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RESEARCH ARTICLE

INFLUENCES OF HOST PLANTS ON THE FUNCTIONAL RESPONSE OF *TRICHOGRAMMA CHILONIS* (ISHII), A PARASITOID OF *HELICOVERPA ARMIGERA* (HÜBNER)

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Abstract

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae), is a polyphagous pest that damages a wide range of crops worldwide. In India, although its incidence is reported for over 200 plant species, it severely reduces productivity in chickpea (*Cicer arietinum* L.), and tomato (*Lycopersicum esculentum* L.), crops. One of the most effective natural enemies reported for its biological control is *Trichogramma chilonis* (Ishii), which attacks the eggs of *H. armigera*. In general, behavioural responses influence parasitoids' ability to control host pests. The functional response i.e., response of a parasitoid to its hosts' egg density can be considered one of them. It may be affected by several abiotic and biotic factors including host plants. However, how the functional response of *T. chilonis* is influenced by host plants is still unknown. In the present study, we attempted to evaluate the influences of host plants (chickpea and tomato) on the functional response of *T. chilonis* at *H. armigera*'s eight different egg densities (2, 5, 10, 20, 30, 40, 60 and 80 eggs/female/day) under laboratory conditions. For all host plants, the logistic regression revealed a type-II functional response. The attack rate (*a*) of *T. chilonis* was observed to be 0.0463±0.0038 and 0.0623 ±0.0058 per hour with estimated handling times (T_h) of 0.4256 ±0.0432, and 0.7245±0.0537 hour for chickpea and tomato, respectively. Although the functional response features, particularly with regard to parasitism, did not vary significantly among host plants (at a 95% confidence interval), the *T. chilonis* females, however, had a grater effectiveness against *H. armigera* eggs on chickpea. The findings of this study provide new insights into host-parasitoid interactions.

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Introduction:-

The American bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) is a polyphagous pest and damages a wide variety of agricultural crops worldwide (Rao et al. 2001; Queiroz-Santos et al., 2018). In India, its incidence is reported throughout the year completing up to seven generations by feeding on 182 plant species including pulse chickpeas, pigeon pea, tomato, brinjal, etc. (Manjunath et al., 1989; Ravi et al., 2005). The yield loss in chickpea due to this dreaded pest was reported as 10-60 per cent under normal weather conditions, while it was reported to be 50-100 per cent in favorable weather conditions (Sharma et al., 2020). The ecological and physiological features like direct attack on fruiting structures, voracious feeding, high fecundity, multi-voltinism, occurrence of overlapping generations and ability to be adapt and develop resistance against all common groups of insecticides applied for its management have exacerbate its serious pest status (Behre et al., 2013). The potential of applied chemicals is also screened off as the grown up *Helicoverpa* larvae mostly feed upon developing grains inside the pods. In addition, large quantities of persistent insecticides are raising concerns about applicator safety, environmental contamination and possible deleterious effects on non-target animals and humans.

As an alternative, biological control of the insect pests using natural enemies has been considered as one of the most important techniques and unlike other chemical control measures its effect is permanent, ecologically non-disruptive, self-sustaining and after the initial costs involving investigations and release, the recurrent costs are nominal (Khetan, 2001). The egg parasitoid, *Trichogramma* spp. Westwood (Hymenoptera: Trichogrammatidae) is is being used as an important biological control agent of lepidopterous pests in greenhouse and field crops of several countries (Smith, 1996; van lanteren, 2003; Mills, 2010). The *T. chilonis* (Ishii) is one among the most commercialized trichogrammatid egg parasitoid for the control of *H. armigera* in different crops worldwide (Li, 1994; Hoffman et al., 2001; Ballal and Singh, 2003; Abbas et al., 2020).

The selection of parasitoids in biological control systems is primarily based on their behavioural responses (Wajnberg et al., 2007). In order to create a successful parasitoid model, it is necessary to take into account both host and parasitoid features. It is beneficial to thoroughly comprehend the temporal and spatial dynamics of species involved. The density of the host, which controls the functional response, is the most crucial element in such models (Solomon, 1949). The functional response refers to the correlation between host density and the number of hosts that a single parasitoid parasitizes in a given period of time (Pervez and Omkar, 2005). Three different functional responses were proposed by Holling in 1965. In type I, the probability of a given parasitoid encountering a host within a fixed spatial region in a given time period relies linearly on the host density; in type II, the number rises curvilinearly to a plateau before levelling off as a result of handling time or satiation; and in type III, the number of hosts attacked rises sigmoidically (Hassell, 2000; Mills and Lacan, 2004). It is evaluated in terms of attack rates and handling times and used determine whether a natural enemy is able to regulate the density of its host (Murdoch and Oaten, 1975).

There is ample evidence that many abiotic and biotic factors, such as temperature, host species, natural enemies, laboratory physical conditions, host plants, and parasitoid age, have an impact on the type and parameters of a functional response (Reay-Jones et al., 2006; Moezipour et al., 2008; Jamshidnia et al., 2010; Jamshidnia and Sadeghi 2014; Ebrahimifar et al., 2017). The influences of host plants can be considered as one of them. In this context, the present study was aimed to evaluate the type of functional response, its parameters and evaluation of host- parasitism of parasitoid wasp, *T. chilonis* on two plant hosts plants, chickpea and pigeon pea at *H. armigera*'s

six different egg densities. The results of this study will advance our knowledge of the connection between host plants and functional response, allowing us to apply biological control strategies more effectively.

Materials and Methods:-

Cocoons of the parasitoid *T. chilonis* and larvae of the host *H. armigera* were collected separately from the chickpea/tomato crops grown near Gorakhpur City. The collected cocoons of the parasitoid and larvae of the host were reared under the laboratory conditions.

Culture of the host: The field-collected *H. armigera* larvae were transferred singly into glass vials (ca. 10 x 3.35 cm) with moistened filter paper at the bottoms using a small camel hair brush. The mouths of the glass vials were plugged with absorbent cotton. Fresh and green leaves and pods of chickpea were provided as food for the host larvae, which were reared until pupation. After pupation, the pupae were transferred to the fresh, sterilised glass vials with moistened filter paper at their bottoms. Emerging adults were provided a 30% honey solution as food.

For the culture of *H. armigera***,** a couple of adults were kept together in a beaker (1000 ml) until mating was observed. Moistened filter paper was kept at the bottom of the beaker to provide humidity inside it. When the flying moth needed to rest, a strip of muslin cloth was hung inside. The mouth of the beaker was covered by a muslin cloth. The mated females were then removed from the beaker and introduced into the small, marked wooden cages (ca. 45 x 50 x 60 cm) containing potted young plants of chickpea at 22±4°C, 70±10% RH and 10:14 h (L:D) photoperiod. A piece of sponge soaked in a 30% honey solution was kept in each cage as food and was changed daily. The eggs deposited each day on the leaves and pods of the host plant, were transferred to the marked beakers (ca. 250 ml) and used as hosts for the experiments.

Culture of the parasitoid: The field-collected cocoons of *T. chilonis* were transferred singly with a small camel hairbrush into glass vials (10 x 3.35 cm), each having moistened filter paper at their bottoms. Adults emerging from the cocoons were then fed 30% honey solution ad libitum for 2-4 hrs. Thereafter, the female and male parasitoids were put together in a glass tube (10 x 3.25 cm) until mating was observed (2-4 hours). The males then were removed from glass tubes. The mated females were introduced into the small marked wooden cages (45 x 50 x 60 cm) having host egg cards having 100 fresh eggs of *H. armigera*. A small piece of sponge soaked in 30% honey solution, was placed into the each wooden cage as food for the parasitoids. After parasitisation, the parasitoids were removed and the parasitized eggs alongwith egg cards were separately placed for further development. After adult emergence, the number of each sex was determined.

To observe the influences of host plants on the functional response of the parasitoid, fresh *H. armigera* eggs were prepared in eight host densities (2, 5, 10, 20, 30, 40, 60, and 80) by randomly distributing the eggs on a 10 mm white card strip. Now, fifteen mated *T. chilonis* females were introduced into wooden wooden cage (Ca. 45 x 50 x 60 cm) having potted young host plant alongwith egg cards and kept at 22±4°C, 70±10% RH and 16:8 h (L:D) photoperiod for parasitisation. A 30% honey solution soaked in sponge was provided as food. Such ten replicates of experiments were made for each host density for each of the host plants. After every 24 h the females were removed from their respective cages and the exposed host egg cards were left under identical environmental conditions until they turned black. The eggs turned blackened (parasitized) were counted and recorded.

Analyses of the data:-

Data concerning the functional response were analysed in two steps. The first step involved determining the type of functional response. It was carried out using logistical methods (regression of the proportion of parasitized hosts versus the initial number of hosts) by fitting a polynomial function (Jamshidnia et al. 2010).

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

The parameters P_0, P_1, P_2, and P_3 correspond to the intercept, linear, quadratic, and cubic coefficients, respectively. N_a is the number of parasitized or attacked host eggs, and N_0 is the initial host egg density. The shapes of the curves can be determined using the signs of P_1 and P_2. If both parameters (P_1 and P_2) are negative, the functional response is type II, while a positive linear parameter (P_1) and a negative quadratic parameter (P_2) indicated that the functional response is type III (Juliano 2001). The parameters of handling time (T_h) and attack rate (a) were determined after the type of functional response had been established. To calculate the Rogers (1972) parameters of the random parasitoid equation (2), we employed nonlinear least squares regression.

$$N_a = N_0 \left[1 - \exp\left(-\frac{aT}{1 + aT_h N_0}\right)\right] \quad (2)$$

Where, N_a, N_0, a and T_h, respectively, stands for number attacked hosts, initial host density, attack rate and handling time.

Results:-

The parasitism efficacy of *T. chilonis* was greatly influenced by host egg densities. Figure 1 displays the functional response curves of the parasitoid to varied densities of host eggs.The average number of hosts parasitized by rising host densities initially increased and then started to stabilise. The findings of the logistic regression analysis (Table 1) showed that the linear coefficient (P_1) was negative for parasitisms on the both host plants. These findings suggest that *T. chilonis* has a type II functional response. In both instances of parasitism, the host plant had no influence on the type of functional response. The estimated a values and host handling times (T_h) for chickpea were 0.0463 h^{-1} and 0.4256 h, respectively, while these values for tomato were 0.0623 h^{-1} and 0.7245 h (Table 2).The upper asymptote value of the maximum number of attacks is determined by the T/T_h ratio (Hassel 1978). For chickpea and tomato, the female parasitoid's daily maximum possible parasitization of host eggs was 52.35 and 37.62, respectively. On both host plants, the observed difference in the values of handling time (T_h) and attack rate (a) was statistically significant at the 95% confidence level.

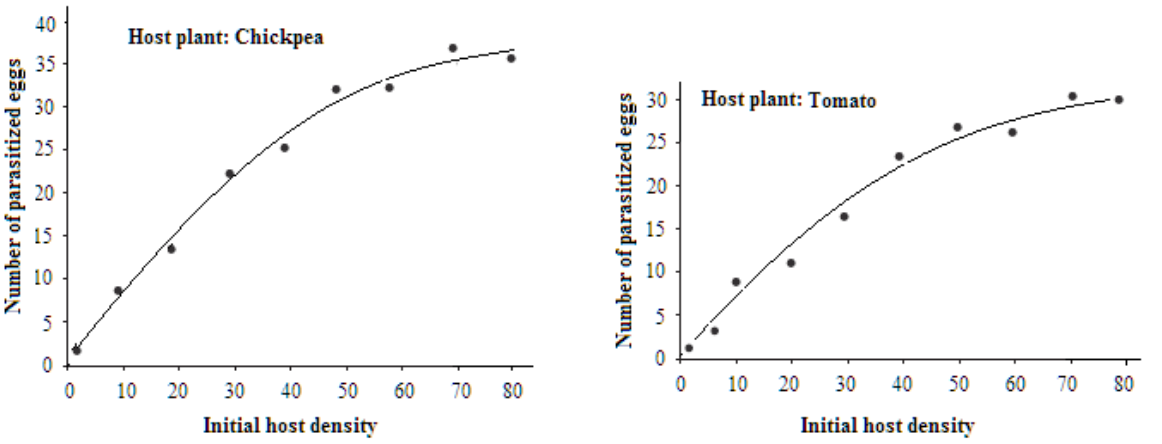

Fig. 1. Functional response of *T. chilonis* on chickpea and tomato to different densities of *H. armigera* eggs (Symbols - observed; lines - predicted by model).

Discussion:-

Our study revealed that host plant did not influence the type of functional response in either case of parasitism. Functional response studies are helpful in establishing a baseline for evaluating the effectiveness of various parasitoids. These also offer details on potential natural enemies' capacities for host-finding (Ebrahimifar et al., 2017). According to various researchstudies on the functional response of insect parasitoids, more than 75 percent exhibit type II functional response (Fernandez-Arhex and Corley 2003). Our result regarding type II functional response in *T. chilonis* is in accordance with previous studies for a number of *Trichogramma* species (Wang and Ferro, 1998; Moezipour et al., 2008; Farrokhi et al., 2010; Milanez et al., 2018; Ghorbani et al, 2019). The accuracy of functional response as a comparison tool is closely related to the use of suitable models and data analysis.

Table 1: Maximum likelihood estimates from regression logistic analysis of the proportion of *H. armigera* eggs parasitized by *T. chilonis* on chickpea and tomato.

Host plant	Behaviour	Coefficient	Estimate	SE	$\chi 2$	p-values
Chickpea	Parasitism	P_0 (Constant)	1.2651	0.1943	32.74	<0.0001
		P_1 (Linear)	-0.00092	0.0231	0.00	0.9765
		P_2 (Quadratic)	-0.00061	0.00034	0.94	0.4463
		P_3 (Cubic)	2.864E- 6	3.121E- 6	0.58	0.5026
Tomato	Parasitism	P_0 (Constant)	2.3241	0.2743	52.42	<0.0001
		P_1 (Linear)	-0.0417	0.0376	0.00	0.1254
		P_2 (Quadratic)	-0.00023	0.00042	1.72	0.7632
		P_3 (Cubic)	2.763E- 6	3.352E- 6	0.56	0.4872

The type of functional response and estimated parameters for an insect species could be affected by several factors, including host palnts. However, we did not observed significant influence of host pnats on the type of functional response of *T. chilonis*.

Table 2: Estimated functional response parameters by Rogers model for *T. chilonis* to different densities of *H. armigera* eggs on chickpea and tomato.

Host plant	Behaviour	Type	Parameter	Estimate	SE	Asymptotic 95% CI	
						Lower	Upper
Chickpea	Parasitism	*II*	a	0.0463	0.0038	0.0424	0.0674
			T_h	0.4256	0.0432	0.3175	0.5267
Tomato	Parasitism	*II*	a	0.0623	0.0058	0.0346	0.0726
			T_h	0.7245	0.0537	0.624	0.7428

The type II functional response suggests that the proportion of parasitism and host density have an inverse density-dependent relationship (Holling 1959). The parasitoid spent more time handling the host as evidenced by the estimated host handling time of *T. chilonis* on tomato in this study (0.7245 h), which is much longer than that on chickpea (0.4256 h). However, it is still unclear what biological factors led to this variation. The term "handling time" refers to the period of time needed by parasitoids to discover, drum up, and parasitize a host as well as to rest, groom, and feed on sap. The values of attack rate (*a*) were decreased on the tomato plant employed in this investigation because it has a surface that is more hairy than chickpeas. It is conceivable that the host plant's hairy surface had an impact on the parasitoids' ability to parasitize their host. Additionally, it appears that the hairy tomato leaf may be limiting the movement of the parasites more so than the chickpea leaf.

Conclusion:-

Based on the results of the current study, we draw the conclusion that *T. chilonis* can control *H. armigera* on chickpea more effectively than tomato crops at low host density. Although functional response is a crucial tool for assessing natural enemies, its success or failure in biological control cannot be solely attributed to this component. Therefore, more research should be done to assess *T. chilonis*' effectiveness as a biological control agent of *H. armigera* on chickpea crops.

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