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The Impact of the Host Plant on the Functional Response Parameters of *Diaeretiella rapae* (Maclntosh) to Different Densities of *Myzus persicae* (Sulzer) (Homoptera: Aphididae).

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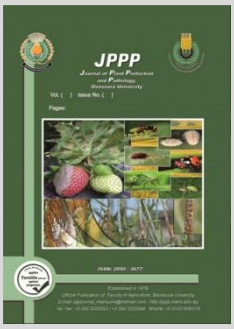

ABSTRACT

The functional responses of *Diaeretiella rapae* (Maclntosh) across various host densities of the 2nd instar nymphs of *Myzus persicae* (Sulzer) were evaluated on three host plants (cowpea, cucumber, and tomato). Experimental results exhibited that the parasitiod attack significantly more individuals of *M. persicae* on cowpea than other host plants. The percentage of hosts subjected to parasitism by *D. rapae* decreased as the density of the hosts increased. The functional response of *D. rapae* on the 2nd instar nymph of *M. persicae* corresponded to a type II model on all host plants. The specific type of functional response for *D.rapae* did not alter with changing host plants. The attack rate (a) and handling time (Th) coefficients varied across different host plants. The values obtained for attack rates and handling time differ depending on the type of plant host. *D. rapae* showed the lowest instantaneous attack rate and the longest handling time on cucumber. Estimated attacking rate values(a) for *D. rapae* against *M. persicae* were 0.259, 0.312 and 0.456 on cucumber, cowpea, and tomato, respectively. The shortest handling time was found for cowpea (0.624 h), followed by that for tomato (0.7104) and cucumber (0.7152 h). In all examined host plants, *D. rapae* exhibited an inverse density-dependent mortality pattern as host density increase. This finding may be regarded as a promising biological control agent for the management of *M. persicae*. Therefore, introducing parasitoids at the onset of the growing season when host populations are low could enhance the effectiveness of pest management strategies.

Keywords: Host plant, functional response, *Diaeretiella rapae, Myzus persicae.*

INTRODUCTION

The green peach aphid, *Myzus persicae* (Sulzer) is amongst the most frequently observed aphid species infesting vegetable crops, including tomato (*Solanum lycopersicum,* Solanaceae) (Civolani, et. al, 2010; Saljoqi, et al; 2019, Imam and Nawar,2020), cucumber (*Cucumis sativus* L., Cucurbitaceae) (Hegab*,* 2017, Singh and Kaur, 2020 and El-Damer et al. 2024) and cowpea, *Vigna unguiculata* (Fabaceae) (Ladipo, et al., 2005 and Abd El-Kareim, et al., 2017; Saleh et al. 2022) plants. It directly damages the plant by depleting its nutrients from the plants and injecting gelling and watery saliva. This saliva aids in the breakdown of plant tissues, which also contributes to the modulation of the host plant's defense mechanisms (Will et al., 2007). In addition, it can transmit more than 150 viral diseases in different host plants (Cloyd and Sadof, 1998, Saljoqi, et al.,2019 and Singh and Kaur, 2020).

M. persicae exhibits significant genetic diversity in its interactions with host plants, as well as in its strategies for resisting insecticides (Blackman and Eastop, 2007; Davis and Radcliffe, 2008 and Ali, et al.,2023). It has the ability to quickly adapt to insecticides and develop resistance to various active ingredients (Machial, 2010). In recent years, there has been a trend to reduce the use of chemicals in plant protection strategies. Biocontrol agents, such as parasitoids, have been associated with aphids from all over the world. One of these is the endoparasitoid, *Diaeretiella rapae* (McIntosh) (Hymenoptera, Braconidae), which parasitizes several aphid species in natural field environments. (Freuler et al., 2003; Blande et al, 2004; Ferreira, et al., 2018; Soni and Kumar 2020 and Soni et al. 2021).

The examination of behavioral characteristics, specifically handling time and attack rate, serves as crucial indicators for understanding the behaviors of natural enemies (Kumar et al., 2020). By analyzing the results of functional response studies, it becomes possible to identify potential candidates for biological control (van Lenteren et al., 2016). Functional response parameters (attacking rate and handling time) are key characteristics of natural enemies that must be considered are analyses in species on different host plants with the capability to serve as agents for biological control. Therefore, a comprehensive study was conducted to assess the functional response parameters (i.e., attack rate and handling time) to determine whether *D. rapae* could be an effective biological agent for *M. persicae*, which infests specific vegetable crops (cowpea, tomato, and cucumber).

MATERIALS AND METHODS

Aphid and parasitoid cultures

The green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae) was collected from the cowpea

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field cultivated in Nubariya, El- Beheira Governorate, Egypt. Cowpea area was cultivated with Kareem 7 at the second week of May during 2022 season. All regular agricultural practices were normally conducted except no insecticides were applied. The parasitoid species *Diaeretiella rapae* (Hymenoptera: Braconidae), utilized in this research, was gathered from mummified aphids (*Aphis craccivora*) in the previously mentioned cowpea field. Leaves that were significantly infested with *A. craccivora* were placed in glass tubes sealed with muslin, secured by rubber bands, until the adult parasitoids emerged. Identification of parasitoids emerged from mummies was done by Prof. Dr. Ahmed Samir Hendawi, Prof. of Economic Entomology, Plant Protection Institute, Ministry of Agriculture, Egypt. The emerged parasitoids were sexed under a stereoscopic microscope according to antennal colour and flagellum segments (Gazmer et.al 2015, and Rakhshani, et al 2015).

Three plant hosts namely, cowpea, *Vigna unguiculata* (Fabaceae), tomato, *Solanum lycopersicum* (Solanaceae) and Cucumber, *Cucumus sativus* L. (Cucurbitaceae) planted into pots (15 cm diameter, 20 cm high). These plant hosts functioned as an aphid host to assess their impact on the searching behaviour of the parasitoid, *D. rapae* as biological agent targeting *M. persicae*. Three colonies of aphid and its parasitoid were reared on cowpea, tomato, and cucumber plants in laboratory for one generation before using in the experiments. Once parasitoids emerged, each newly emerged wasps (one male and one female) were placed in a separate glass tube for a day to allow mating with 20% honey for parasitoid feeding before using in experiments.

Functional Response Experiments:

Twenty pots (one seedling/pot) of each tested host plants free of aphid infestation were grown under laboratory conditions. Three fully expanded leaves were chosen from each plant for functional response experiments. Once *M. persicae* reached to the second instar nymphs, were transferred on leaves of each plant seedling into a clip cage (Huang, et al ,2021) attached to one leaf. The cages were placed on plant leaves over patches containing the varying densities of *M. persice*. A drop 20% of honey was placed on the leaf section covered by each clip cage for parasitoid feeding. The behavioural response of *D.rapae* at different levels of density of *M. persice*, (15, 25, 35, 45 and 55 second instar nymphs) was evaluated on each host plant species. Each nymphal density was contained in one clip-cage (4.5 cm dia.) attached to one full expanding leaf (Huang, L. et al, 2021). For each density, there were twelve clip-cages (as replicates) were utilized for each host plant (three clip-cages on each plant). Prior to commencing the functional response experiments, it was established that *D. rapae* exhibited a preference for 2nd instar nymphs of *M. persice* (Soni and Kumar, 2021). Therefore, once *M. persicae* reached to the second instar nymphs in the colonies maintained at laboratory were transferred on leaves of each plant into clip cage in the functional response experiments. For every level of host population density, a pair of newly emerged male and female parasitoids (<48 h old) was introduced into the experimental clip-cage. A drop of 20 % honey was placed on the leaf section covered by each clip cage for parasitoid feeding. After 24 h, the clip cages were removed, and the parasitoids were recorded as being alive, dead, or missing. Incidence of parasitism for *D. rapae* was evaluated within 7–8 days. In addition, nymphs that were not parasitized were flipped over to examine for any remaining eggs or parasitoid eggs that have not yet hatched indicating unsuccessful parasitism. The number of parasitized aphids (Na) at each host density (N_0) was recorded.

Data analysis

Data analysis for studying the impact of host plant on functional response of *D. rapae* to *M. persicae* nymphs requires identifying the category of functional response. To ascertain this, a logistic regression model is performed between the available host density (N_0) and the proportion of host parasitized (Na/N0) as described by Juliano (2001). Consequently, the data were modeled using the polynomial function outlined in Equation 1, that illustrates the interaction between Na / N_0 and N_0.:

$$\frac{N_a}{N_0} = \frac{\exp(P_0 + P_1 N_0 + P_2 N_0^2 + P_3 N_0^3)}{1 + \exp(P_0 + P_1 N_0 + P_2 N_0^2 + P_3 N_0^3)} \quad (1)$$

Where P_0, P_1, P_2, and P_3 are parameters intercept, linear, quadratic and cubic coefficients, respectively, that should be evaluated. Na is the number of parasitized nymphs and N_0 is the initial host density. These parameters were estimated using the SPSS procedure (SPSS, 2006). The values of P1 and P2 can be used to differentiate the shape of the curves (Juliano 2001). If the linear parameter (P1) is positive, it signifies a type III functional response, whereas a negative value for this parameter suggests a type II functional response (Juliano 2001). After determining the type of functional response, the parameters a' (the coefficient of attack rate), T_h (handling time), and b (the maximum number of parasitized hosts) of a Type II response were estimated using Holling's disc equation (equation2) (Holling 1959) and using SPSS procedure (SPSS, 2006).

$$Na = \frac{a' N_0 T}{1 + a' N_0 T_h} \quad (2)$$

Where: Na is the number of parasitized nymphs and N_0 is the initial host density; a' = Rate of attack; T_h = Time taken for handling; T is the total time available for search (here 24 h).

RESULTS AND DISCUSSION

Results

The mean parasitism rates of second-instar nymphs of *M. persicae* on the tested host plants are shown in Table 1. The obtained results cleared that host plant has been shown to influence the number of hosts parasitized, where the highest parasitism rates of *D. rapae* was on cowpea followed by tomato and cucumber. In addition, the average number of hosts parasitized significantly increased with increasing host density on each host plant.

Table 1. Mean (± SE) 2nd instar nymphs of *Myzus persicae* (Sulzer) parasitized by *Diaeretiella rapae* at various host densities on different host plants.

Density	Mean hosts parasitized at different host plants		
	Cowpea	Tomato	Cucumber
15	5.50 ± 0.31a,D	3.90 ± 0.38 b,D	3.25 ± 0.28 b,D
25	8.25 ± 0.35 a,C	6.67 ± 0.51 b,C	5.75 ± 0.51 b,C
35	11.67 ± 0.50 a,B	9.67 ± 0.40 b,B	7.30 ± 0.38 c,B
45	13.25 ± 0.46 a,A	11.83 ± 0.56 b,A	9.40 ± 0.42 c,A
55	13.50 ± 0.47 a,A	10.58 ± 0.5 b AB	8.33 ± 0.38 c,AB

Means signed by the same lowercase letter was non-significant in the same row. While means signed by the uppercase letter was non-significant in the same column at P= 0.05.

As shown in Table 2, the percentage of hosts parasitized by *D. rapae* decreased as the density of hosts increased. The number of hosts that were parasitized rose with an increase in host density until it reached a peak, after which it gradually declined. This suggests that parasitizing response of the parasitoid *D. rapae* saturates at a certain level.

Table 2. Mean (± SE) proportion of parasitized Individuals of *Myzus persicae* (Sulzer) parasitized by *Diaeretiella rapae* at various host densities on different host plants.

Density	Mean hosts parasitized at different host plants		
	Cowpea	Tomato	Cucumber
15	0.367 ± 0.071 a	0.261 ± 0.083 a	0.216 ± 0.061 a
25	0.330 ± 0.046 ab	0.267 ± 0.068 a	0.230 ± 0.068 a
35	0.333 ± 0.047 ab	0.276 ± 0.037 a	0.209 ± 0.036 a
45	0.290 ± 0.032 b	0.262 ± 0.041 ab	0.208 ± 0.029 a
55	0.245 ± 0.028 c	0.193 ± 0.030 b	0.151 ± 0.023 b

The findings from the logistic regression differentiate between Type II and Type III responses are presented in Table 3. The linear coefficient (P_1) and coefficient of determination (R_2) values were (P_1 = - 0.72, R^2 =0.99), (P_1 =-1.43, R^2 =0.97), (P_1 =- 0.67, R^2 =0.96) on cowpea, cucumber and tomato, respectively, which were negative and significantly < 0. The linear coefficients (P1) exhibiting negative values suggest that *D. rapae* indicated a type II functional response for all evaluated host plants. Also, the percentage of hosts affected by *D. rapae* decreased as the density of the hosts increased (Table 2), this indicating that the functional response of *D. rapae* to *M. persicae* nymph was classified as type II.

Table 3. Logistic regression analysis of the proportion of *Myzus persicae* 2nd nymphs parasitized by *Diaeretiella rapae* at different host plants.

Coefficients	Host plants		
	Cowpea	Cucumber	Tomato
Constant (Po)	5.03	4.24	5.64
Linear (P1)	- 0.72	- 0.67	-1.43
Quadratic (P2)	0.49	0.48	0.63

The coefficient of attack rate (a) and handling time (Th) of *D. rapae* on five densities of second instar nymphs of *M. persicae* was estimated on cowpea, cucumber, and tomato plants (Table 4). The obtained results indicated that host plant is a significant element that influences search behavior (attack rate and handling time) of *D. rapae*. The attacking rate of *D.rapae* that indicated the proportion of the total area explored by the parasitod per foraging time unit. So, the attack rate (the proportion of the total area explored by the parasitod per foraging time unit) was 0.264, 0.312, and 0.456 per hour on cucumber, tomato, and cowpea respectively. Furthermore, estimated handling times (Th) were 0.715, 0.710, and 0.624, respectively. *D. rapae* showed the lowest instantaneous attack rate and the longest handling time on cucumber. Handling time is a crucial characteristic in the interaction between hosts and parasitoids, influencing the relationship between exposure time and handling time (T/Th) is an indicator for maximum rate of parasitism. The predicted maximum attack rate of the parasitoid on cowpea, tomato and cucumber was 38.46, 33.78 and 33.56 aphids/ parasitoid/ day, respectively.

Table 4. Estimates of attack rate (a), handling time (T_h), maximum attack rate (T/T_h) and a/T_h values of Diaeretiella rapae on second nymph instars of *Myzus persicae* on different host plants.

Host plant	Attack rate	Handling time (h)	Maximum attack rate	R2
Cowpea	0.312	0.624	38.46	0.99
Cucumber	0.264	0.715	33.56	0.96
Tomato	0.456	0.710	33.78	0.97

Discussion

In the present investigation, the density of the host had a notable impact on the ratio of hosts that were parasitized by *D. rapae*. As a result, *D. rapae* is efficient in targeting larger numbers of aphids as host density rises, peaking before experiencing a gradual decrease. In a type II response, as the density of hosts rises, it is expected that the percentage of hosts that are parasitized will decrease. Moreover, the notable negative values associated with the linear parameters obtained in the present study on the different hosts verify the type II for *D. rapae*, and it was not influenced by the type of host plant species. A type II functional response is the most frequently observed response in most parasitoids. Similar results were obtained by Soni and Kumar (2021) that *D. rapae* showed a type II functional response on rapeseed-mustard. Also, this type of functional response has also been noted for *D. rapae* on *M. persicae*. (Yu et al., 1993), on the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Lester and Holtzer, 2002; Tazerouni, et al. 2012) reared on wheat seedlings and on *Brevicoryne brassicae* on cabbage plants (Fathipour et al. 2006). Type II functional responses have been documented in other species including *Aphidus colemani* Viereck and *Aphidius matricariae* (Haliday) on *Aphis gossypii* (Glover) reared on cucumber leaf disk (Zamani et al., 2006). On the contrary, a type III functional response was observed for *D. rapae* on *Schisaphis graminium* (Rondani) reared on wheat (Dashti et al., 2010 and Jokara et al., 2012). However, previous studies have indicated that type III of functional response occurs in *A. colemani* on *S. graminum* on wheat (Jones et al., 2003). The type of functional response exhibited by parasitic wasps can vary depending on several factors, including experimental conditions, the specific cultivar of plants, variations in parasitoid strains, and various host species (Bernal et al., 1994; Coll and Ridgway, 1995; Messina and Hanks, 1998; Lester and Holtzer, 2002; Fathipour et al., 2006).

The parasitoid, *D. rapae* showed different attack rates and handling time depending on the type of host plant. The lowest estimated coeffieint value of attack rate (a) and the highest handling time (T_h) were obtained for the parasitoid parasiting *M, persicae* on cucumber. However, handling time was 0.624, 0.715 and 0.710 h on cowpea, cucumber and tomato, respectively. According to Bernal et al., (1994) and Lester and Holtzer (2002) *D. rapae* exhibited shorter handling time on *D. noxia*. Nonetheless, comparing the handling time of *D. rapae* in our research with that of other studies is challenging due to various factors, including differences in the origin of both the parasitoid and the host, as well as differing experimental conditions (e.g., test arena, temperature). The obtained results indicated that host plant is an important factor affects parasitism rate and searching behavior (attack rate and handling time) of *D. rapae*. Abdel-

Baky and Aldeghairi (2008) illustrated that biological characteristics of parasitoid are clearly affected by host plants.

The attack rate coefficient and handling time are factors utilized to assess the extent of functional responses (Pervez and Omkar 2005). In the present study, the parasitoids exhibited relatively longer handling time on tomato and cucumber than cowpea plants. Ebrahimifar, et al. (2017) reported that hairy leaves of tomato affected the parasitism of parasitoids and may be slowing the parasitoid movement. Cetintas and McAuslane (2009) indicated that host plant cultivars with fewer trichomes are more likely to achieve successful biological control. To explore the influence of plant trichomes on insect parasitoids, several studies have been conducted (Hoddle et al. 1998; Gruenhagen & Perring 2001). Hulspas-Jordaan and van Lenteren (1978) found that leaf hairs negatively impacted the walking speed and patterns of *Encarsia formosa* on cucumber varieties. Similarly, van Lenteren et al. (1995) observed a linear decrease in the level of parasitism of the greenhouse whitefly, *Trialeurodes vaporariorum*, by the parasitoid *E. formosa* as leaf hair density on cucumber hybrids increased. In a greenhouse study examining the parasitism of the silverleaf whitefly by *Eretmocerus eremicus* across five host plants, it was noted that plants with higher trichome densities harbored fewer parasitized whiteflies (Gruenhagen & Perring 2001). Even simple non-glandular trichomes can disrupt movement and decrease walking speed. Research has shown that various egg parasitoids (*Trichogramma* spp.) move more quickly on smooth cotton leaves and pigeonpea pods compared to those with hairs (Romeis et al., 2005). Additionally, the walking speed of parasitoids can be further reduced by exudates from glandular trichomes. These findings support our observations, which demonstrated that a higher average number of aphid nymphs were parasitized on cowpea leaves compared to cucumber or tomato by *D. rapae*.

On all tested host plants, *D.rapae* has an inverse density-dependent mortality as host density increased. According to Hughes et al*.,* 1992; Fernández-Arhex and Corley, 2003, and Tazerouni, *et al*. (2012) and vanLenteren et al. (2016) parasitoids that exhibiting a type II response (*i.e*., inversely density dependent mortality) have effectively established and managed host populations. So, *D. rapae* may be more successful in decreasing the population of *M. persicae* (Tazerouni, et al. ,2012).

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تأثير النبات العائل على معايير الاستجابة الوظيفية للطفيل *Diaeretiella rapae* (MacIntosh) لكثافات مختلفة من حشرة مّن الخوخ الأخضر

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الملخص

تم تقييم الاستجابة الوظيفية للطفيل (MacIntosh) *Diaeretiella rapae* على كثافات مختلفة من حوريات العمر الثاني لمن الخوخ الأخضر (Sulzer) *Myzus persicae* على ثلاث نباتات (اللوبيا والخيار والطماطم). أظهرت النتائج أن الطفيل يهاجم عددًا أكبر من أفراد المن على اللوبيا مقارنة بالنباتات الأخرى. وقد سجل انخفاض نسبة العوائل التي تطفل عليها الطفيل مع زيادة كثافة العائل. أظهر تحليل العلاقة بين نسبة العوائل المتطفل عليها بواسطة الطفيل *D. rapae* والكثافة الكلية المتاحة من العائل، مما يشير إلى أن الطفيل يبدى استجابة من النوع الثاني. لم يتغير نوع الاستجابة الوظيفية للطفيل مع تغيير العائل النباتي. في حين تختلف قيم معدل الهجوم ووقت المناولة اعتمادًا على نوع النبات العائل. أظهر الطفيل أدنى معدل هجوم لحظي وأطول وقت مناولة على الخيار مقارنة بنباتات اللوبيا أو الطماطم. كانت قيم معدل الهجوم 0.259 و0.312 و0.456 على الخيار واللوبيا والطماطم على التوالي. بينما كان اقل وقت للأداء (التناوب) على اللوبيا (0.624)، تليها الطماطم (0.7104) والخيار (0.7152). ابدى الطفيل نمط وفيات يعتمد على عكسيا على الكثافة مع زيادة كثافة العائل. يمكن اعتبار هذا السلوك عامل تحكم بيولوجي واعد لإدارة جشرة المن. لذلك، فإن إدخال الطفيليات في بداية موسم النمو عندما تكون أعداد العوائل منخفضة يمكن أن يعزز فعالية استراتيجيات مكافحة الآفات.

الكلمات الدالة: العائل النباتى- الاستجابة الوظيفية- *Diaeretiella rapae*- من الخوخ الأخضر