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Feeding inhibitory activity of different medicinal plant oils against *Papilio demoleus* L

Deepika Chauhan and Poonam Srivastava

Abstract
The study was carried out to evaluate feeding inhibitory activity of plant oils *viz.*, Lemon grass- Chirharit, Lemon grass- Krishana, Jatropha, Citronella grass, Eucalyptus, Nilgiri, Lippia, Lemon tulsi, Levender, Fennel, Mint, Palmrosa, *Geranium* sp. (at 1% and 2% conc.) against 5d and 10d old larvae of *Papilio demoleus*. The data showed varying degree of antifeedant activities of plant oils against *P. demoleus.* At 1 % conc. Maximum antifeedant activity was exhibited by Lemon grass- Chirharit (94.34 %) followed by Lemon grass- Krishna (78.11 %). At 2 % conc. similar trend was examined and Lemon grass- Chirharit revealed maximum antifeedant activity. Out of the twelve medicinal plant oils tested at 1 and 2% conc. against 10d old larvae of *P. demoleus*, all the plant oils significantly lowered the feeding. However a non -significant reduction in feeding was observed with *Geranium* (6.7 and 4.25cm^2) at 1 and 2% conc., respectively.

Keywords: Feeding inhibitory activity, Plant oils, *Papilio demoleus*

1. Introduction
The lemon butterfly, *Papilio demoleus* is an economically imperative pest where larval forms cause severe injure to citrus family in the field by consuming huge quantity of foliage during later stages of their growth. This insect is regarded as the most vital leaf feeding insect in India [1]. The caterpillars defoliate citrus trees and are very damaging to plants in the seed beds and nurseries. The larvae have preference young plants of 1-2 feet high and are proficient of completely defoliating nursery groves [2-5]. Dispersal capability and ability for rapid population growth make *P. demoleus* a potentially severe pest.
So, suitable management of this pest could play considerable economic impact on production and profitability of the citrus crop. Besides the use of new insecticides, there is a need of holistic approach towards insect pest management which includes the use of botanicals such as plant products and plant essential oils to combat residue and resistance problem. In recent years, great importance has been given on the use of natural products, which are non-toxic, safe, low cost and biodegradable alternative to the conventional control of insects by synthetic pesticides. Earlier studies have indicated that antifeedant compounds derived from seeds, flowers, fruits, leaves and roots of the plants could be used as effective bio-compounds against the growth and metamorphosis of the noxious insects. There is a vital need for the development of safer substitute crop protectants such as botanical insecticides and antifeedants. Plants are rich source of natural essences that can be employed in the enlargement of environmentally safe methods for insect control [6]. Nowadays the application of synthetic pesticides due to their high effectiveness and speedy action has become popular. Besides, these pesticides have some harmful effects and source of ecological damage and health hazards. For that reason, a study was performed with the aim of managing *P. demoleus* population at Pantnagar, through eco-friendly approaches.

Materials and Methods
Studies on the feeding inhibitory activity of different medicinal plant oils against *P. demoleus* L. was carried out in the department of Entomology, G.B. Pant University, Pantnagar during the year 2015-16. A citrus nursery consisting of cultivar Pant lemon-1 was maintained at Horticulture Research Centre, Patharchatta for collecting the culture of *P. demoleus*.

Culture of Lemon butterfly, *Papilio* spp.

Eggs and larvae were collected from the citrus and bel nurseries. Eggs were kept in petri plates (diameter 9cm) for hatching and larvae were transferred separately to petri plates (dia. 9cm) and fed on fresh citrus leaves. The pupae from these petri plates were collected placed in separate jars and covered with muslin cloth to get the adults of lemon butterfly. The male and female butterfly collected from jars were separated and transferred to other glass jars and covered with muslin cloth. The adults of lemon butterfly were supplied with cotton soaked in glucose solution in petri plates. Tender twigs of citrus in a small beaker having water was placed inside the glass jar to get the eggs from these adults. The eggs were kept in petri dishes. In order to provide proper humidity, a lining of wet filter paper was kept at the bottom. The neonate larvae were transferred to big petri dishes containing fresh and soft lemon leaves with the help of fine brush. The nursery was maintained under irrigated conditions in order to obtain faster and luxuriant growth of foliage. Fresh food was supplied daily and proper hygienic conditions were maintained. Second instar larvae of desired age groups were sorted out and divided into two groups; experimental/test and control larvae. The larvae were used for conducting the various experiments.

Feeding inhibitory activity of some plant oils was studied against 5d and 10d old larvae of *P. demoleus,* under laboratory conditions using no-choice feeding bioassay method. Two concentrations (1% and 2%) of each of the plant oils were prepared in acetone. Fresh leaf discs of (size: 3 x 3 cm^2) were cut from the leaves of citrus, dipped in the respective plant oils for approx. 4 -5 seconds and air dried. Control leaf discs were treated with acetone only [7]. The treated leaf discs were kept in corning glass petri dishes (dia.9cm) lined with an inner layer of moist filter paper. All the treatments were replicated three times. Freshly moulted (3h starved) larvae of *P. demoleus* (n=2) were released in each petri dish and allowed to feed until more than 75% of the leaf area was eaten away in control (approx. 6 h). The data on the leaf area consumed was recorded on graph paper in the various treatments and the calculation was made on the following parameters *viz.* Antifeedant activity (A.A.) following Singh and Pant (1980) [8]; Feeding inhibition (F.I.) following Pande and Srivastava (2003) [9]; and Feeding percentage (F.P.) following Purwar and Srivastava (2003) [10].

Observations

The observations were recorded on leaf area consumed with the help of graph paper. The calculations were made on the following parameters:

I. Feeding percentage (F.P.)

$$\text{F.P.} = \frac{(\text{Initial leaf area provided for feeding}) - (\text{Leaf area left after feeding})}{\text{Initial leaf area provided}} \times 100$$

II. Feeding inhibition (F.I.) following Isman *et al.* (1990) [11]

$$\text{F.I.} = \frac{C - T}{C + T} \times 100$$

Where C=consumption of control disc

T=consumption of treated disc

III. Antifeedant activity (A.A.)

$$\text{A.A.} = \frac{\text{Leaf protection in treated disc (\%)} - \text{leaf protection in control disc (\%)}}{\text{100- Leaf protection in control disc (\%}} \times 100$$

IV. C -value (Preference index) following Kogan and Goeden (1970) [12]

$$C = \frac{2M}{M + B}$$

Where, B = Eaten area of control leaf disc

M = Eaten area of treated leaf disc

The index measures the virtual amount of feeding on 2 species of plants present in the arena in a 0 to +2 scale. A value of 1 indicates that feeding on test plant was equivalent to the feeding on the standard. A, C -value > 1 indicates a preference for the test plant and a C- value < 1 indicates fewer reception to the test plant. On the basis of C- values, the experimental plant oils were assigned categories as under [13].

Category		**(C-value)**
1. Extremely antifeedant	:	0.1-0.25
2. Strongly antifeedant	:	0.26-0.50
3. Moderately antifeedant	:	0.51-0.75
4. Slightly antifeedant	:	0.76-0.99
5. Preferred	:	≥1

Statistical analysis: All the laboratory experiments were conducted in completely randomized design (CRD) [14] and the data was analyzed by One Way Analysis of Variance (ANOVA) following [15]. The means were separated using, Duncan Multiple Range Test (DMRT) [16] based SPSS16 (Statistical Product and Service Solutions) computer programme.

Results

Antifeedant activity of different medicinal plant oils against 5d old larvae of *P. demoleus*

Mean leaf area consumed (MLAC)

The analyzed data was presented in table 1. It is evident from the table 1 that all the treatments caused significant reduction in feeding over control. Minimum feeding was observed in *C. flexuosus* (Lemon grass-Chirharit) (0.50 cm^2) at 1% followed by *C. flexuosus*-Krishna (1.95cm^2), *O. tenuiflorum* (2.00), *J. curcus* (2.30), *C. martinii* (2.50 cm^2), *M. arvensis* (2.53cm^2), *C. nardus* (2.90), *L. angustifolia* (3.00 cm^2), *L. alba* (3.50 cm^2), *E. citriodora* (3.75 cm^2), *F. vulgare* (4.50 cm^2). At 1% maximum feeding was observed in *Geranium* (6.10 cm^2). At 2 % all the plant oils significantly reduced the feeding in the following order *C. flexuosus*- Chirharit (0.10 cm^2) < *C. flexuosus*- Krishna (0.30 cm^2) < *J. curcus* (0.40 cm^2) < *M. arvensis* (0.50 cm^2) < *O. tenuiflorum* (0.70 cm^2) < *L. angustifolia* (0.80 cm^2) < *C. nardus* (1.10 cm^2) < *L. alba* (1.25 cm^2) = *C. martinii* (1.25 cm^2) < *E. citriodora* (1.50cm^2) = *F. vulgare* (1.50 cm^2) < *Geranium* (4.75 cm^2).

Antifeedant activity

The data showed varying degree of antifeedant activities of plant oils against 5d old larvae of *P. demoleus.* At 1 % conc. maximum antifeedant activity was exhibited by *C. flexuosus*-Chirharit (94.34 %) followed by *C. flexuosus*- Krishna (78.11 %) > *O. tenuiflorum* (77.55 %) > *J. curcus* (74.18 %) > *C.*

martinii (71.94 %) > *M. arvensis* (71.60 %) > *C. nardus* (67.44 %) > *L. angustifolia* (66.32%) > *E. citriodora* (57.90 %) > *F. vulgare* (49.49 %) and least antifeedant activity was found in *Geranium* (31.53 %). At 2 % conc. similar trend was observed and *C. flexuosus*- Chirharit exhibited maximum antifeedant activity of 98.78 % but least was observed in *Geranium* (46.68 %).

Feeding inhibition

In the present enquiry all the plant oils showed evidence of feeding inhibitory activity and their activity increased with increase in conc. *Geranium* at 1 and 2% caused minimum feeding inhibition with 13.47 and 25.49 %. *C. flexuosus*-Chirharit showed maximum feeding inhibitory activity with 67.96 and 97.53 at 1 and 2% conc. followed by *C. flexuosus*-Krishna (60.80 and 92.77%) at 1 and 2% respectively. These plant oils with substantial antifeedant and feeding inhibition activity can be integrated in management programme of this pest at higher conc.

Preference index

At 1 and 2% concentrations *C. Flexuosus*- Chirharit proved to be extremely antifeedant with C- value of 0.17 and 0.12 (range: 0.1 – 0.25). *C. flexuosus*- Krishna and *J. curcus* proved to be strongly antifeedant and extremely antifeedant with C-value of 0.39 and 0.44 at 1%; 0.14 and 0.16 at 2% respectively. *Geranium* at 1% fall under slightly antifeedant category with C- value of 0.86 (range: 0.76-0.99) and at 2% fall under slightly antifeedant category with C-value of 0.74 (range: 0.51-0.75). Whereas *C. nardus, L. angustifolia, L. alba, E. citriodora F. vulgare* at 1% showed moderately antifeedant activity with C- value of 0.53, 0.54, 0.60, 0.63 and 0.72 respectively (range: 0.51-0.75). At 2% conc. *C. nardus, L. alba, E. citriodora and F. vulgare* proved to be strongly antfeedant with C-value of 0.24, 0.30, 0.35 and 0.31 respectively (range: 0.25-0.50).

The data exposed that among the tested plant oils *C. flexuosus*- Chirharit, *C. flexuosus* –Krishna and *J. curcus* showed preference index of less than 0.25 and were considered acquiring antifeedant activity.

Antifeedant activity of different medicinal plant oils against 10d old larvae of *P. demoleus*

Mean leaf area consumed (MLAC)

From the analyzed data presented in table 2 indicated that out of the twelve medicinal plant oils tested at 1 and 2% concentrations against 10d old larvae of *P. demoleus*. All the plant oils significantly lowered the feeding. However minimum reduction in feeding was observed with *Geranium* (6.7 and 4.25cm^2) at 1 and 2% concentrations respectively. All the plants tested were effective in causing significant reduction in feeding over control (MLAC=8.25cm^2) at p=0.05. However at 1% minimum feeding was observed in *M. arvensis* (2.0 cm^2) followed by *C. flexuosus*- Chirharit (2.09 cm^2), *L. alba* (2.50 cm^2), *J. curcus* (2.80 cm^2), *O. tenuiflorum* (2.80 cm^2), *C. martinii* (3.0 cm^2), *C. flexuosus*- Krishna (3.10 cm^2), *C. nardus* (3.80 cm^2), *E. citriodora* (4.00 cm^2), *L. angustifolia* (4.20 cm^2), *F. vulgare* (5.25 cm^2) and *Geranium* (6.7 cm^2). While at 2% conc. minimum feeding was observed with *C. flexuosus*- Chirharit (0.50 cm^2) and *J. curcus* (0.50 cm^2).

Anti-feedant activity

The data showed varying degree of antifeedant activities of plant oils against 10d old larvae of *P. demoleus.* At 1 % concentration Maximum antifeedant activity was exhibited by *M. arvensis* (77.60 %) followed by *C. flexuosus*- Chirharit (76.59 %) and least antifeedant activity was found in *Geranium* (16.59 %). At 2 % concentration maximum antifeedant activity was showed by *C. flexuosus*- Chirharit and *J. curcus* (94.40 %) followed by *C. flexuosus*- krishna (91.60 %), *O. tenuiflorum* (89.36 %), *C.nardus* (85.44 %), *L. alba* (83.20), *M. arvensis* (80.40 %), *E. citriodora* (79.84 %), *L. angustifolia* (77.60 %), *F. vulgare* (67.53 %) and least was observed in *Geranium* (52.41 %).

Feeding inhibition

In the present investigation all the plant oils exhibited feeding inhibitory activity and their activity increased with increase in concentration *M. arvensis* and *C. flexuosus*- Chirharit showed maximum feeding inhibitory activity with 60.9 and 59.57 % at 1% concentration followed by *L. alba* (53.48%), *J. curcus* (49.32%), *O. tenuiflorum* (49.32%), *C. martinii* (46.6%), *C. flexuosus* –Krishna (45.37%), *C. nardus* (35.59%), *E. citriodora* (34.69), *L. angustifolia* (32.53%), *F. vulgare* (22.22%) and *Geranium* (10.36%) respectively. While at 2% concentration maximum feeding inhibition was observed by *C. flexuosus*- Chirharit and *J. curcus* (88.57%) and minimum was exhibited by *Geranium* (32.0%).

Preference index

At 1% on the basis of preference index (C-value), *C. flexuosus*- Chirharit (0.40), *J. curcus* (0.50), *L. alba* (0.46), *O. tenuiflorum* (0.50), *M. arvensis* (0.39) were placed under ‘strongly antifeedant’ category (range: 0.26-0.50), *C. flexuosus*- Krishna (0.54), *C. nardus* (0.63), *E. citriodora* (0.65), *L. angustifolia* (0.67), *C. martinii* (0.53) under ‘moderately antifeedant’ (range: 0.50-0.75) and *F. vulgare* (0.77), *Geranium* (0.94) were come under ‘slightly antifeedant’ category (range: 0.76-0.99). However at 2% *C. flexuosus*- Chirharit (0.11), *C. flexuosus*- Krishna (0.16), *J. curcus* (0.11), *O. tenuiflorum* (0.20) proved to be extremely antifeedant (range: 0.1-0.25) and *C. nardus* (0.60), *E. citriodora* (0.27), *L. alba* (0.30), *M. arvensis* (0.35) fall under strongly antifeedant category (range: 0.26-0.50) while *Geranium* showed moderately antifeedant activity with C-value of 0.68 (range: 0.51-0.75).

Maximum anti-feedant activity was displayed by *C. flexuosus* at 2% (87.88%). The present investigation was carried out to measure the anti-feeding cause of plant essential oils against *P. demoleus*. All the essential oils demonstrated the imperative feeding anticipation activities and fall under different antifeedant category. *C. flexuosus*- Chirharit, *C. flexuosus*- Krishna and *J. curcus, O. tenuiflorum* acquired preference index of less than 0.25 and were considered possessing antifeedant activity against 10d old larvae of *P. demoleus*. Validation of insecticidal activities in essential oils and find out their active components may provide a source for generate new trade for plant origin insecticides, seeking to enlarge and develop substitute ways to enhance production in agro ecosystems and diminish synthetic insecticide exploitation.

Table 1: Effect of plant oils on feeding behaviour of 5d old larvae of *P. demoleus*

S. No.	Plant species Scientific name (Common name)	MLAC (cm^2)		Antifeedant activity (%)		Feeding inhibition (%)		Preference index (C- value)		Antifeedant category	
		1 %	2 %	1 %	2 %	1 %	2 %	1 %	2 %	1 %	2 %
1.	*Cymbopogon flexuosus* Stapf. (Lemon grass-Chirharit)	0.50 ± 0.05^{a}	0.10 ± 0.26^{ab}	94.34 ± 0.023^{l}	98.78 ± 0.01^{j}	67.96 ± 0.01^{i}	97.53 ± 0.01^{l}	0.17 ± 0.05^{a}	0.12 ± 0.05^{a}	EA	EA
2.	*Cymbopogon. flexuosus* Stapf.(Lemon grass-Krishana)	1.95 ± 0.01^{b}	0.30 ± 0.05^{a}	78.11 ± 0.005^{k}	93.26 ± 0.01^{i}	60.80 ± 0.01^{h}	92.77 ± 0.05^{k}	0.39 ± 0.5^{b}	0.14 ± 0.05^{ab}	SA	EA
3.	*Jatropha curcas* L. (Jatropha)	2.30 ± 0.05^{b}	0.40 ± 0.05^{ab}	74.18 ± 0.011^{i}	92.14 ± 00.2^{h}	55.33 ± 0.17^{g}	90.47 ± 0.05^{j}	0.44 ± 0.02^{bc}	0.16 ± 0.23^{c}	SA	EA
4.	*Cymbopogon nardus* L.(Citronella grass, Ganjri)	2.90 ± 0.05^{c}	1.10 ± 0.05^{c}	67.44 ± 0.02^{f}	87.65 ± 0.01^{d}	46.78 ± 0.01^{e}	75.82 ± 0.01^{d}	0.53 ± 0.05^{de}	0.24 ± 0.05^{e}	MA	SA
5.	*Eucalyptus citriodora* Hook. (Eucalyptus,Nilgiri)	3.75 ± 0.02^{ef}	1.50 ± 0.05^{c}	57.90 ± 0.02^{c}	83.16 ± 0.00^{c}	44.68 ± 0.11^{e}	68.42 ± 0.01^{b}	0.63 ± 0.012^{gh}	0.35 ± 0.02^{h}	MA	SA
6.	*Lippia alba* L.(Lippia)	3.50 ± 0.28^{de}	1.25 ± 0.14^{c}	60.71 ± 0.00^{d}	73.89 ± 0.05^{b}	39.13 ± 0.05^{d}	72.97 ± 0.05^{c}	0.60 ± 0.05^{fg}	0.30 ± 0.05^{gh}	MA	SA
7.	*Ocimum tenuiflorum* L. (Lemon tulsi, Tulsi,)	2.00 ± 0.28^{b}	0.70 ± 0.28^{ab}	77.55 ± 0.05^{j}	92.14 ± 0.01^{f}	60 ± 2.8^{h}	83.90 ± 0.05^{h}	0.40 ± 0.04^{bc}	0.16 ± 0.11^{cd}	SA	EA
8.	*Lavandula angustifolia* L.(Levender)	3.00 ± 0.28^{cd}	0.80 ± 0.14^{b}	66.32 ± 0.02^{e}	91.02 ± 0.01^{e}	36.3 ± 0.05^{c}.	81.18 ± 0.01^{f}	0.54 ± 0.05^{ef}	0.18 ± 0.05^{d}	MA	EA
9.	*Foeniculum vulgare* Mill. (Fennel)	4.50 ± 0.28^{g}	1.50 ± 0.14^{c}	49.49 ± 0.005^{a}	83.16 ± 0.00^{c}	28.0 ± 0.57^{a}	78.94 ± 0.05^{e}	0.72 ± 0.05^{i}	0.31 ± 0.5^{gh}	MA	SA
10.	*Mentha arvensis* L.(Mint)	2.53 ± 0.017^{bc}	0.50 ± 0.28^{ab}	71.60 ± 0.05^{g}	94.34 ± 0.05^{g}	51.94 ± 0.05^{f}	88.23 ± 0.17^{g}	0.46 ± 0.011^{bc}	0.11 ± 0.017^{ab}	SA	EA
11.	*C. martinii* (Roxb.) Wats. (Palmrosa)	2.50 ± 0.28^{bc}	1.25 ± 0.05^{c}	71.94 ± 0.02^{h}	73.89 ± 0.02^{b}	52.38 ± 0.05^{f}	81.81 ± 0.05^{i}	0.47 ± 0.01^{cd}	0.27 ± 0.017^{ef}	SA	SA
12.	*Geranium* sp. L.(Cranesbills)	6.10 ± 0.05^{fg}	4.75 ± 0.11^{d}	31.53 ± 0.00^{b}	46.68 ± 0.5^{a}	13.47 ± 0.01^{b}	25.49 ± 0.04^{a}	0.86 ± 0.05^{kl}	0.74 ± 0.11^{i}	SLA	MA
13.	Control	8.00 ± 0.02^{h}	8.00 ± 0.02^{h}	-	-	-	-	1 ± 0.0^{j}	1 ± 0.00^{j}	P	P
	SEM	0.1821	0.134	0.075	0.077	0.844	0.008	0.224	0.019	-	-
	CD at 5 %	0.529	0.391	0.220	0.227	2.48	0.024	0.065	0.056	-	-
	F-value	**	**	**	**	**	**	**	**	-	-

Means followed by common letters do not differ significantly by DMRT (p=0.05%)., Mean±SE (Standard Error)
MLAC = Mean leaf area consumed, EA – Extremely antifeedant, SA = Strongly antifaadant, MA = Moderately antifeedant, P = Preffered, following [12]

Table 2: Effect of plant oils on feeding behaviour of 10d old larvae of *P. demoleus*

S. No.	Plant species Scientific name (Common name)	MLAC (cm^2)		Antifeedant activity (%)		Feeding inhibition (%)		Preference index (C- value)		Antifeedant category	
		1 %	2 %	1 %	2 %	1 %	2 %	1 %	2 %	1 %	2 %
1.	*C. flexuosus* Stapf. (Lemon grass-Chirharit)	2.09 ± 0.00^{ab}	0.50 ± 0.05^{ab}	76.59 ± 0.57^{h}	94.40 ± 1.27^{h}	59.57 ± 3.21^{f}	88.57 ± 2.3^{h}	0.40 ± 0.05^{a}	0.11 ± 0.0005^{a}	SA	EA
2.	*C. flexuosus* Stapf.(Lemon grass-Krishana)	3.10 ± 0.05^{d}	0.75 ± 0.14^{ab}	65.29 ± 0.05^{e}	91.60 ± 0.20^{gh}	45.37 ± 0.57^{g}	83.33 ± 1.5^{g}	0.54 ± 0.05^{bc}	0.16 ± 0.023^{ab}	MA	EA
3.	*Jatropha curcas* L. (Jatropha)	2.80 ± 0.17^{cd}	0.50 ± 0.02^{a}	68.65 ± 0.05^{f}	94.40 ± 0.57^{h}	49.32 ± 1.1^{d}	88.57 ± 1.7^{h}	0.50 ± 0.02^{b}	0.11 ± 0.26^{bcde}	SA	EA
4.	*Cymbopogon nardus* L.(Citronella grass, Ganjri)	3.80 ± 0.23^{e}	1.30 ± 0.01^{c}	57.45 ± 0.00^{d}	85.44 ± 1.15^{f}	35.59 ± 0.52^{bc}	72.77 ± 0.03^{e}	0.63 ± 0.04^{cd}	0.60 ± 0.02^{e}	MA	SA
5.	*Eucalyptus citriodora*Hook. (Eucalyptus,Nilgiri)	4.00 ± 0.34^{e}	1.80 ± 0.01^{de}	55.21 ± 1.16^{c}	79.84 ± 0.55^{cd}	34.69 ± 0.57^{bc}	64.17 ± 0.01^{c}	0.65 ± 0.01^{d}	0.27 ± 0.01^{abcd}	MA	SA
6.	*Lippia alba* L.(Lippia)	2.50 ± 0.11^{bc}	1.50 ± 0.28^{cd}	72.01 ± 1.15^{g}	83.20 ± 1.5^{def}	53.48 ± 0.58^{e}	68.42 ± 1.13^{d}	0.46 ± 0.03^{ab}	0.30 ± 0.06^{abcd}	SA	SA
7.	*Ocimum tenuiflorum* L. (Lemon tulsi, Tulsi,)	2.80 ± 0.02^{cd}	0.95 ± 0.02^{b}	68.65 ± 0.02^{f}	89.36 ± 0.5^{g}	49.32 ± 0.5^{d}	79.34 ± 0.5^{f}	0.50 ± 0.02^{b}	0.20 ± 0.00^{abc}	SA	EA
8.	*Lavandula angustifolia* L.(Levender,)	4.20 ± 0.15^{f}	2.00 ± 0.05^{e}	52.98 ± 1.16^{b}	77.60 ± 2.8^{bc}	32.53 ± 1.15^{b}.	66.97 ± 1.7^{cd}	0.67 ± 0.00^{d}	0.39 ± 0.01^{bcde}	MA	SA
9.	*Foeniculum vulgare* Mill. (Fennel,)	5.25 ± 0.57^{a}	2.90 ± 0.05^{g}	41.22 ± 0.58^{a}	67.53 ± 0.56^{a}	22.22 ± 0.01^{a}	47.98 ± 0.58^{a}	0.77 ± 0.05^{i}	0.52 ± 0.00^{e}	SLA	MA
10.	*Mentha arvensis* L.(Mint)	2.0 ± 0.57^{d}	1.75 ± 0.04^{de}	77.60 ± 0.05^{h}	80.4 ± 0.63^{cde}	60.9 ± 0.05^{f}	65.0 ± 1.1^{cd}	0.39 ± 0.0^{e}	0.35 ± 0.01^{de}	SA	SA
11.	*C. martinii* (Roxb.) Wats. (Palmrosa,)	3.0 ± 0.57^{d}	1.4 ± 0.05^{c}	66.41 ± 0.00^{e}	84.32 ± 2.3^{ef}	46.6 ± 2.6^{d}	70.98 ± 0.01^{e}	0.53 ± 1.1^{a}	0.29 ± 0.02^{abcd}	MA	SA
12.	*Geranium* sp. L.(Cranesbills)	6.7 ± 0.5^{e}	4.25 ± 0.09^{f}	16.59 ± 0.6^{c}	52.41 ± 0.58^{b}	10.36 ± 0.6^{c}	32.0 ± 0.02^{b}	0.94 ± 0.01^{b}	0.68 ± 0.01^{abcd}	SLA	MA
	Control	8.00 ± 0.02^{g}	8.25 ± 0.02^{g}	-	-	-	-	1 ± 0.02^{d}	1 ± 0.017^{cde}	P	P
	SEM	0.149	0.104	0.672	1.29	1.35	1.20	0.033	0.078	-	-
	CD at 5 %	0.435	0.304	1.96	3.76	3.96	3.50	0.096	0.229	-	-
	F-value	**	**	**	**	**	**	**	**	-	-

Means followed by common letters do not differ significantly by DMRT (p=0.05%)., Mean±SE (Standard Error)
MLAC = Mean leaf area consumed, EA – Extremely antifeedant, SA = Strongly antifeedant, MA = Moderately antifeedant, SLA= Slightly antifeedant, P = Preffered following [12]

Discussion

Not as much of work is done on management of *P. demoleus* by using essential oils, therefore more plant oils should be screened to measure the efficiency against *P. demoleus*.

The antifeedant and growth inhibitory effects of the essential oil of *Lippia alba* were evaluated against *S. obliqua*, *S. litura* and *Heliothis armigera* [*Helicoverpa armigera*]. The essential oil, which was found to be rich in linalool, exhibited feeding deterrence (FD_{50}) of 6.9, 10.3 and 11.0 mg/g diet and growth inhibition (GI_{50}) of 4.2, 7.8 and 9.0 mg/g diet against *S. obliqua*, *S. litura* and *H. armigera*, respectively [17].The study exposed by Basera, 2009 [18] to find out antifeedant activity of nine plant oils (1 and 2% concentration in acetone) *viz., Azadirachta indica, Eucalyptus citriodora*, *Cinnamomum camphora, Ricinus communis, Cymbopogon winterianus, Pongamia pinnata, Cymbopogon flexuosus* and *Curcuma longa, Jatropha curcas* against 9d old larvae of *S. litura* using 'no-choice' bioassay method showed similar findings with our study that all the plant oils taken in the investigation significantly deterred feeding at both of the concentrations (1.0% and 2.0%).

Similar results were obtained by [19] who conducted a experiment to find out antifeedant activity of seven plant oils (1% and 2% concentration in acetone) *viz., Cymbopogon winterianus* Bio 13; *C. flexuosus*.-Krishna; *C. flexuosus*.-Chirharit, *Ocimum tenuiflorum*, *Vetiveria zizanioides*, *Eucalyptus citridora* and *Pogostemon patchouli* - Indonesia against 7d old larvae of *S. litura* revealed that, all plant oils except, *P. patchouli* - Indonesia and *E. citriodora* at 1 and 2% concentration showed promising results in terms of lowering the larval feeding.

The antifeeding effects of *Melia azedarach*, *Colocynthis citrullus*, *Nicotiana tabacum* and *Eucalyptus camaldulensis, Azadirachta indica* against *Tribolium castaneum, Ryzopertha dominica,* and *Trogoderma granarium* under laboratory conditions was studied by [20]. All treatments illustrated the major feeding anticipation activities. The most efficient essential oil not in favour of all insect pests was found in *A. indica*, with utmost reduction in weight loss (0.56, 1.02, 1.69%) and feeding deterrence index (75.44, 54.57 and 39.21%) against *T. castaneum*, *T. granarium* and *R. dominica*, respectively followed by *M. azedarach* (0.63, 1.05 and 1.76%) (67.59, 50.85 and 34.92%), *C. citrullus* (0.65, 1.17 and 1.76%) (65.35, 43.57 and 33.94%), *N. tabacum* (0.7, 1.22 and 1.84) (58.43, 38.87 and 30.28%) and *E. camaldulensis* (0.84, 1.32 and 1.97%) (45.11, 38.98 and 23.18), respectively.

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