fruits in free choice tests.

MATERIALS AND METHODS

Plants and plant extracts

The plant materials namely ‘sweetflag’ *Acorus calamus* L. (*Acorales*:*Acoraceae)* rhizome were collected from Kashmir area, ‘tumba’ *Citrullus colocynthis* L. (Cucurbitales: Cucurbitaceae) fruits from Jhang and rhizome of ‘turmeric’ *Curcuma longa* L. (Zingiberales: Zingiberaceae), ‘kuth’ *Saussurea lappa* (Decaisne) C. B. Clarke (Asperales: Asteraceae), ‘balchar’ *Valeriana jatamansi* Jones (Dipsacales: Valerianaceae), and seeds of ‘harmal’ *Peganum harmala* L. (Sapindales: Nitrariaceae) were purchased from ayurvedic shop. The collected plant materials were dried in shade. The dried plant materials were ground to fine powders of 60 mesh for extraction with different organic solvents. .

The test plant materials were extracted on Soxhlet’s extraction apparatus for at least 8hrs each with petroleum ether (B.P. 60-80°C), acetone, and ethanol provided by LAB-SCAN. The extracts were concentrated on rotary evaporator (Rotavapor R-IIA (Buchi) Switzerland) and finally made solvent free in a vacuum desiccators.

Rearing of fruit fly Bactrocera zonata *(Saunders)*

The culture of *B. zonata* was maintained under controlled laboratory conditions at 26±1°C and 60±5% R.H in cages measuring (45 x 40 x 40 cm). The adult flies were reared on artificial diet consisting of two banana, six eggs yolk, four spoons of honey, eight spoons of sugar, half spoon of brewers yeast, and one spoon of multivitamins syrup (Akhtar *et al.,* 2004; Siddiqui *et al.,* 2006).

The flies were offered fresh guava fruits for oviposition in cages. The infested fruits were kept in plastic jars having 3 cm thick layer of sand at the base for pupation. The jars were covered with muslin cloth. The pupae were isolated from the sand and placed in separate cages. The adults on emergence were reared on artificial diet as mentioned above along with a supplement of protein hydrolysate.

Administration of plant extracts

For the preparation of 2% solution, 2.0 gm of each extract was weighed separately in a glass beaker to which 4ml of distilled water with 10 mg detergent(commercial product- 'surf') was added, and stirred continuously for 10 minutes with a glass rod to make homogenous thick paste. Another 96 ml of water was then added to get the desired concentration (Akhtar *et al*., 2004; Siddiqui *et al.,* 2006). Guava fruits were coated with each solution by dipping for 10 seconds and dried at room temperature for two hours.

Treated and untreated guava fruits were offered to 8 pairs of 20-23 days old gravid flies in plastic cages measuring (45 x 40 x 40 cm) for 48 hours in a free choice bioassay for settling and oviposition response (Singh and Singh, 1998). Number of fruit flies settled on treated and untreated guava fruits were counted after every one hour interval for 10 hours (5 hours daily from 10:00 am to 3.00 pm). Fruits were then removed from the cages and number of eggs in treated and untreated fruits counted. For egg counting skin of the fruit was pealed off carefully, eggs in pealed skin and pulp were removed and placed in a petri dish having water. Experiments were replicated three times and results subjected to `t' test using M.StatC program.

Percent repellency and oviposition deterrence were calculated by using the following formulae:

% Repellency:

$$\frac{\text{Half of the number of flies settled on both treated and untreated guavas - number of flies settled on treated guava}}{\text{Half of the number of flies settled on both treated and untreated guavas}} \times 100$$

% Oviposition deterrence:

$$\frac{\text{Half of the number of eggs laid on both treated and untreated guavas - number of eggs laid on treated guava}}{\text{Half of the number of eggs laid on both treated and untreated guavas}} \times 100$$

RESULTS AND DISCUSSION

Repellency

Table I shows mean number of flies settled on untreated guava and on those treated with various solvent extracts of different plants. As can be seen comparatively lower numbers of flies were observed on guava treated with extracts. Among the test materials, the acetone extract of *V. jatamansi* was the most effective against settling response as only 3.2 out of 16 flies released were observed on both treated and untreated guava during 10 observations taken at hourly intervals. Its ethanol extract was next in order allowing 6.5 flies while 20.49 flies settled in control treatment. Number of settled flies was in between these limits in other treatments.

Regarding the repellent effects, ethanol extract of *P. harmala* was the most promising. Although a higher number of 8.4 flies settled, yet it was the most promising as it had only 1.7 flies on the treated as against 6.7 in untreated guava fruit showing 59.38% repellency of the extract. This was followed by petroleum ether extract of *C. longa* showing 57.14% repellency as 1.00 fly settled on treated fruit as against 3.67 on untreated fruits. Acetone extract of *P. harmala* was next in order with 46.19% repellency. Mean numbers of flies settled on treated fruit were 2.3 as against 6.3 on untreated fruit. Similarly, ethanol extracts of *V. jatamansi, C. colocynthis and C. longa* had 38.46, 34.55 and 34.29% repellency, respectively. Extracts of *S. lappa* and *A. calamus* had no repellent effect as

Table I.- Mean number(±SE) of *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 number of flies settled		% repellency	t value
		Untreated guava	Treated guava		
Acorus calamus	petroleum ether	8.67±1.04	6.50±3.50	14.29	1.02 ^{ns}
	acetone	6.00±3.91	3.83±1.53	22.03	0.89 ^{ns}
	ethanol	4.67±3.01	3.50±1.80	14.29	0.57 ^{ns}
Curcuma longa	petroleum ether	3.67±1.26	1.00±0.50	57.14	2.52 ^{ns}
	acetone	7.50±1.80	4.83±2.57	21.62	1.47 ^{ns}
	ethanol	7.83±0.29	3.83±2.02	34.29	3.39 ^{ns}
Citrullus colocynthis	petroleum ether	4.67±2.36	2.67±1.15	27.27	1.31 ^{ns}
	acetone	5.50±1.80	3.33±1.26	24.53	1.70 ^{ns}
	ethanol	6.17±1.89	3.00±0.86	34.55	2.63 ^{ns}
Saussurea lappa	petroleum ether	5.0±4.09	3.2±0.58	22.40	0.76 ^{ns}
	acetone	4.7±1.26	4.5±4.27	1.85	0.06 ^{ns}
	ethanol	6.5±4.92	6.3±4.37	1.33	0.04 ^{ns}
Peganum harmala	petroleum ether	6.2±1.26	4.0±0.50	21.34	2.77 ^{ns}
	acetone	6.3±1.04	2.3±1.89	46.19	3.21 ^{s}
	ethanol	6.7±0.29	1.7±1.39	59.38	6.07 ^{s}
Valeriana jatamansi	petroleum ether	5.5±1.80	4.7±2.02	8.16	0.53 ^{ns}
	acetone	2.0±2.19	1.2±0.58	25.48	0.61 ^{ns}
	ethanol	4.5±0.87	2.0±1.80	38.46	2.16 ^{ns}
Control (untreated fruit)		10.12±4.76	10.37±4.80	-1.22	0.07 ^{ns}

Each value is mean of 3 replications with 16 insects per replicate.
^{ns}Non-significant, ^{s}Significant

there was almost no difference in the number of flies settled on treated or untreated fruits. Similarly, flies showed almost equal response to the fruits where no treatment was applied as the flies settled were 10.37 and 10.12 on both untreated fruits, respectively.

Petroleum ether extract of *C. longa* not only repelled the flies but also affected overall settling of flies on both fruits. Acetone and ethanol extracts of *V. jatamansi* also affected overall settling of fruit fly. Extracts of *P. harmala* in the same solvents worked as repellent because comparatively lower number of flies settled on guava fruits treated with these extracts, although total number of flies settled were higher as compared with those settled where acetone and ethanol extract of *V. jatamansi* and petroleum ether extract of *C. longa* were applied. In control fruits, flies did not show any non-preference to either fruits and visited them in equal numbers.

Oviposition deterrence

Table II shows that exposure to vapours of plant extracts inhibited overall oviposition irrespective of treated or untreated guava and the numbers of eggs laid were comparatively lower on treated guava than those on untreated irrespective of the total number of eggs laid both on treated or untreated fruits.

Out of six plants *C. colocynthis* suppressed overall egg laying of exposed flies. In majority, ethanol extracts of plants suppressed overall egg laying except *C. colocynthis* and *S. lappa* where suppression was more pronounced in petroleum ether extracts as compared to their ethanol extracts. Petroleum ether extracts of *P. harmala* and *V. jatamansi* were not promising. Acetone extracts of all the plants except *C. colocynthis* allowed comparatively more oviposition. *A. calamus* did not seem to have any effect on egg laying. However,

Table II.- Mean number (±SE) of eggs laid 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 number of flies settled		% Egg inhibition	t value
		Untreated guava	Treated guava		
Acorus calamus	petroleum ether	40.33±19.78	39.83±18.71	0.62	0.02[ns]
	acetone	22.50±5.57	35.50±31.22	-22.41	0.58[ns]
	ethanol	22.67±13.32	17.83±12.19	11.93	0.46[ns]
Curcuma longa	petroleum ether	31.00±14.60	12.17±8.25	43.63	1.27[ns]
	acetone	72.00±34.10	36.00±25.24	33.33	1.46[ns]
	ethanol	35.83±23.29	15.67±8.39	39.16	1.41[ns]
Citrullus colocynthis	petroleum ether	7.67±5.03	4.83±3.33	22.67	0.58[ns]
	acetone	16.17±10.97	10.83±4.01	19.75	0.79[ns]
	ethanol	25.83±15.82	7.67±4.90	54.23	1.89[ns]
Saussurea lappa	petroleum ether	20.93±2.80	4.00±1.32	67.91	0.85[ns]
	acetone	50.33±9.50	19.33±11.02	44.50	2.69[ns]
	ethanol	17.33±4.73	20.00±2.65	-7.14	0.16[ns]
Peganum harmala	petroleum ether	52.17±21.27	55.83±45.18	-3.40	0.13[ns]
	acetone	90.67±60.01	14.83±9.83	71.88	2.16[ns]
	ethanol	12.00±8.05	5.67±1.76	35.85	0.61[ns]
Valeriana jatamansi	petroleum ether	50.67±30.83	24.17±14.06	35.41	1.08[ns]
	acetone	47.00±26.85	9.83±6.45	65.40	2.15[ns]
	ethanol	11.67±8.25	2.17±1.04	68.67	1.30[ns]
Control (untreated fruit)		53.50±16.64	64.50±14.75	-9.32	0.47[ns]

Each value is mean of 3 replications with 16 insects per replicate.
* Non-significant

highest oviposition deterrence of 71.88% was observed in guava treated with acetone extract of *P. harmala* followed by 68.67 and 67.91% deterrence in ethanol extract of *V. jatamansi* and petroleum ether extract of *S. lappa*. Acetone extract of *V. jatamansi*, ethanol extract of *C. colocynthis*, acetone extract of *S. lappa* and petroleum ether extract of *C. longa* were also promising showing 65.40, 54.23, 44.50 and 43.63% oviposition deterrence, respectively.

Petroleum ether extract of *C. colocynthis*, ethanol extracts of *V. jatamansi* and *P. harmala* allowed minimum oviposition as the total number of eggs laid was 12.50 (1.5 eggs/female), 13.84 (1.7 eggs/female) and 17.67 (2.2 eggs/female), respectively, as compared with 118.00 (14.75 eggs/female) in the control fruits. This behaviour of oviposition inhibition was more or less pronounced in all the extracts except 108.00 (13.50 eggs/female) in acetone extract of *C. longa* and petroleum ether extract of *P. harmala.*

Petroleum ether extract of *P. harmala*, acetone extract of *A. calamus* and ethanol extract of *S. lappa* did not affect oviposition of the flies rather they allowed higher oviposition in treated fruits as compared with their respective untreated fruits.

The above observations indicated that minimum overall settling on both treated and untreated guava occurred in acetone extract of *V. jatamansi* but it was not good repellent while extract of *C. longa* in petroleum ether affected settling and was also a promising repellent. The repellent compounds in petroleum ether extract of *C. longa* are turmerone and ar-turmerone (Su *et al*., 1982). Turmeric oil repelled *Rhizopertha dominica* and its petroleum ether extract was repellent to *Tribolium castaneum* (Jilani and Su, 1983; Jilani *et al*., 1984; Noorullah *et al*., 1990). However, ethanol and

acetone extracts of *P. harmala* having comparatively higher overall settling were the most promising repellents. Regarding egg laying, petroleum ether extract of *C. colocynthis* had overall lowest oviposition on both treated and untreated guava but it had not deterred oviposition, *P. harmala* in its ethanol extract behaved similarly. While ethanol extract of *V. jatamansi* allowed minimum oviposition and at the same time had very high oviposition deterrence of 68.67%. Mean number of eggs laid was 2.17 and 11.67 in treated and untreated fruits, respectively. Acetone extract of *P. harmala* having the highest overall oviposition also indicated the highest oviposition deterrence of 71.88%.

Oviposition by settling females was also affected by the type of plant extract. There was clearly lowest oviposition in ethanol extracts followed by petroleum ether and acetone extracts. Further to this in ethanol extracts maximum oviposition inhibition per visit of fly was exhibited by *P. harmala* followed by *V. jatamansi, S. lappa, C. colocynthis, C. longa* and *A. calamus* showing 2.10, 2.13, 2.92, 3.65, 4.49 and 4.95 eggs/visit. In case of acetone extracts maximum oviposition inhibition was recorded in *C. colocynthis* followed by *A. calamus, S. lappa, C. longa, P. harmala* and *V. jatamansi* showing 3.06, 5.90,7.57, 8.75, 12.62 and 17.76 eggs/visit of the fly. The order was still different in petroleum ether extracts where maximum oviposition inhibition was exhibited by *C. colocynthis* followed by *A. calamus, S. lappa ,V. jatamansi, C. longa* and *P. harmala* with 1.70, 1.77, 3.04, 7.34, 9.22 and 10.59 eggs/visit.

It was therefore, concluded that polarity of the solvent used for preparation of extracts had visible effect on the efficiency of the fly to oviposit. In ethanol extracts having highest polarity, *V. jatamansi* and *P. harmala* had the highest oviposition inhibition whereas in acetone and petroleum ether extracts, they had comparatively lower effect. However, in lower polarity solvent extracts *i.e.* petroleum ether extracts of *C. colocynthis* and *S. lappa* extracts were more effective, while in medium polarity solvent extracts *i.e.* acetone extract of *C. colocynthis* was more effective than other plant extracts.

The above observations can be related with the polarity sequence of the group of chemicals extracted with different solvents and subsequent response of the fly to settle and oviposit on the fruits treated with these extracts. The extracts having comparatively more amount of the chemicals with higher molecular weight have shown more oviposition inhibition.

In the above studies three solvents viz. petroleum ether, acetone, and ethanol having low, medium, and high polarities, respectively, were used to prepare extracts containing compounds of corresponding polarities. Results indicated that in case of *A. calamus, P. harmala* and *V. jatamansi* polarities of the extracts were directly related to their repellent effect and indirectly related to overall oviposition and oviposition on extract treated guava fruits. This indicated that low polarity compounds extracted from these plants with petroleum ether were non-repellent where as those extracted with acetone and ethanol had higher repellent effect. Similarly, lower polarity extracts allowed overall higher oviposition and on the treated guava. The oviposition decreased with increase in polarity; ethanol extracts showing the lowest oviposition. However, in case of *S. lappa*, highest oviposition deterrence of 67.91% was exhibited by petroleum ether extract, which decreased to 44.56 in acetone extract.

Oviposition deterrency however, appeared to be directly related with polarity of the test plant extracts in case of *V. jatamansi, C. colocynthis, C. longa* and otherwise in *S. lappa*. Therefore, higher oviposition deterrency of 68.67 and 67.91% was achieved in ethanol extract of *V. jatamansi* and petroleum ether extract of *S. lappa*, respectively. In case of *P. harmala* middle polarity of the acetone extract had the highest oviposition deterrent effect. Similar behaviour in insects has also been indicated by (Meera and Mann, 2002) that ether extracts of *P. harmala* at 10 % concentration were the most effective in reducing egg laying in *Callosobruchus chinensis*. The chemical compounds in *P. harmala* are aromatic with molecular weights ranging from 172 to 392 (Khan, 1990). The repellent action of *P. harmala* might be due to the low molecular weight volatile compounds ranging from 172 to 198, which were extracted in acetone. In its ethanol extract these compounds repelled the flies while the high

Mol. Wt. compounds *i.e.* >200 persisted, deterred and suppressed the egg laying. Hence, it can be assumed that the low molecular weight compounds in *P. harmala* affected settling and were good repellents, while the high molecular weight compounds affected egg laying of *B. zonata.* Vapours of plant extracts had affected or inhibited the overall egg laying of flies irrespective of treated or untreated guava fruits. Total number of eggs laid was very low where extracts were applied as compared to control fruits. This suppression or inhibition was more pronounced in ethanol extracts than in acetone and petroleum ether extracts. Detailed studies are required to investigate relation between biologically active compounds and their effect on egg inhibition. Chen *et al.* (1996) reported the role of non-volatile neem components detected by the ovipositor as a signal to reduce egg laying. So, in case of ethanol extract of *P. harmala* and *V. jatamansi*, it is possible that biologically active heavy molecular weight compounds might have played their role in reducing egg laying and therefore need to be identified.

Similar type of response in insects caused by plant extracts has also been reported from other laboratories. Sharaby (1988) reported pronounced reduction in egg production and egg viability when *Phthorimaea operculella* were exposed to the vapours arising from paper treated with 220 µl of *Citrus sinensis.* The reduction in fecundity and egg hatchability was more pronounced when both sexes were treated than when only one sex was treated and allowed to mate with an untreated one of the opposite sex. Dongre and Rahalkar (1982) reported that exposure of adults of *Earias vitella* to oil vapours of *Blumea eriantha* reduced their mating ability, predominantly that of males. The mating percentage and fecundity of mated females decreased with increase in pre-oviposition period up to a concentration of 10 µl oil exposure.

The leafhopper, *Nephatettix virescens*, and the planthopper, *Nilaparvata lugens*, caged on rice plants treated with 12 percent neem oil showed decreased egg production. *N. lugens and N. virescens* collected from rice plants sprayed with neem seed kernel extract revealed significantly lower frequencies of meiotic cells in progenies of *N. lugens* (Saxena, 1989).

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 geno-toxic effects. Such compounds may also have effects on hormonal imbalance and reproductive physiology of insects. This information can be helpful in developing some effective formulations for commercial use against insects.

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