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Attractiveness and Effects of some Flowering Plants on the Longevity and Foraging Behavior of Certain Predatory Insects

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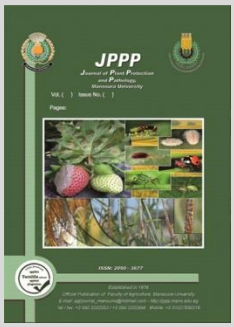

ABSTRACT

The reaction of the insect predators, *Eupeodes corollae* Fabr (Diptera, Syrphidae), *Coccinella undecimpunctata* L. and *Hippodamia tredecimpunctata* L. (Coleoptera, Coccinellidae) and *Chrysoperla carnea* (Steph.) (Neuroptera, Chrysopidae) was compared in response to odor and color of five flowers (Marigold, *Calendula officinalis*; Chamomile, *Matricaria chamomilla*; Fennel, *Foeniculum vulgare* Miller; Caraway, *Carum carvi* L and Marguerite, *Chysanthemum coronarium* L.) under laboratory conditions. The experimental tube indicated that the tested predators exhibited different degrees of attractiveness in response to flower colors and nectars of the tested plants. The nectar plant species of Chamomile and Fennel were significantly more attracted to *E. corollae* and *Ch. carnea* as compared to other tested species. *C. undecimpunctata* and *H. tredecimpunctata* exhibited the highest attractiveness to Marigold and Chamomile nectars. All predators exhibited the lowest preferability toward Marguerite and Caraway nectars. Preferability experiments illustrated that all tested predators exhibited the highest preferability to yellow flower colors (Fennel, Marigold and Chamomile) followed by white colors (Caraway). The present study evaluates the role of *C. officinalis*; *M. chamomilla*; and *Chy. Coronarium* flowers as supplemental food on the longevity and foraging behavior of the coccinellid predators, *C. undecimpunctata* and *H. tredecimpunctata* adult females. Flowers increased survival and searching rate in *C. undecimpunctata* and *H. tredecimpunctata* in comparison with prey diet-only treatments. This suggests that the availability of flowers of Marigold and Chamomile as supplemental foods (pollen and nectar) in the field can serve to improve efficacy of coccinellid predators under conditions of prey limitation.

Keywords: Flowering plants, Searching rate, *Hippodamia tredecimpunctata*, *Eupeodes corollae*, *Coccinella undecimpunctata*., *Chrysoperla carnea*

INTRODUCTION

Introducing flowering plants into agricultural systems to increase nectar and pollen resources required by some natural enemies of insect pests is a form of conservation biological control (Poveda *et al*., 2008 and Gurr and You, 2016). Supply of a non-prey food such as pollen is very important and beneficial for the use of natural enemies in agricultural systems (Ambrosino *et al*., 2006; Rebek *et al*., 2006; Abd El-Kareim *et al*., 2007; Fiedler *et al*., 2008; Marouf, 2011 and Lu *et al*., 2014).

Flowering plants offer suitable food for adult natural enemies, an alternative prey organism (non-prey food), and shelter from adverse conditions (Pfiffner and Wyss, 2004), and can increase natural enemies' longevity, fecundity, and predation, which in turn can enhance the effectiveness of natural enemies as biocontrol agents (Lee and Heimpel, 2008: Fiedler *et al*., 2008; Haaland *et al*., 2011; Russell, 2015; van Rijn and Wäckers, 2016 and He and Sigsgaard 2019). According to van Rijn *et al.* (2006) to provide effective natural enemies with suitable food, providing floral species must be attractive to these natural enemies. According to Lu *et al.* (2014) more research is still required to identify which plants have the greatest potential as beneficial insectary plants. The predators, *Eupeodes corolla* (F.) (Abdel-kareim *et al*., 2011), *Chrysoperla carnea* (Khuhro *et al*., 2012) and the coccinellids, *Coccinella undecimpunctata* L & *Hippodamia tredecimpunctata* L. (Turnock and Wise, 2004; Cabral *et al*., 2006; Al-Deghairi *et al*., 2014; Salman *et al*., 2014; and Khalifa and Mesbah, 2019) approved to be the main mortality factor on piercing-sucking insect pests. So, the present study aims to the reaction of the insect predators (*E. corollae*, *C. undecimpunctata*, *Ch. carnea*, and *H. tredecimpunctata* was compared in response to odor and color of the tested flowers (Marigold, Chamomile, Fennel, Caraway and Marguerite) and to determine the effect of selected flowers on longevity and foraging behavior parameters related to *C. undecimpunctata* and *H. tredecimpunctata* adults.

MATERIALS AND METHODS

1. The reactions of some predatory insects in response to floral color and nectars:

The reactions of the insect predators (*Eupeodes corollae*, *Coccinella undecimpunctata*, *Chrysoperla carnea*, and *Hippodamia tredecimpunctata tibialis* were observed in response to odor and color of the tested flowers (Marigold, Chamomile, Fennel, Caraway and Marguerite under laboratory conditions.

Insect and plant sources:

The tested insect predators (*E. corollae*, *Ch. carnea*, *C. undecimpunctata* and *H. tredecimpunctata* were collected from the Experimental Farm, Faculty of Agriculture, Mansoura University and kept in laboratory for bioassay. Newly emerged flowers of each tested host plant, Marigold, Chamomile, Fennel, Caraway and Marguerite were collected from the Experimental Farm.

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Reaction of the insect predators in response to flower nectar:

The response of the tested predators (adults of *E. corollae*, *C. undecimpunctata*, *Chry. carnea* and *H. tredecimpunctata*) to floral nectar of Marigold, Chamomile, Fennel, Caraway and Marguerite were evaluated using an experimental Y-tube. (Abd El-Kareim *et al.*, 2007). The experimental Y-tube consists of three dark cylinder arms (3.5 cm diameter x 15 cm highest) attached with an exposure plastic cylinder chamber (6.0 cm in diameter x 5.0 cm height). Each tube (arm) was closed by black plastic cover. The internal wall of each cover was plated by Tangle foot as a sticky material. The predators were introduced inside the exposure chamber which was closed immediately. Flowers of each tested host plant were offered in one odor arm to test predators, while the other two arms of the Y-tube were odorless (control). Flowers of tested plants were immersed in glass tube of water through a pore in the plastic tube cover. Every treatment was repeated five times using five individuals of each species/time for each floral host plant. Counts were done 15 min after exposure of adult.

Reaction of the insect predators in response to flower color:

Choice test was carried out to assess the preferability of the tested natural enemies by using transparent experiment tube with five arms. The experimental tube consists of five transparent arms (2 cm diameter and 5 cm height) attached with an exposure cylinder chamber. Flowers of the five tested host plants were stacked outside the bottom of the five arms (one arm/ flower).

Each experiment was repeated five times by using five predators/ time. The tested predator adults were placed at the center of the exposure chamber. Individual which was introduced inside transparent arms (throughout 15 min.) was registered as positive. The number of each species entering each arm was counted and the percentage of attractiveness was calculated.

2. Influence of plant flowers on the mean longevity of ladybeetle adults.

No choice experiments were conducted in the laboratory to estimate the influence of the tested flowers on the mean longevity of *C. undecimpunctata* and *Hippodamia tredecimpunctata.* aduts against *Myzus persica*e. The flowers and newly infested cowpea seedlings with *M. persicae* insects were enclosed in a cylindrical cage (30 cm high and 15 cm in diameter). The Cages consisted of an acetate sheet with fine mesh on the top and foam on the bottom. The treatments consisted of Marigold and Chamomile. Flowers were inserted into water-filled tubes with cotton plugs around the floral stem. In prey diet-only treatment, infested cowpea seedlings with *M. persicae* without flowers were placed inside the cages. Cowpea seedlings and flower shoots were changed every two days. Ten female predators were checked daily to assess longevity and recorded. Statistical analysis was done by using one-way ANOVA and mean comparison were carried out using L.S.D. at 5%.

3. Influence of plant flowers on foraging behavior.

The foraging behavior (searching rate and mutual interference) of the predator females fed on forbs (Marigold, Chamomile and Marguerite flowers) or no forbs (water only) was estimated on cowpea seedlings infested with *M. persica*. Newly emerged predator of *C. undecimpunctata* and *H. tredecimpunctata* adult females from every species were supplied with: Marigold flowers, Chamomile flowers and Marguerite flowers for three days. The searching rates of the two predators feed on different food sources were compared. Five densities consist of 1, 3, 5 and 7 females of each predator species, respectively, were examined by confining 50 aphid individuals on cowpea seedlings with each density in a glass lamp chimney. The top of the chimney was covered with fine-mesh screen. The predator females were left in the chimney for 48 hrs. with their prey. Each predator density was replicated five times. After the removal of the predator females, predates preys were counted and recorded. The search rate (at), and mutual interference (m) values were calculated according to Varley *et al.* (1978).

RESULTS AND DISCUSSION

Results

1. Reaction of predatory insects in response to floral source:

The reactions of the insect predators (*Eupeodes corollae*, *Coccinella undecimpunctata*, *Chrysoperla carnea*, and *Hippodamia tredecimpunctata* were observed in response to odor and color of the tested flowers (Marigold, Chamomile, Fennel, Caraway and Marguerite).

In response to flower odor.

As seen in Table (1), the experimental tube indicated that the tested predators exhibited different degrees of attractiveness in response to flower odor of the tested plants. The nectar plant species of Fennel and Chamomile were significantly more attracted to *Ch. carnea* and *E. corollae* as compared to the other tested plant species. The percentages of responses were (90 ± 7.1 & 80 ± 10.0), (84 ± 5.5 & 88 ± 8.4) with no significant difference for Fennel and chamomile respectively. Marguerite and caraway were significantly less attractive to *Ch. carnea* and *E. corollae* (52 ± 8.4 & 50 ± 7.1 and 56±8.9 & 50 ± 7.1). Both predators exhibited significantly low response to Marguerite and caraway. *Ch. carnea* and *E. corollae* showed intermediate response to Marigold with a total percentage of attractiveness (70 ± 7.1 and 62 ± 8.4 %), respectively. Meanwhile, *C. undecimpunctata* adult females exhibited the highest attractiveness toward Marigold (84 ± 16.7) followed by *H. tredecimpunctata* toward Chamomile flowers (80 ± 7.1). Caraway nectar was significantly less attractive to both coccinellid predators.

Table 1. Percentage of attracted insect predators (*Eupeodes corollae, Chrysoperla carnea, Coccinella undecimpunctata* and *Hippodamia tredecimpunctata*) to different flower odors of tested plants (Fennel, Chamomile, Marigold, Marguerite and Caraway).

Insect predators	Host plants					
	Fennel	Chamommile	Marigold	Marguerite	Caraway	L.S.D. (p= 5%)
Eupeodes corollae	80 ± 10.0 a	88 ± 8.4 a	62 ± 8.4 b	50 ± 7.1 c	50 ± 7.1 c	10.88
Chrysoperla carnea	90 ± 7.1 a	84 ± 5.5 a	70 ± 7.1 b	52 ± 8.4 c	56 ± 8.9 c	9.87
Coccinella undecimpunctata	62 ± 8.4 bc	72 ± 8.4 ab	84 ±16.7 a	52 ± 8.4 cd	46 ± 8.9 d	14.08
Hippodamia tredecimpunctata	66 ± 5.5 b	80 ± 7.1 a	78 ± 8.4 a	64 ± 5.5 bc	54 ±11.4 c	10.39

In response to flower colors.

A comparison was also made of the preference when given a choice between flower colors of the tested plants. As shown in Table (2), *E. corollae* and *Ch. carnea* exhibited the highest preferability to Marigold (30 ± 7.1). While, C. *undecimpunctata* showed the highest response to Fennel (42

+ 8.4). On the contrary, *H. tredecimpunctata* exhibited similar response to all tested host plant flowers. Preferability experiments illustrated that *E. corollae*, *Ch. carnea* and C. *undecimpunctata* exhibited the highest preferability to yellow flower colors followed by white colors. The tested aphidophagous predators showed the lowest preferability toward caraway flower colors (rose and pink colors) when selecting between flower colors (Table, 2).

Table 2. Percentage of attracted insect predators (*Eupeodes corollae, Chrysoperla carnea, Coccinella undecimpunctata,* and *Hippodamia tredecimpunctata*) to different flower colors of tested plants (Fennel, Chamomile, Marigold, Chrysanthemum and Caraway).

Insect predators	Host plants					
	Fennel	Chamommile	Marigold	Marguerite	Caraway	L.S.D. (p = 5%)
Eupeodes corollae	16 ± 5.5 b	22 ± 4.5 b	30 ± 7.1 a	20 ± 7.1 b	12 ± 4.5 b	7.69
Chrysoperla carnea	26 ± 8.9 ab	20 ± 7.1 ab	30 ± 7.1 a	16 ± 8.9 bc	8 ± 4.5 c	9.87
Coccinella undecimpunctata	42 + 8.4 a	26 + 5.5 b	18 + 8.4 b	8 + 4.5 c	6 + 5.5 c	8.75
H. tredecimpunctata	16 ± 5.5 a	26 ± 11.4 a	22 ± 8.4 a	26 ± 8.9 a	12 ± 8.4 a	11.5

2. Effect of food sources on mean longevity of *C.undeciumpunctata* and *H. tredecimpunctata* adult female.

The prey with flower treatments resulted in the longest longevity of both females of the both coccinellid species and was significantly longer than prey only treatments (Table, 3). However, survival on Marigold and Chamomile treatments for both species was significantly greater than on prey only treatment. The mean longevity for *C. undecimpunctata* and *H. tredecimpunctata* feeding on Marigold and Chamomile flowers were (56.0 ± 5.8 and 51.1 ± 4.0 days) and (52.3 ± 4.3 and 49.5± 5.6 days), respectively. Meanwhile the mean longevity of individuals fed on prey only was 46.4 ±3.4 and 44.1 ± 3.9 days for *C. undecimpunctata* and *H. tredecimpunctata*, respectively. So, it could be concluded that marigold and chamomile approved to be beneficial insectary plants for *C. undecimpunctata* and *H. tredecimpunctata.*

Table 3. Mean longevity (day) of *Coccinella undecimpunctata* and *Hippodamia tredecimpunctata* adult females with different food resources.

Treatments	H. tredecimpunctata	C. undecimpunctata
Aphid+marigold flower	51.1 ± 4.0 a	56.0 ± 5.8 a
Aphid+chamomile flower	49.5± 5.6 a	52.3 ± 4.3 a
Aphid only	44.1 ± 3.9 b	46.4 ±3.4 b
L. S. D. (P = 5 %)	4.23	4.21

3. Influence of plant flowers on the searching behavior of the coccinellid predators.

The relation between, food sources and the searching behavior of the lady beetles (*C. undecimpunctata*, and *H. tredecimpunctata*) were evaluated under laboratory conditions. The foraging behavior (searching rate and mutual interference) of the predator females fed on forbs (Marigold, Chamomile and Marguerite flowers) or no forbs (water only) was estimated on gardenia seedlings infested with *M. persicae. H. tredecimpunctata* and *C. undecimpunctata*, females fed on Marigold flowers exhibited the high searching rate (0.366 and 0.321) followed by Chamomile and Marguerite, respectively (Table 4, Fig 1). The lowest mutual interference value was recorded for *H. tredecimpunctata* (0.120) and *C. undecimpunctata* (0. 171) females when fed on Marigold and Chamomile, respectively.

Table 4. Searching rate (at) and mutual interference (m) of *Coccinella undecimpunctata*, and *Hippodamia tredecimpunctata* females fed on different food.

Treatment	H. tredecimpunctata		C. undecimpunctata	
	a_t	m	a_t	M
Marigold	0.366	0.120	0.321	0.185
Chamomile	0.341	0.136	0.297	0.171
Marguerite	0.306	0.134	0.284	0.220
Water (control)	0.290	0.143	0.280	0.236

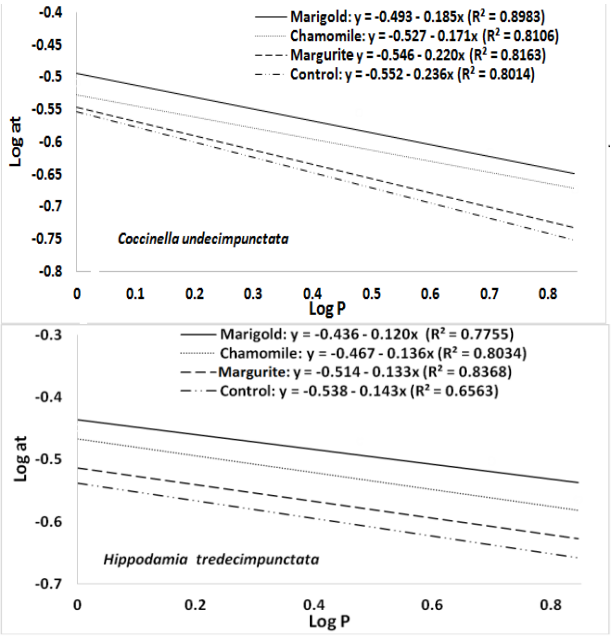

Fig. 1. The relation between predator density (log P) and searching rate (log a_t) of *Coccinella undecimpunctata*, and *Hippodamia tredecimpunctata* females under laboratory conditions.

Discussion

The results obtained showed that the tested aphidophagous species (*Eupeodes corollae*, *Chrysoperla carnea*, *Coccinella undecimpunctata*, and *Hippodamia tredecimpunctata*) varied in their innate response to nectars based on odors and flower colors. Attraction to as host plant from a distance often appears to involve both olfactory and visual elements of behavior (Wäckers, 2005). Aphidophagous predators, *E. corolla* and *Chry. Carnae*, exhibited a relatively higher preference for Chamomile nectar flowers followed by Fennel. According to Colley and Luna (2000), hoverflies (Syrphidae) are selective in their flower feeding and exhibited the highest response to Fennel. Lunau and Wacht (1994) indicated that feeding behavior is stimulated in the laboratory by yellow color. Fennel was attractive and has yellow flowers (Colley and Luna, 2000). In the current study, Chamomile and Fennel also, have yellow and white colors were exhibited attractiveness to *E. corollae* and *Chry. carnae*.

Attraction to as host plant from a distance often appears to involve both olfactory and visual elements of behavior (Wackers, 2005). The factory signal is the indicator of an appropriate host, causing the insect to take off and more towards the source of the odor. But the olfactory system will rarely act alone; a response to odor will be combined with a

visual response. It is probably true that color is important in the final stage of attraction of many days. Many insects have an innate visual preference for yellow (Wäckers, 1994 and Jönsson *et al*.,2005), when combined with flower odors from oilseed rape, *Brassica napus*, the attraction was even more pronounced for *T. heterocerus*, a species preferring older larvae occurring in flowering rape. Fennel, coriander, buckwheat and alyssum were all attractive and have white or yellow flowers (Colley and Luna, 2000).

The present results indicated that the searching rate of tested predators was decreased as the predator density increased. Similar conclusion was obtained by Abd El-Kareim (1998) and El-Batran (2003). The obtained results revealed that the searching rate and mutual interference value of eleven-spotted and thirteen- spotted ladybirds were affected by the prey and host plant flowers. Similar convolution was obtained by Abd El-Kareim *et al*. (2019) that the foraging behavior (searching rate and mutual interference values) of the parasitoids was affected according to supplemental food sources (sweet basil and geranium flowers). He and Sigsgaard (2019) demonstrated that the suitability of each food source was different for the ladybird beetles. The coccinellid, *C. undecimpunctata*, and *H. tredecimpunctata* showed different searching behavior to the prey, *M. persicae* with different flower species. Also, the efficiency of the coccinellid predators (*R. cardinalis and C. bipustulatus*) was affected by host plant species (Abd El-Kareim, 2002 and Abdel-Mageed, 2005). Also, the searching characteristics (searching rate and interference value) of the predators (*C. bipustulatus*, *E. flavipes* and *C. undecimpunctata*) were affected by host plant species (Abd El-Kareim ,2002)

The mixed diet of flowers and prey treatments resulted in the longest longevity of both female of the Coccinellid species and was significantly longer than prey-only treatments. Survival on marigold and chamomile treatments for both species was significantly greater than on prey only treatment. Similar results were obtained by He and Sigsgaard, (2019) indicated that *Adalia bipunctata* adult longevity on flower diets of different species varied greatly. Floral nectar is mainly composed of carbohydrates, amino acids, proteins, lipids, vitamins and secondary plant metabolites (Wäckers, 2005). The composition determines the nutritional suitability (Hausmann, *et al*., 2005; Vattala *et al*., 2006), feeding stimulation (Romeis and Wäckers, 2000). Pollen is primarily a source of amino acids and proteins, with protein levels ranging from 2.5 to 61% (Wäckers, 2005). According to Schoonhoven *et al*., 2005; Hogg *et al*., (2011); van Rijn and Wäckers, (2016) the accessibility and quality of the nectar and pollen are important factors that affect the relative preference of natural enemies for specific plant species. Natural enemies usually require a carbohydrate energy source during their adult stage, such as floral nectar, to increase longevity (He and Sigsgaard, 2019), and motivation to seek hosts (Wäckers, 1994; Winkler *et al*., 2006). Consequently, provision of nectar plants in the agroecosystems can increase the effectiveness of biological control programs. (Wäckers and Steppuhn, 2003; Wäckers, 2005). The present data emphasize the importance of non-prey foods for C. *undecimpunctata* and *H. tredecimpunctata* in agroecosystems when prey populations are low. So, it could be concluded that flowering plants, marigold and chamomile may be more suitable as beneficial insectary plants for C. *undecimpunctata* and *H. tredecimpunctata*.

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جاذبية وتأثير بعض النباتات الزهرية على فترة البقاء والسلوك البحثى لبعض المفترسات

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تم تقييم الاستجابة السلوكية لبعض المفترسات الحشرية (ذبابة السرفس وأبو العيد 11 نقطة وأبو العيد 13 نقطة وأسد المنّ الأخضر) تجاه رائحة ولون 5 أنواع من الأزهار هي Marigold, Chamomile, Fennel, Caraway, Marguerite وذلك تحت الظروف المعملية. أبدت المفترسات الخمسة المختبرة درجات مختلفة من الانجذاب تجاه رائحة ولون الازهار المختبرة; حيث أبدت ذبابة السرفس وأسد المنّ الأخضر أعلى نسبة انجذاب لرائحة كلا من Chamomile, Fennel ، كما وجد أن أبو العيد 11 نقطة وأبو العيد 13 نقطة كانت أكثر المفترسات انجذابا لرائحة كلا من Marigold, Chamomile. واظهرت كل المفترسات استجابة ضعيفة تجاه روائح Marguerite, Caraway كما اتضح من خلال تلك الدراسة أن كل المفترسات فضلت الأزهار ذات اللون الأصفر (Fennel, Marigold) يليها الأزهار ذات اللون الأبيض (Caraway). كذلك تم دراسة دور التغذية على أزهار نباتات Marigold, Chamomile, Marguerite وتأثيرها على مدى بقاء ومعدل الكفاءة البحثية لكلا من اناث مفترسي أبو العيد 11 نقطة وأبو العيد 13 نقطة اظهرت الدراسة ان التغذية على الازهار كغذاء اضافى تزيد من فترة البقاء والكفاءة البحثية لكلا من المفترسين وذلك بالمقارنة بالتغذية على حشرات المنّ فقط.