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Effect of Semiochemicals and Plant Extracts on Performance of Aphid Parasitoid, *Diaeretiella rapae*

S. Bushra[1,*], M. Tariq[1], M. Naeem[1], M. Ashfaq[1], I. Bodlah[1] and M. Ali[2]

[1]*Department of Entomology, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi*

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

ABSTRACT

Aphids are the major pests of plant crops in temperate areas of the world. They are monophagous as well as polyphagous and damage wheat, oilseeds, vegetables and fruit crops. This study was carried out to observe the effect of plant extracts and semiochemicals on physiology and performance of endoparasitoid of aphids, *Diaeretiella rapae*. Seven different treatments of semiochemicals and plant extract were applied on aphid pests, *Sitobion avenae* and *Rhopalosiphum padi* and parasitoid was released. The data regarding emergence, parasitism, sex ratio, tibia length, adult weight and adult longevity of parasitoid *D. rapae* after the application of treatments was studied and analyzed statistically. The study revealed that plant extract can be toxic to paprasitoid *D. rapae*. This study will help us to use those insecticide formulations, which not only kill the aphid pests but are also eco-friendly to natural enemies and our environment.

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MT and MN conceived and designed the study. SB performed all the experiments and wrote the article. IB and MA analyzed the data.

Key words
***Beauveria bassiana, Musca domestica,* Biological aspects, Sublethal effects.**

INTRODUCTION

About 5000 aphid species are crop pests (Morrison and Peairs, 1998). They weaken the plant growth by sucking sap, transmit viruses in their host and result the yield losses (Dehkordi *et al*., 2013; Asiry, 2015). Aphid pests *Sitobion avenae* and *Rhopalosiphum padi* coexist in spring wheat crop and cause economic damage (Chen *et al*., 2007). Several insecticides are used to control these aphids which are also harmful. The adverse effects of insecticides on mammals are caused by insecticide residues left on edible crops when they are consumed (Bale *et al*., 2008). One the other hand, some plants consist of valuable active chemicals such as alkaloids, semiochemicals, terpenoids, glycosides, flavonoids and cucurbitacins, which are toxic to insect pests (Koul and Walia, 2009). These extracts are used to reduce the losses caused by agricultural pests by killing them. These include neem, turmeric, garlic etc. These plant extracts are used in IPM, medicine and industry. Some of the plant extracts have a negative impact on natural enemies like parasitiods (Sohail *et al*., 2012).

The braconid wasp, *Diaeretiella rapae* is an endoparasitoid of aphids (Fathipour *et al*., 2006). But, parasitoid performance also increases with increase in aphid population (Holling, 1959). Aphid parasitoids need chemical volatiles to find suitable hosts and reproduce. These chemical volatiles are semiochemicals that indicate the presence of their hosts (Blande *et al*., 2007). Semiochemicals are volatile chemical compounds which are emitted by plants as alarming signals, when they are damaged. They repel herbivores (Francis *et al*., 2004; Verheggen *et al*., 2007). They attract parasitoid wasps which are antagonistic to aphid pests (El-Sayed *et al*., 2006). Among semiochemicals, aphid alarm pheromone has the direct influence on aphid density (Xiangyu *et al*., 2002). This pheromone consists α-pinene, β-pinene and E-β-farnesene (Eβf) and some trace compounds. These compounds attract natural enemies of aphids (Sasso *et al*., 2007; Leroy *et al*., 2012).

In this study the effect of different semiochemicals and plant extracts was studied on the performance and physiology of aphid parasitoid, *Diaeretiella rapae.* This study will help us to use those insecticide formulations, which not only kill the aphid pests but they are also eco-friendly to natural enemies and environment. Long term studies on the effect of semiochemicals and plant extracts towards pests and natural enemies are required before recommending their use as pesticide (Asiry, 2015; Arshad *et al*., 2016). In this way, we can conserve natural enemies and manage the aphid pests.

MATERIALS AND METHODS

Wheat seeds of variety Fareed-06 were sown in

* Corresponding author: bushraentomologist@gmail.com
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pots in glass house under controlled conditions (25±2°C) and 65% RH under an LD 16:8 h. About 25 plants per pot were sown. After 6 weeks of germination the plants were subjected to aphid culture of *Sitobion avenae* and *Rhopalosiphum padi* separately. About 100 aphids per pot were released. These plants were covered with ventilated polythene sheets to avoid accidental aphid infestation and escape of applied culture. Two weeks later, three hundred aphids per pot were left behind and rest of them were removed via camel hair brush.

Mummified aphids were collected from wheat field crops. They were placed in glass vials till hatching. Newly emerged *Diaeretiella rapae* females were paired into a 2.5 x 8 cm glass tube and were reared on 1droplet honey+1 droplet water per day.

Seven treatments having combination of semiochemical and plant extracts were applied to these plants in 3% concentration. Five pairs of *D. rapae* were released under polythene sheets just after the application of seven treatments. These combinations are presented in Table I.

Table I.- Treatments of plant extracts and semiochemicals.

Treatments	Semiochemical and plant extract	Concentration
T_1	Turmeric	Control, 3%
T_2	*β*-pinene	Control, 3%
T_3	E-*β*-Farnesene (E*β*f)	Control, 3%
T_4	Turmeric, *β*-pinene	Control, 3%
T_5	Turmeric, E-*β*-Farnesene	Control, 3%
T_6	*β*-pinene, E-*β*-Farnesene	Control, 3%
T_7	Turmeric, *β*-pinene and E-*β*-Farnesene	Control, 3%

Parasitoids were removed after 24 h. Aphids were allowed to develop for 10-14 days for mummy formation. Mummies were collected in individual gelatine capsules. The data regarding emergence, parasitism, sex ratio, tibia length, adult weight and adult longevity of *D. rapae* after the application of seven treatments as mentioned above.

Statistical analysis

The data pertaining to emergence, parasitism, sex ratio, tibia length, adult weight and adult longevity of *D. rapae* after the application of seven significant treatments were subjected to Statistical package R with CRD design.

Table II.- Emergence (%), sex ratio (%) and parasitism (%) of *D. rapae* on *Sitobion avenae and Rhopalosiphum padi.*

	Emergence %	Sex ratio %	Parasitism %	Tibia length
Sitobion avenae				
Control	83.81±1.88	35.27±2.32	56.2±1.59	0.52 ± 0.02
T_1	77.0±2.57	35.18±2.01	30.4±1.33	0.46 ± 0.01
T_2	86.82±0.51	35.25±5.04	54.4±1.72	0.54 ± 0.01
T_3	86.37±1.49	42.09±1.61	42.8±1.66	0.40 ± 0.02
T_4	75.63±1.89	43.89±3.47	28.8±1.85	0.43 ± 0.01
T_5	85.81±1.37	36.99±2.44	35.6±1.99	0.46 ± 0.02
T_6	90.67±0.70	36.69±2.45	66.8 ±1.8	0.55 ± 0.01
T_7	87.43±1.8	39.24±2.39	44.8 ±1.8	0.42 ± 0.02
Rhopalosiphum padi				
Control	84.02±0.92	45.96±3.92	55.2±1.59	0.53 ± 0.02
T_1	77.18±2.33	37.44±4.01	31.8±1.98	0.44 ± 0.02
T_2	91.62±0.98	34.22±1.04	56.8±1.88	0.52 ± 0.01
T_3	87.73±0.96	36.54±4.76	46.2±2.27	0.47 ± 0.01
T_4	80.21±2.32	37.98±2.00	50.86±2.7	0.45 ± 0.02
T_5	83.16±2.83	37.44±2.24	33.0±2.39	0.47 ± 0.01
T_6	91.06±0.47	43.88±3.70	64.8±1.93	0.54 ± 0.02
T_7	85.07±1.44	41.13±2.85	43.2±1.66	0.44 ± 0.01

All values are Mean±SEM. T_1, Turmeric; T_2, *β*-pinene; T_3, E-*β*-Farnesene (E*β*f); T_4, (Turmeric, *β*-pinene); T_5, (Turmeric E-*β*-Farnesene; T_6, (*β*-pinene E-*β*-Farnesene; T_7, Turmeric, *β*-pinene and E-*β*-Farnesene.

RESULTS AND DISCUSSION

Emergence of D. rapae *reared on aphids*

The comparison of means of *D. rapae* emergence at 5% level of probability is shown in Table II. The *D. rapae* exhibited 83.81% emergence in untreated controls when it was reared on *S. avenae.* It was found that *D. rapae* exhibited minimum mean emergence (75.63%) in T_4 and maximum mean emergence (90.67%) after the application of T_6. The mean emergence of *D. rapae* was found 85.81% after the application of T_5, which was statistically similar to T_3 (86.37%) which was statistically at par with T_2 (86.82%). The mean emergence of *D. rapae* was found to be 77.0% and 87.43% after the application of T_1 and T_7, respectively. The overall emergence of *D. rapae,* ranged from 75.63-90.67% after the application of seven different treatments (Table II). This shows that T_6 was the combination of semiochemicals which enhanced the total emergence of parasitoids significantly as compared to other six treatments. While semiochemical alone also exhibited the significant results (T_2, T_3). The treatment with turmeric

and Ebf exhibited significantly higher emergence in T_5.

The *D. rapae* exhibited 84.02% emergence in untreated controls when it was reared on *R. padi.* It was found that *D. rapae* exhibited minimum mean emergence (77.18%) in T_1 and maximum mean emergence (91.62%) after the application of T_2. The mean emergence of *D. rapae* was found to be 87.73% after the application of T_3, followed by T_7 (85.07%), which was statistically similar to T_5 (83.16%), which was statistically at par with T_4 (80.21%), respectively. The overall emergence of *D. rapae* ranged from 77.18-91.62% after the application of seven different treatments Table II.

It was found that treatment T_6 having combination of two semiochemicals exhibited the higher level of significance. Similarly treatment T_2 which consisted of only one semiochemical, also exhibited higher level of significance. The treatment with only turmeric exhibited significantly lowest level of emergence as compared to other treatments (T_1).

Analysis of variance of the data revealed significant differences among both aphid species, parasitoid and treatments applied. It exhibited a non significant effect of aphid species and treatments on the emergence of *D. rapae* (F=1.254, df=7, P<1). A highly significant effect of treatments on the emergence of *D. rapae* was found (F=16.329, df=7, P<0.001). A non-significant effect was found between aphid species and emergence of *D. rapae* (F=0.848, df=1, P<1).

Parasitism (%) of D. rapae *reared on aphids*

The comparison of means of *D. rapae* parasitism rate at 5% level of probability is shown in Table II. The *D. rapae* exhibited 56.2% parasitism rate in untreated controls when it was reared on *Si. avenae.* It was found that *D. rapae* exhibited minimum mean parasitism rate (28.8%) in T_4 and maximum mean parasitism (66.8%) after the application of T_6. The mean parasitism of *D. rapae* was found 30.4% and 35.6% after the application of T_1 and T_5, respectively. The *D. rapae* exhibited mean parasitism after the application of T_3 was 42.8%, which was statistically at par with T_7 (44.8%) followed by T_2 (54.4%), respectively. The overall parasitism of *D. rapae* ranged from 28.8-66.8% after the application of seven different treatments (Table II). It was found that treatment T_6 having combination of two semiochemicals exhibited the higher level of significance. The treatment with turmeric and *β*-pinene exhibited significantly low level of parasitism (T_4). The treatment with only turmeric exhibited significantly low level of parasitism as compared to other treatments (T_1).

The *D. rapae* exhibited 55.2% parasitism rate in untreated controls when it was reared on *R. padi.* It was found that *D. rapae* exhibited minimum mean parasitism rate (31.8%) in T_1 and maximum mean parasitism (64.8%) after the application of T_6. The *D. rapae* exhibited mean parasitism after the application of T_2 (56.8%), followed by T_4 (50.86%) and T_3 (46.2%), which was statistically similar to T_7 (43.2%), followed by T_5 (33.0%). The overall parasitism of *D. rapae* ranged from 31.8-64.8% after the application of seven different treatments (Table II). It was found that treatment T_6 having combination of two semiochemicals exhibited the higher level of significance. The treatment with turmeric and E*β*f significantly low level of parasitism (T_5). The treatment with only turmeric exhibited significantly lowest level of parasitism as compared to other treatments (T_1).

A non-significant effect was observed between aphid species and treatments on the parasitism rate of *D. rapae* (F=0.613, df=7, P<1). The treatments have highly significant effect on parasitism rate of *D. rapae* (F=82.961, df=7, P<0.001). The aphid species have non significant effect on parasitism rate of *D. rapae* (F=0.014, df=1 P<1).

The *D. rapae* exhibited 35.27% male proportion in untreated controls when it was reared on *S. avenae.* It was found that *D. rapae* exhibited minimum mean male emergence (35.18%) in T_1 and maximum male emerged (43.89%) after the application of T_4. The male population of *D. rapae* was found to be 35.25% after the application of T_2, which was statistically similar to T_6 (36.69%) which was statistically at par with T_5 (36.99%). It was found that mean male population of *D. rapae* after T_4 (43.89%) is statistically similar to T_3 (42.09%). The overall male emergence of *D. rapae* ranged from 75.63-90.67% after the application of seven different treatments (Table II). The treatment with turmeric and *β*-pinene exhibited significantly highest level of male emerged (T_4). The treatment with only turmeric exhibited significantly lowest level of emerged males as compared to other treatments (T_1).

A non-significant effect of aphid species and treatments was found on the sex ratio of *D. rapae* (F=1.568, df=7, P<1). Similarly, a non-significant effect of treatments on sex ratio of *D. rapae* was found (F=1.162, df=7, P<1). Both aphid species exhibited non significant effect on *D. rapae* (F=0.503, df=1, P<1).

Sex ratio of D. rapae *reared on* R. padi

The comparison of means of *D. rapae* sex ratio at 5% level of probability is shown in Table II. The *D. rapae* exhibited 45.96% male proportion in untreated controls when it was reared on *R. padi.* It was found that *D. rapae* exhibited minimum mean male emergence (34.22%) in T_2 and maximum male emerged (43.88%) after the application of T_6. The male population of *D. rapae* after the application of T_1 and T_5 was found similar to each

other (37.44%), which was statistically similar to T_4 (37.98%) which was statistically at par with T_3 (36.54%). It was found that mean male population of *D. rapae* after T_6 (43.88%) is statistically similar to T_7 (41.13%). The overall male emergence of *D. rapae* ranged from 34.22-43.88% after the application of seven different treatments (Table II).

The treatment T_4 having *β*-pinene alone exhibited significantly lowest level of male emerged. The treatment T_6 was the combination of two semiochemicals enhanced the total emergence of male parasitoids significantly as compared to other six treatments.

Tibia length of D. rapae *reared on* S. avenae

The *D. rapae* exhibited 0.52% tibia length in untreated controls when it was reared on *S. avenae*. It was found that *D. rapae* exhibited minimum mean tibia length (0.40%) in T_3 and maximum mean tibia length (0.55%) after the application of T_6. The mean tibia length of *D. rapae* was found to be 0.42% after the application of T_7, which was statistically similar to T_4 (0.43%), which was statistically at par with T_1 (0.46%). The mean tibia length of *D. rapae* after the application of T_2 (0.54%) was statistically similar to T_6 (0.55%). The overall tibia length of *D. rapae* ranged from 0.40% to 0.55% after the application of seven different treatments (Table II). The treatment T_6 which was the combination of two semiochemicals enhanced the tibia length of female parasitoids significantly compared to other six treatments. The tibia length of female parasitoids reduced significantly in E*β*f (T_3) compared to other six treatments.

The *D. rapae* exhibited 0.53% tibia length in untreated controls when it was reared on *R. padi*. It was found that *D. rapae* exhibited minimum mean tibia length (0.44%) in T_1 and maximum mean tibia length (0.54%) after the application of T_6. The mean tibia length of *D. rapae* was found to be 0.47% after the application of T_3 and T_5, which was statistically similar to T_4 (0.45%), which was statistically at par with T_6 (0.54%) followed by T_2 (0.52%). The overall tibia length of *D. rapae* ranged from 0.40-0.55% after the application of seven different treatments (Table II). It was found that treatment T_6 having combination of two semiochemicals exhibited higher level of significance. The treatment with turmeric exhibited significantly reduced tibia length (T_1, T_7) compared to other treatments.

A non-significant effect of aphid species and treatments was found on the tibia length of *D. rapae* (F=0.975, df=7, P<1). The treatments have highly significant effect on tibia length of *D. rapae* (F=15.82, df=7, P<0.001). The aphid species have non significant effect on parasitism rate of *D. rapae* (F=0.162, df=1 P<1).

Table III.- Adult longevity and adult weight of *Diaeretiella rapae* on *Sitobion avenae*.

Treatments	Means ± SEM			
	Adult longevity (days)		Adult weight (mg)	
	♂	♀	♂	♀
Sitobion avenae				
Control	8.80±0.58	14.6±0.51	0.15±0.01	0.23±0.01
T_1	5.40±0.40	9.80±0.49	0.12±0.01	0.20±0.01
T_2	8.20±0.58	13.0±0.89	0.18±0.01	0.25±0.01
T_3	9.40±0.68	12.0±0.71	0.16±0.01	0.24±0.01
T_4	6.0±0.45	11.0±0.71	0.11±0.01	0.23±0.01
T_5	6.0±0.45	11.0±0.71	0.15±0.01	0.26±0.01
T_6	9.8±0.58	16.2±0.37	0.18±0.01	0.20±0.01
T_7	7.40±0.51	11.4±0.51	0.20±0.01	0.32±0.01
Rhopalosiphum padi				
Control	9.2±0.37	13.2±0.86	0.17±0.01	0.24±0.01
T_1	6.2±0.37	9.6±0.40	0.12±0.01	0.22±0.01
T_2	8.4±0.51	11.8±0.97	0.17±0.01	0.27±0.01
T_3	9.8±0.58	14.6±0.51	0.13±0.01	0.27±0.01
T_4	6.0±0.32	10.4±0.51	0.12±0.01	0.24±0.01
T_5	5.8±0.37	10.4±0.68	0.16±0.01	0.27±0.01
T_6	9.4±0.68	14.4±0.51	0.18±0.01	0.29±0.01
T_7	7.2±0.58	12.0±0.84	0.19±0.01	0.30±0.01

For statistical detail and abbreviations, see Table II.

Adult weight of male D. rapae *reared on aphids*

The comparison of means of *D. rapae* adult weight at 5% level of probability is shown in Table III. The *D. rapae* exhibited 0.15% adult weight in untreated controls when it was reared on *S. avenae*. It was found that *D. rapae* exhibited minimum mean adult weight (0.11%) in T_4 and maximum mean adult weight (0.20%) after the application of T_7. It was found that mean adult weight of *D. rapae* after the application of T_2 and T_6 was similar to each other (0.18%), which was statistically similar to T_3 (0.16%) at par with T_5 (0.15%). The overall adult weight of *D. rapae* ranged from 0.11-0.20% after the application of seven different treatments (Table III).

The *D. rapae* exhibited 0.17% adult weight in untreated controls when it was reared on *R. padi*. It was found that *D. rapae* exhibited minimum mean adult weight (0.12%) in T_1 and T_4 and maximum mean adult weight (0.19%) after the application of T_7. It was found that mean adult weight of *D. rapae* after the application of T_3 (0.13%), which was statistically similar to T_5 (0.16%) at par with T_6 (0.18%). The overall adult weight of *D. rapae* ranged

from 0.12-0.19% after the application of seven different treatments (Table III). It was found that treatment T_7 having combination of two semiochemicals and turmeric exhibited the highest level of significance. The treatment with only turmeric (T_4, T_1) exhibited significantly lowest male weight compared to other treatments.

Adult weight of female D. rapae *on aphids*

The comparison of means of *D. rapae* adult weight at 5% level of probability is shown in Table III. The *D. rapae* exhibited 0.23% adult weight in untreated controls when it was reared on *S. avenae*. It was found that *D. rapae* exhibited minimum mean adult weight (0.20%) in T_4 and T_6 and maximum mean adult weight (0.32%) after the application of T_7. It was found that mean adult weight of *D. rapae* after the application of T_4 was 0.23%, which was statistically similar to T_3 (0.24%) and T_2 (0.25%), which statistically was at par with T_5 (0.26%). The overall adult weight of *D. rapae* ranged from 0.20-0.32% after the application of seven different treatments (Table III).

The *D. rapae* exhibited 0.24% adult weight in untreated controls when it was reared on *R. padi*. It was found that *D. rapae* exhibited minimum mean adult weight (0.22%) in T_4 and maximum mean adult weight (0.30%) after the application of T_7. The mean adult weight of *D. rapae* after the application of T_2, T_3 and T_5 was similar to each other (0.27%). It was found that mean adult weight of *D. rapae* after the application of T_6 was 0.29%, followed by T_4 (0.24%). The overall adult weight of *D. rapae* ranged from 0.22% to 0.30% after the application of seven different treatments (Table III). It was found that treatment T_7 having combination of two semiochemicals and turmeric exhibited the highest level of significance. The treatment with only turmeric (T_1) exhibited significantly lowest female weight compared to other treatments.

A non significant effect of aphid species and treatments on the adult weight of *D. rapae* was exhibited (F=0.153, df=7, P<1). A highly significant effect of treatments on adult weight of *D. rapae* was found (F=5.398, df=7, P<0.001). A non-significant effect was found between aphid species and adult weight of *D. rapae* (F=0.188, df=1, P<1).

Adult longevity of male D. rapae *reared on aphids*

The comparison of means of adult *D. rapae* longevity at 5% level of probability is shown in Table III. The *D. rapae* exhibited 8.80% adult longevity in untreated controls when it was reared on *S. avenae*. It was found that *D. rapae* exhibited minimum mean adult longevity (5.40%) in T_1 and maximum mean adult longevity (9.8%) after the application of T_6. It was found that mean adult longevity of *D. rapae* after the application of T_4 and T_5 was similar to each other (0.6%). The mean adult longevity of *D. rapae* after the application of T_6 was 9.8%, which was statistically similar to T_3 (9.40%), which was statistically at par with T_2 (8.20%). The overall adult longevity of *D. rapae* ranged from 5.40-9.8% after the application of seven different treatments (Table III). It was found that treatment with Eβf alone and Eβf with β-pinene (T_3, T_6) have highest longevity of male parasitoids compared to other treatments. The treatment with only turmeric exhibited significantly lowest level of male longevity compared to other treatments (T_1).

A non significant effect of aphid species and treatments on the adult longevity of *D. rapae* was exhibited (F=0.228, df=7, P<1). A highly significant effect of treatments on adult longevity of *D. rapae* was found (F=8.059, df=7, P<0.001). A non-significant effect was found between aphid species and adult longevity of *D. rapae* (F=0.001, df=1, P<1).

The *D. rapae* exhibited 9.2% adult longevity in untreated controls when it was reared on *R. padi*. It was found that *D. rapae* exhibited minimum mean adult longevity (5.8%) in T_5 and maximum mean adult longevity (9.8%) after the application of T_3. It was found that mean adult longevity of *D. rapae* after the application of T_3 (9.8%) was statistically similar to T_6 (9.4%), which was followed by T_2 (8.4%), which was statistically at par with T_7 (7.2%). The overall adult longevity of *D. rapae* ranged from 5.8-9.8% after the application of seven different treatments (Table III). It was found that treatment with Eβf alone and Eβf with β-pinene (T_3,T_6) have highest longevity of male parasitoids as compared to other treatments. The treatment with only turmeric, turmeric with β-pinene exhibited significantly lowest level of male longevity as compared to other treatments (T_4, T_1).

Adult longevity of female D. rapae *reared on aphids*

The comparison of means of adult *D. rapae* longevity at 5% level of probability is shown in Table III. The *D. rapae* exhibited 14.6% adult longevity in untreated controls when it was reared on *S. avenae*. It was found that *D. rapae* exhibited minimum mean adult longevity (9.80%) in T_1 and maximum mean adult longevity (16.2%) after the application of T_6. It was found that mean adult longevity of *D. rapae* after the application of T_4 and T_5 was similar to each other (11.0%), which was statistically at par with T_7 (11.0%). The mean adult longevity of *D. rapae* after the application of T_2 was 13.0%, which was statistically similar to T_3 (12.0%). The overall adult longevity of *D. rapae* ranged from 9.80-16.2% after the application of seven different treatments (Table III). It was found that treatment T_6 having combination of two semiochemicals exhibited the higher level of significance. The treatment

with only turmeric exhibited significantly lowest level of female longevity as compared to other treatments (T_1).

The *D. rapae* exhibited 13.2% adult longevity in untreated controls when it was reared on *R. padi*. It was found that *D. rapae* exhibited minimum mean adult longevity (9.6%) in T_1 and maximum mean adult longevity (14.6%) after the application of T_3. It was found that mean adult longevity of *D. rapae* after the application of T_4 and T_5 was similar to each other (10.4%), which was statistically similar to T_2 (11.8%), which was statistically at par with T_7 (12.0%). The overall adult longevity of *D. rapae* ranged from 9.6-14.6% after the application of seven different treatments (Table III). The treatment with only turmeric exhibited significantly lowest level of female longevity compared to other treatments (T_1). It was found that treatment having Eβf alone and combination of two semiochemicals (T_3,T_6) exhibited the highest level of significance.

Gowling and van Emden (1994) observed the variation in parasitism rate of *B. brassicae* by *D. rapae* in various cultivars in the field experiments. Bayhan *et al*. (2007) reported the highest level of parasitism of *B. brassicae* in cabbage (40.20%), and the lowest level of parasitism in turnip (32.64%). Mölck *et al*. (2000) found that plant volatiles facilitate or enhance parasitoid foraging efficiency to respond towards these odors. Fernandez and Nentwig (1997) found that development time, fecundity, sex ratio, longevity, parasitization rate and size of *A. colemani* are significantly affected by nutritional value of host plant.

Insect parasitoids need suitable hosts to reproduce. Parasitoids use cues that indicate the presence of their hosts (Blande *et al*., 2007). Successful host foraging behavior by insect parasitoids includes host-habitat location, host location, host acceptance, host suitability, and host regulation provided by olfactory cues (Vinson, 1985).

It was found that *D. rapae* takes 9 to 15 days to complete its life cycle in laboratory. Adult female longevity was 10-15 days, while male can live for 7-10 days (Reed *et al*., 1992). Females live significantly longer than males (Bayhan *et al*., 2007). Bernal and Gonzales (1997) found that the longevity of female *D. rapae* was 11.5 days at 21.1°C on *Diuraphis noxia*.

CONCLUSION

This study suggested that long term studies on the effect of semiochemicals and plant extracts towards pests and natural enemies are required before recommending their use as pesticide. In this way, we can conserve natural enemies and manage the aphid pests.

Statement of conflict of interest

Authors have declared no conflict of interest.

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