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Weather Parameter's Impact on Natural Parasitization by *Campoletis chlorideae* Uchida in Chickpea Ecosystem - New Alluvial Zone of West Bengal

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ABSTRACT

Background: A major biotic constraint in chickpea (*Cicer arietinum* L.) production is gram pod borer, *Helicoverpa armigera* (Hübner). However, the population of this pest is reduced to some extent by a solitary endo-larval parasitoid, *Campoletis chlorideae* Uchida under field conditions. Climate change has a greater impact on natural enemies' effectiveness used in field-level pest management. Therefore, the present study was conducted to understand the impact of weather factors on *C. chlorideae* parasitization rate of *H. armigera* in chickpea grown in the new alluvial agro-climatic zone of West Bengal.

Methods: Chickpea was grown in a randomized complete block design (RCBD) with three replications during *Rabi* 2017-18, 2018-19 and 2019-2020, at Mondouri farm, Bidhan Chandra Krishi Visawavidayala, Mohanpur, West Bengal. To know the most significant weather parameter which influences *C. chlorideae* parasitization or parasitoid incidence, *H. armigera* larvae (2nd instar) collected from the field experiment were reared until cocoon formation and parasitization % was correlated with weather parameters and subsequently subjected to stepwise regression analysis.

Result: The larval endo-parasitoid, *C. chlorideae* marked its first appearance from 3rd SMW after the appearance of *H. armigera* and its activity was high (68% to 72% parasitization) during the flowering to pod initiation stage and thereafter declined gradually. Among the weather variables, only temperature (maximum and minimum) had a consistent and significant negative correlation with *C. chlorideae* incidence and was responsible for nearly 50% *C. chlorideae* incidence. An increase in 1°C temperature results in a decrease of 4% parasitoid incidence. Thus, climate change in the near future will have a considerable influence on the overall survival, development and rate of parasitization of parasitoids.

Key words: Chickpea, *Campoletis chlorideae, Helicoverpa armigera*, Parasitization.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) also known as Bengal gram or chana is one of the most important pulse crops of India and is considered as "king of pulses" (Bhatt and Patel, 2001). Though India contributes around 71% and 70% of the global chickpea area and production, respectively, the country lags in terms of productivity. Nearly around 60 insect species are known to infest chickpeas. Among that legume pod borer, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) is the most important biotic constraint and an insatiable feeder of chickpea flowers, pods and developing seeds (Reed *et al.,* 1987). Repeated usage of conventional insecticides led to high-level resistance development in *H. armigera* (Kranthi *et al.,* 2002). Despite the application of insecticides costing over US$500 million annually, *H. armigera* causes an estimated loss of US$325 million in chickpea which is uneconomical under subsistence farming (Sharma, 2005). Thus, biological control, an important Integrated Pest Management component, comes as a rescue. Chickpea crop harbours very few natural enemies such as *Campoletis chlorideae* Uchida, *Carcelia illota* Curran, *Banchopsis ruficornis* Cameron and *Eriborus* sp. (Srinivas and Jayaraj, 1989; Singh *et al.,* 1991). Among that, the endo-larval parasitoid *Campoletis chlorideae* Uchida (Ichneumonidae: Hymenoptera) is predominant in the chickpea ecosystem.

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The most preferred host of *C. chlorideae* is *H. armigera* and their parasitization ranges from 8.33% to 78% (Pawar *et al.,* 1989; Dhillon and Sharma, 2007; Gupta and Raj, 2003; Agnihotri *et al.,* 2011). It prefers to parasitize 4 to 5 days-old late 2nd instar *H. armigera* larvae (Dhembare, 1999). Survival threshold and thermal requirements influence the abundance and activity of natural enemies, which in turn influence biological control programs' success (Butler and Lopez, 1980; Chihrane *et al.,* 1993). As a result of climate change, the likely increase in temperature and relative humidity (RH) will have a great bearing on the effectiveness of natural enemies for pest management at the field level. For framing a future *H. armigera* bio-intensive management strategy in the chickpea ecosystem, quantification of *H. armigera* mortality by natural field parasitization of *C. chlorideae* and its activity in relation to changing abiotic factors are of major importance. Keeping this in view, the present study was undertaken to study the effect of the influence of weather parameters on the natural parasitization of gram pod borer by *C. chlorideae* in the new alluvial zone of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted during three consecutive *Rabi* seasons of 2017-18, 2018-19 and 2019-2020, at Mondouri farm (22°56' N, 88°32'E with an altitude of 9.75 m above the msl), Bidhan Chandra Krishi Visawavidayala (BCKV), Mohanpur, which comes under the new alluvial agro-climatic zone of West Bengal. Chickpea seeds (variety: Anuradha) were sown in a 20 m^2 plot with a spacing of 30 cm×10 cm (r-r × p-p). The experiment was laid out in randomized complete block design (RCBD) with three replications and the plots were separated by an alley of 1 m. The crop was grown by following all the recommended agronomic practices except plant protection practices and kept free from pesticide application. From the time of larva appearance in the field, every week thirty late 2nd instar *H. armigera* larvae were randomly collected, brought to the laboratory and reared individually on chickpea leaves in plastic vials. The food was changed regularly as and when required until cocoon formation. Every week, parasitization % by *C. chlorideae* was calculated based on the total number of *H. armigera* larvae collected and number of cocoons formed. Observations on daily data of weather parameters *viz.,* minimum and maximum temperatures (°C), morning and evening RH (%) and rainfall (mm) prevailed during three cropping seasons (December to April 2017-18, 2018-19 and 2019-20) were collected from Department of Agricultural Meteorology, BCKV and then daily data were converted to standard meteorological week (SMW) weather data. *C. chlorideae* mean larval parasitization % (dependent variable) was correlated with the weather parameters (independent variables) and a stepwise multiple regression analysis (both forward and backward) was carried out to get the regression equation for every season. All these statistical analyses were carried out using Minitab software (version 21).

RESULTS AND DISCUSSION

Natural parasitization (%) of *H. armigera* by *C. chlorideae*

During all three cropping seasons, a high parasitism level of *H. armigera* by its larval-endo parasitoid *C. chlorideae* was recorded and this parasitoid marked its 1st appearance (24% parasitization) on 3rd SMW after the appearance of *H. armigera* (Fig 1). During 2017-18 and 2018-19, the larval parasitization % by *C. chlorideae* gradually increased and reached its peak (64% and 72%, respectively) in 7th SMW (3rd week of February). From 8th SMW (4th week of February) there was a regular decline in parasitization from 20% and 40%, respectively, to 4% (11th SMW). While, during 2019-20 *C. chlorideae* parasitization % increased gradually and reached its peak of 68% parasitization in 6th SMW (2nd week of February). Thereafter, from 7th SMW (3rd week of February) a gradual decrease in parasitization of 60% to 4% (11th SMW). Thus, a maximum parasitization of 64% to 72% was recorded during 6th to 7th SMW *i.e.,* flowering to pod initiation stage. During all three years, parasitization became almost nil in 12th SMW (4th week of March) (Fig 1). Jagdish *et al.* (2016) reported the coincidence of parasitoid activity with the crop's flowering and pod formation stage. The maximum parasitization recorded in this study was in agreement with

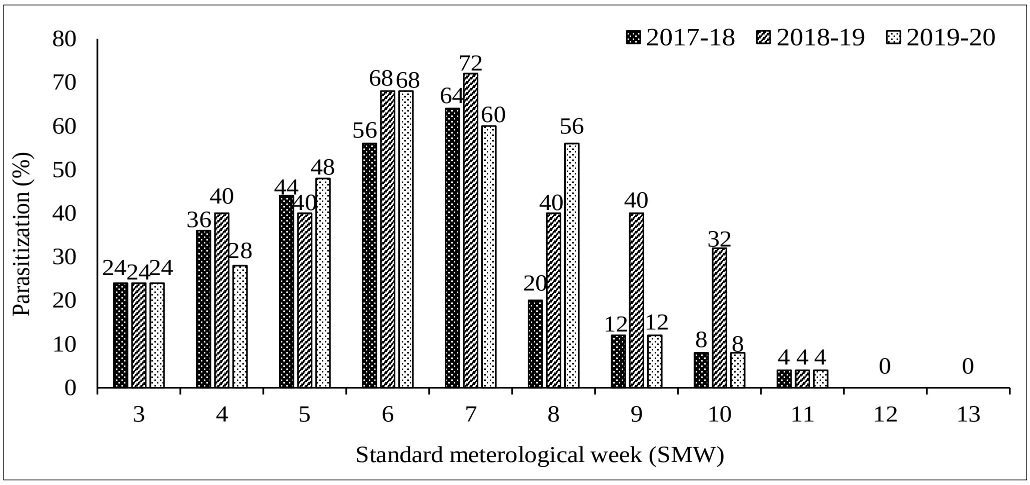
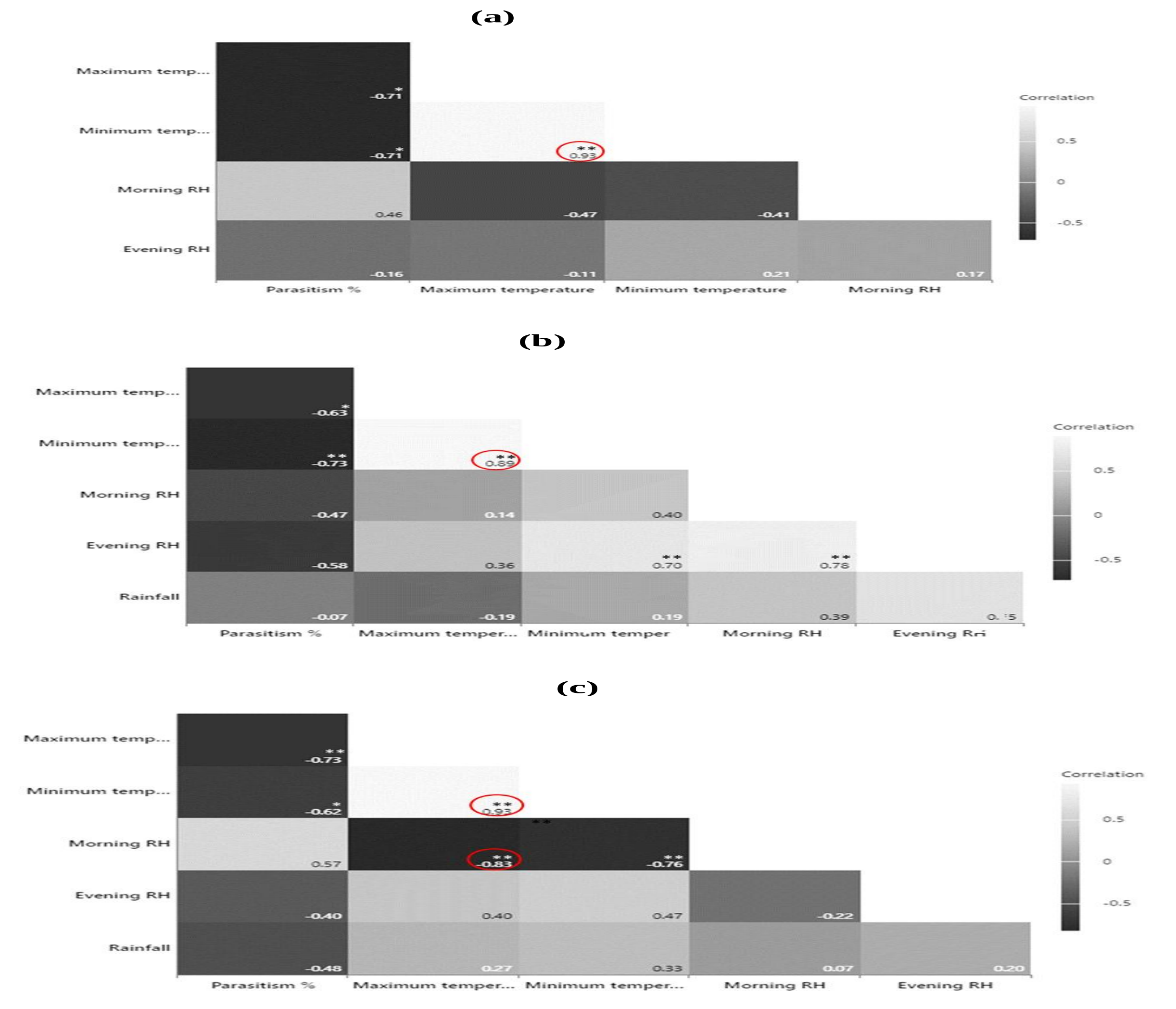


Fig 1: Natural field *C. chlorideae* parasitization % of *H. armigera* during *Rabi* 2017-18, 2018-19 and 2019-20.

the findings of Ojha *et al.* (2017) and Divija and Agnihotri (2021) who recorded a maximum parasitization of 51.67% to 56.67% and 68% to 72%, respectively, in late sown crop. Ravi and Verma (1997) and Kaur *et al.* (2000) reported that in normal and late-sown crops, *H. armigera* parasitism by *C. chlorideae* was maximum in 6th and 7th SMW, respectively, which was followed by a gradual decline supports the present findings. During three years, the range of minimum - maximum temperatures and morning - evening RH of 9.7°C to 11.01°C - 27.94°C to 28.36°C and 93% to 96.71% - 43% to 50.37%, respectively, along with nil rainfall were found to be favourable for *C. chlorideae* population build-up. The minimum to a maximum threshold temperature and RH of 12°C to 35°C and 95%, respectively, were ideal for the survival, development and increased incidence of *C. chlorideae* (Kaur *et al.*, 2000; Dhillon and Sharma, 2008). Pillai *et al.* (2016) documented that the minimum - maximum temperature as well as morning - evening RH in the range of 8.3°C to 9.2°C - 23°C to 24°C and 89% to 90% - 44% to 54%, respectively and nil rainfall were found to be favourable for the increased *C. chlorideae* incidence in Terai region of Uttarakhand.

Association of *C. chlorideae* incidence with weather variables

A simple correlation was worked out between the weather parameters and *H. armigera* parasitization % by *C. chlorideae* during all three *Rabi* seasons (Fig 2). *C. chlorideae* parasitization % had a significant negative correlation with maximum temperature (r= -0.71* p= 0.02; r= -0.63* p= 0.04 and r= -0.73**, p= 0.01, respectively) and minimum temperature (r= -0.71*, p= 0.02, r= -0.73**, p= 0.01, r= -



where * and ** indicates correlation coefficients significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.

Fig 2: Correlogram showing the association of weather variables and parasitization % *C. chlorideae* during *Rabi* (a) 2017-18, (b) 2018-19 and (c) 2019-20.

0.62*, *p*= 0.04), While, remaining independent variables such as evening RH (r= -0.16, *p*= 0.64; r= -0.58, *p*= 0.06 and r= -0.40, *p*= 0.23, respectively), morning RH (r= 0.46, *p*= 0.16; r= -0.47, *p*= 0.14 and r=-0.57, *p*= 0.07, respectively) and rainfall (not available; r= -0.07, *p*= 0.84 and r= -0.48, *p*= 0.14, respectively) showed non-significant association with *C. chlorideae* parsitization (Fig 2). Thus, among the weather variables only temperature (maximum and minimum) had a strong negative association with parasitoid incidence *i.e.,* as the temperature increases, the parasitoid incidence (calculated based on parasitization %) decreases sharply and other weather variables did not play any significant role in influencing parasitization %. The temperature had a negative association with *C. chlorideae* larval and pupal periods and the parasitoid activity was found to cease at a temperature above 35°C to 40°C (Gupta and Raj, 2003; Teggelli *et al.,* 2004; Dhillon and Sharma, 2008). Though Pillai *et al.* (2016) as well as Divija and Agnihorti, (2021) reported that the maximum and minimum temperatures had a significant negative association with *C. chlorideae* incidence, which supports the present result, they have also pointed out that there exists a positive correlation between morning/evening RH and parasitoid incidence. As per Singh *et al.* (2015) RH and rainfall did not play any precise function in *C. chlorideae* parasitization of *H. armigera* which is in agreement with the present findings.

Stepwise regression analysis of parasitoid incidence and weather variables

Based on all three years of weather data, it was confirmed that multicollinearity exists *i.e.,* a condition where explanatory/independent variables are interdependent or a high correlation is observed between independent variables (indicated inside the red colour circle) (Fig 2). Under multicollinearity conditions, one or two best explanatory variables with adequate information that appropriately explain the dependent variable were selected by dropping out other explanatory variables using stepwise regression (Farrar and Glauber, 1967). Based on both forward and backward regression analysis, during 2017-18 and 2019-20, maximum temperature was responsible for 50.28% and 52.71% variation in parasitoid incidence. While, during 2018-19 minimum temperature emerged as the best explanatory variable, responsible for 52.93% variation in parasitoid incidence. The effect of maximum temperature (2017-18 and 2019-20) and minimum temperature (2018-19) was statistically significant at 95% probability level which was evident from the t probability values (*p*= 0.05) (Table 1). Thus, only 50% *C. chlorideae* incidence was significantly influenced by temperature (maximum and minimum). Since the parasitoid incidence does not depend only on weather variables alone, some other factors such as the host density for parasitization and food availability for adults might have contributed to the remaining parasitoid population build-up. Bisane *et al.* (2013) reported that in pigeonpea *H. armigera* larva parasitization by *C. chlorideae* exhibited a density-dependent relationship. In contrast to the present result

Table 1: Estimates of the regression coefficient and t-probability for the explanatory variable selected using stepwise regression analysis of *C. chlorideae* incidence.

Year	Constant	Estimate	Standard error	t Statistics	t Probability	R square	Adjusted R square	Equation (*y=a+bx*)
2017-18	Constant	150.35	42.1	3.57	0.006	50.28%	44.75%	y (parasitoid incidence) = 150.37-
	Maximum temperature	-4.16	1.38	-3.02	0.015			4.16 (maximum temperature)*
2018-19	Constant	92.16	19.43	4.74	0.001	52.93%	47.70%	y (parasitoid incidence) = 92.15-
	Minimum temperature	-4.78	1.50	-3.18	0.011			4.78 (minimum temperature)**
2019-20	Constant	165.4	43.75	3.78	0.004	52.71%	47.46%	y (parasitoid incidence) =165.41-
	Maximum temperature	-4.83	1.52	-3.17	0.011			4.83 (maximum temperature)**

*, ** Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.

Gupta and Raj (2003) reported that RH and total rainfall had a significant effect of 74.15% on larval parasitism, both individually as well as in association with other abiotic factors. Pillai *et al.* (2016) revealed that various abiotic factors such as minimum and maximum temperatures, morning and evening RH, rainfall, sunshine hours and wind velocity were influencing 97.9% to 99.3% of parasitization. Keeping other factors constant, the model regression equation ($y=a+bx$) indicates that during 2017-18 and 2019-20, every 1°C decrease in maximum temperature resulted in 4.16% and 4.83% increase in the parasitoid population, respectively. During 2018-19 there was 4.78% increase in parasitoid incidence for every 1°C decrease in minimum temperature (Table 1).

CONCLUSION

The maximum and minimum temperatures in the range of 29.14°C to 33.14°C and 12.36°C to 14.69°C, along with the gradual build of *H. armigera* larvae during the flowering to pod initiation stage of the crop favoured *C. chlorideae* population to sustain in the environment. Though *H. armigera* larval incidence increased throughout the cropping season, the parasitoid population declined gradually as the temperature increased. Thus, only temperature (maximum and minimum) has the most significant influence as well as being responsible for nearly 50% *C. chlorideae* incidence or parasitization %. An increase in 1°C of maximum and minimum temperature results in a 4% decrease in parasitoid incidence. Thus, as a result of climate change, the temperature changes may have a considerable influence on the survival, development and parasitization of *C. chlorideae.*

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Conflict of interest

The authors declare that they have no conflict of interest.

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