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Influence of prevailing weather parameters on population dynamics of spotted stem borer, *Chilo partellus* (Swinhoe) and its natural enemies on maize in Haryana

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ABSTRACT

The experiment was conducted at CCS Haryana Agricultural University Regional Research Station, Karnal to ascertain the influence of prevailing meteorological parameters on population dynamics of *Chilo partellus* and its natural enemies on maize during *Kharif*, 2017. Maximum oviposition (0.75 egg masses per plant) was recorded during 28th standard meteorological week (SMW) whereas larval population was at peak during 31st SMW (3.8 larvae per plant). Cumulative (47.5%) and fresh plant infestation (11.5%) were maximum during 34th and 28th SMW, respectively. Maximum egg parasitisation (6.53%) by *Trichogramma* sp. and larval parasitisation (31.64%) by *Cotesia flavipes* was recorded during 28th and 33rd SMW, respectively. Changes in pest population were correlated and regressed with weather parameters. Egg and larval populations of *C. partellus* and parasitisation by *Trichogramma* sp. exhibited significant positive correlation with average minimum temperature whereas *C. flavipes* exhibited significant negative correlation with average maximum temperature (r = -0.741) and highly significant positive correlation with evening relative humidity (r = 0.695). Plant infestation and dead heart formation were significantly correlated with average minimum temperature and non-significantly correlated with all other weather parameters. The multiple linear regression analysis explained the variability due to various weather parameters. This information can be utilised while formulating integrated management tactics against this pest.

Key words: Seasonal incidence, Trichogramma, Cotesia flavipes, parasitisation, biological control

Maize (*Zea mays* L.) is popularly known as "Queen of cereals" due to its extraordinary level of genotypic diversity and highest genetic yield potential. Its wider genetic base and adaptability enables it to thrive under different agro-climatic zones of India (Singh and Jaglan, 2018) and grown over an area of 9.63 million ha producing 25.90 million MT of maize annually (Indiastat, 2018). Although the area under maize cultivation has increased considerably, the productivity is still lower than global average due to various biotic and abiotic constraints and among them insect-pests are considered as major yield reducing factors (Ngoko *et al.,* 2002). Around 250 species of insect and mite pests have been reported attacking maize at different stages of crop growth (Mathur, 1991). Among them, spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae) is the most serious insect-pest of maize in India as well as other Asian countries (Singh *et al.,* 2018). Pest infestation starts from 10-15 days after germination when neonate larvae scrap off the chlorophyll content of newly emerged leaves and finds their way into the leaf sheath where they feast upon the growing stem of tender plants (Singh *et al.,* 2018). Pin hole formation, dead hearts and stem tunneling are the characteristic damaging symptoms of the pest infestation and it reportedly cause up to 80.4 per cent yield reduction in different agro-climatic zones of the country (Panwar *et al.,* 2000; Reddy and Zehr, 2004). It has become a serious threat in maize and sorghum based cropping systems not only in India and Asia but also throughout the world (Sylvain *et al.,* 2015). It has attained the status of key pest causing 18 to 25% yield losses in maize and has also been reported feeding on paddy, sugarcane and other millets (Harris, 1990; Kumar and Kanta, 2011). Due to internal nature of damage, this pest is very difficult to control by conventional insecticides. Thus, it is necessary to have basic knowledge about pest biology and ecology to effectively manage it under different sets of agro-climatic conditions.

Studies on seasonal incidence of insect-pests in relation to abiotic and biotic factors are imperative for better understanding of pest scenario in different agro-climatic and agro-ecological zones. It helps in determining weak link in insect-pest life cycle and ultimately, in developing effective pest management strategies (Fand *et al.,* 2018). Scrutiny of literature revealed that information on influence of weather parameters on population dynamics of *C. partellus* and its natural enemies on maize is scanty under this part of the country. Keeping this in view, population dynamics of *C. partellus* and its relation with prevailing weather parameters in Haryana conditions were studied.

MATERIAL AND METHODS

The experiment was conducted at research area of CCS Haryana Agricultural University, Regional Research Station, Karnal (Haryana) during *Kharif*, 2017. Maize crop was sown during last week of June (26th SMW) by following all the recommended package of practices (CCS Haryana Agricultural University) except pesticide application. Maize genotype, HM 10 was raised on a plot size of 125 m^2 by adopting 75cm X 20 cm spacing in randomized block design and replicated four times. All life stages of *C. partellus* were observed at weekly interval starting from five days after germination (DAG) till harvesting of the crop.

A total of 25 plants were randomly tagged in each replication at weekly interval and observations were recorded on egg masses, larval population, pupal counts, and natural enemies. Tagged plants were uprooted on the very next day, brought to the laboratory and dissected on the same day by longitudinally splitting the stem for recording larval and pupal population. Larvae obtained from the split stems were reared in the laboratory till pupation on cut pieces of maize stem to record the presence of larval parasitoids, *Cotesia flavipes* (Cameron). The average number of *C. flavipes* larvae emerged from the collected *C. partellus* larvae, parasitisation rate and average number of *C. flavipes* cocoons per parasitized larva were quantified at weekly interval. *C. partellus* egg masses from the tagged plants were transferred to Petri-plates and kept at room temperature for incubation. Thereafter, individual eggs were observed under stereo zoom microscope for the presence of egg parasitoids, if any. Pupae were kept in the glass jars filled with moist sand to allow adult emergence and record the presence of pupal parasitisation.

For recording plant infestation and dead heart formation, 100 plants per replicate were selected randomly and tagged 5 DAG (days after germination) of crop. Total number of damaged plants and dead hearts were counted starting from 5 DAG till harvesting of the crop and expressed as per cent infestation and dead hearts. Total plant infestation and dead heart formation up to each standard meteorological week (SMW) were expressed as cumulative plant infestation (%) and cumulative dead hearts (%), respectively whereas weekly fresh infested plants and dead hearts were expressed as fresh plant infestation (%) and fresh dead hearts (%), respectively.

The weather data of different standard meteorological weeks (SMW) during crop growth period was obtained from the meteorological observatory of Central Soil Salinity Research Institute (CSSRI), Karnal. Correlation co-efficient and multiple linear regression of different abiotic factors (temperature, relative humidity, rainfall, sunshine hours) with seasonal incidence of *C. partellus* and its natural enemies was estimated using OPSTAT software (http://192.168.2.174/opstat/default.asp) *i.e.* online platform for on-campus user.

RESULTS AND DISCUSSION

Egg masses of C. partellus in relation to weather parameters

Oviposition started during 27th SMW (first week of July, 5 DAG) and most of the egg masses were recorded on leaf blades, lower leaves and under surface of leaves (Neupane *et al.*, 1985). Initially, the mean egg masses were low (0.30 egg masses/plant) during the 27th SMW which attained the peak (0.75 egg masses/plant) during 28th SMW (Table 1). Thereafter, a declining trend was observed in the egg laying up to 31st SMW and no further egg laying was recorded. In contrast, Divya *et al.* (2009) recorded maximum egg laying (0.09 egg masses per plant) on sweet sorghum during 37th SMW in Dharwad. This could be due to difference in crops and agro-climatic conditions of these regions.

C. partellus egg masses exhibited highly significant positive correlation with average minimum temperature (r=0.775) and significant negative correlation with morning relative humidity (r=-0.593) whereas it was non- significantly correlated with other weather variables (Table 2).

Egg parasitisation of C. partellus in relation to weather parameters

Eggs of *C. partellus* were majorly parasitized by egg parasitoid, *Trichogramma* sp. from 27th SMW (1st week of July, 5 DAG) to 31st SMW (last week of July, 33 DAG) and the extent of parasitisation ranged from 0.80 to 6.53 per cent (Table 1). Similarly, *T. chilonis* was first recorded during mid-

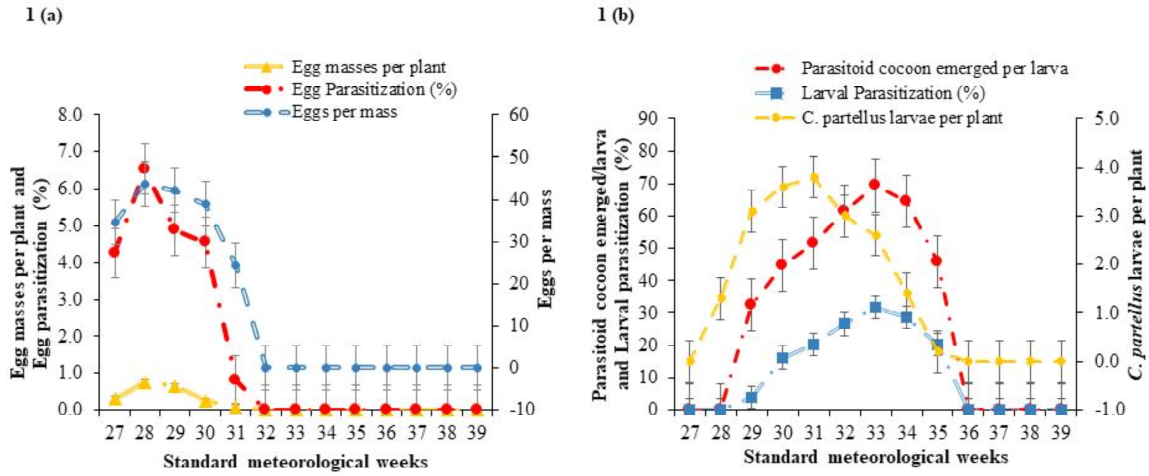

Fig.1: Parasitisation of *C. partellus* by egg parasitoid, *Trichogramma* sp. (1a) and larval parasitoid.

July and extent of parasitisation varied from 14 to 40 per cent in Pakistan (Farid *et al.,* 2007). Contrary to Jalali & Singh, 2003, we observed low rate of parasitisation during early stages when egg masses per plant (0.30 egg masses/ plant) and eggs per mass (34.56 eggs/mass) were low. However, parasitisation increased considerably with increase in egg masses per plant (0.75 egg masses/plant) and eggs per mass (43.78 eggs/mass) during 28th SMW (Fig 1a), and no egg parasitisation was recorded after 31st SMW due to cessation of egg laying by *C. partellus* (Fig 1a).

Egg parasitoid, *Trichogramma* sp. exhibited highly significant positive correlation with average minimum temperature (r=0.797) and negative correlation with morning relative humidity (r=-0.506) (Table 2). Likewise, *T. chilonis* had highly significant and positive correlation with temperature (r=0.718) but non-significant relation with relative humidity in Pakistan (Ahmad *et al.,* 2017). Interestingly, it exhibited significant positive correlation with eggs masses (r=0.941) and eggs per mass (r=0.957) of *C. partellus* indicating a proportionate increase in parasitisation with increase in number of eggs laid (Table 3). Same was reported by Pats *et al*., (1997) suggesting a positive density dependent response.

Larval population of C. partellus and weather parameters

During early stages of crop, larval population was confined to fewer plants but as the crop grew older, population increased during 2nd and 3rd week after crop emergence (Dharmasena, 2002) and it spread all over the field. Larval population of *C. partellus* was first noticed during the 28th SMW (second week of July) and increased up to 31st SMW (last week of July). It experienced a declining trend which continued up to 35th SMW (last week of August) (Table 1) and no larval population was observed thereafter. Mohan *et al.* (1990) also reported maximum larval population from 3rd week of August to 2nd week of September in *Kharif* sorghum in Haryana.

C. partellus remains active from March to November in Northern plains of India (Panwar, 2005) but mainly infest *Kharif* maize during 1st week of July to 2nd week of September with peak activity during August (Patel, 2005). Pest population was found to be active from 3rd week of July to 3rd week of September with maximum population (1.12 larvae/plant) during August (34th SMW) (Patel *et al.,* 2016) and its incidence was higher during July-August sown crop as compared to September-October sown crop in South India (Trehan and Butani, 1949). However, Divya *et al.* (2009) reported maximum larval population in the month of October (0.4 larvae/plant) during *Kharif* season at Dharwad. These variations in the peak activity period could be due to different growing seasons and different meteorological factors prevailing at the time of experimentation.

Larval population of *C. partellus* exhibited significant positive correlation with minimum temperature and evening relative humidity (Table 2) which was also reported by Patel *et al.* (2016). Larval population was non-significantly correlated with rainfall, however, Patel (2005) reported significant positive correlation with rainfall. Kandalkar *et al.* (2000) also reported non-significant correlation with maximum temperature, morning relative humidity, evening relative humidity, total rainfall but contrary to our findings, larval population was found to be significantly negatively correlated (r=-0.734) with minimum temperature in their study.

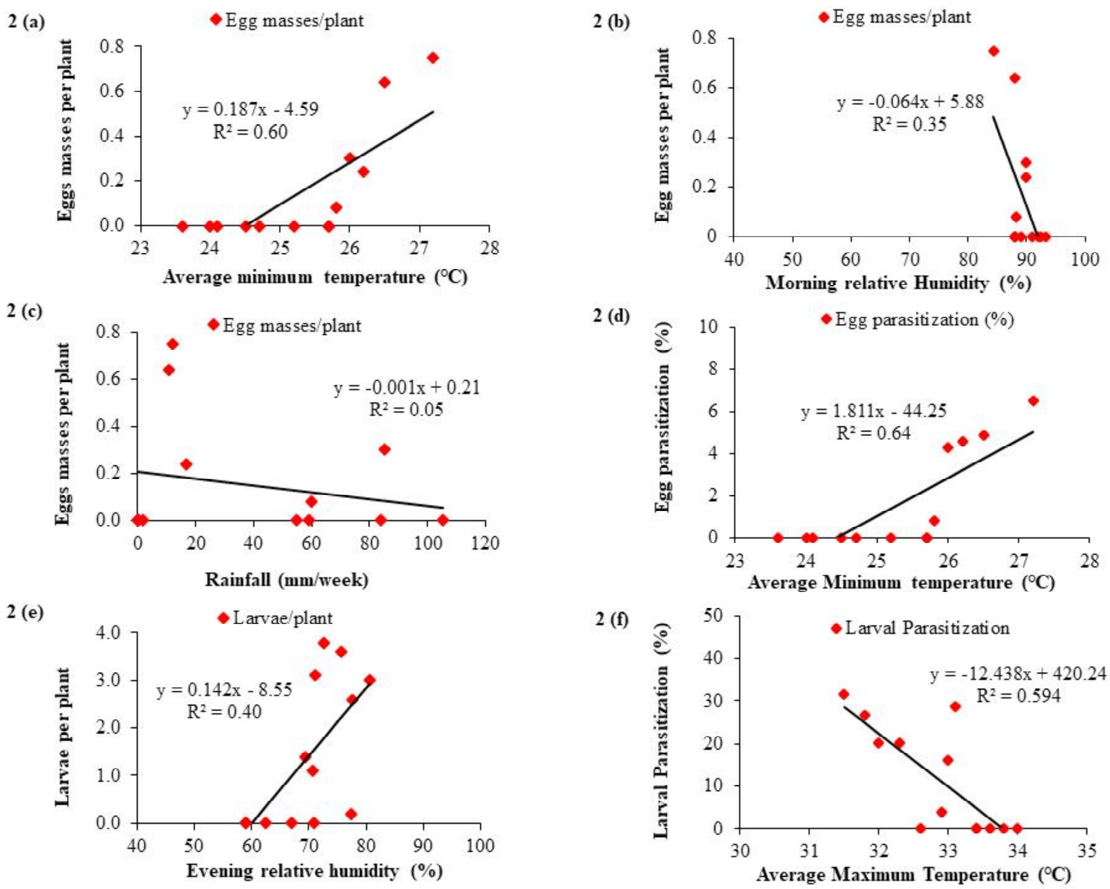

Fig.2: Linear regression line plots of *C. partellus* egg masses with average minimum temperature (2a), morning relative humidity (2b), rainfall (2c), egg parasitisation by egg parasitoid, *Trichogramma* sp. with average minimum temperature (2d), larval population of *C. partellus* with evening relative humidity (2e) and larval parasitisation by braconid wasp, *Cotesia flavipes* with average maximum temperature (2f).

Larval parasitisation of C. partellus in relation to weather parameters

C. partellus larvae were majorly parasitized by Braconid parasitoid, *Cotesia flavipes* starting from 5 DAG till the maturity of the crop with maximum parasitisation (31.64 %) during 33rd SMW (Table 1). Mohan *et al.* (1991) reported 2.0 - 33.2 per cent larval parasitisation of *C. partellus* by *C. flavipes* on sorghum. Likewise, 35-50 per cent larval parasitisation rates has been reported in Himachal Pradesh (Devi and Raj, 1996). Average number of cocoons formed per larva were maximum (69.34 cocoons per larva) when larval parasitisation was at peak (33rd SMW) (Fig 1b). *C. flavipes* adult preferred late instar larvae of *C. partellus* and duration of pupal stage (cocoon formation to adult emergence) (5.05±0.25 to 6.25±0.19 days) was minimum in cocoons emerged from final instar *C. partellus* larvae. *C. flavipes* preferred 4th instar larvae and failed to complete life cycle on 1st, 2nd and 3rd instars of *C. partellus* (Khan *et al.,* 2017). They further reported significant difference in pupal duration of *C. flavipes* from parasitized 3rd, 4th and 5th instar larvae (6.46 ± 0.13, 5.06 ± 0.21 and 5.12 ± 0.31 days, respectively).

Larval parasitoid, *C. flavipes* had a highly significant negative correlation with maximum temperature (r= -0.741), highly significant positive correlation with evening relative humidity (r=0.695) and significant positive correlation with rainfall (r=0.622) (Table 2). Minimum temperature, morning relative humidity and sunshine hours were non-significantly correlated with *C. flavipes* activity. In contradiction, Shrivastava (2015) reported non-significant negative correlation with temperature, rainfall and positive significant correlation with relative humidity. These variations could be due to crop sown during different seasons and climatic conditions prevailing at the time of experimentation. A

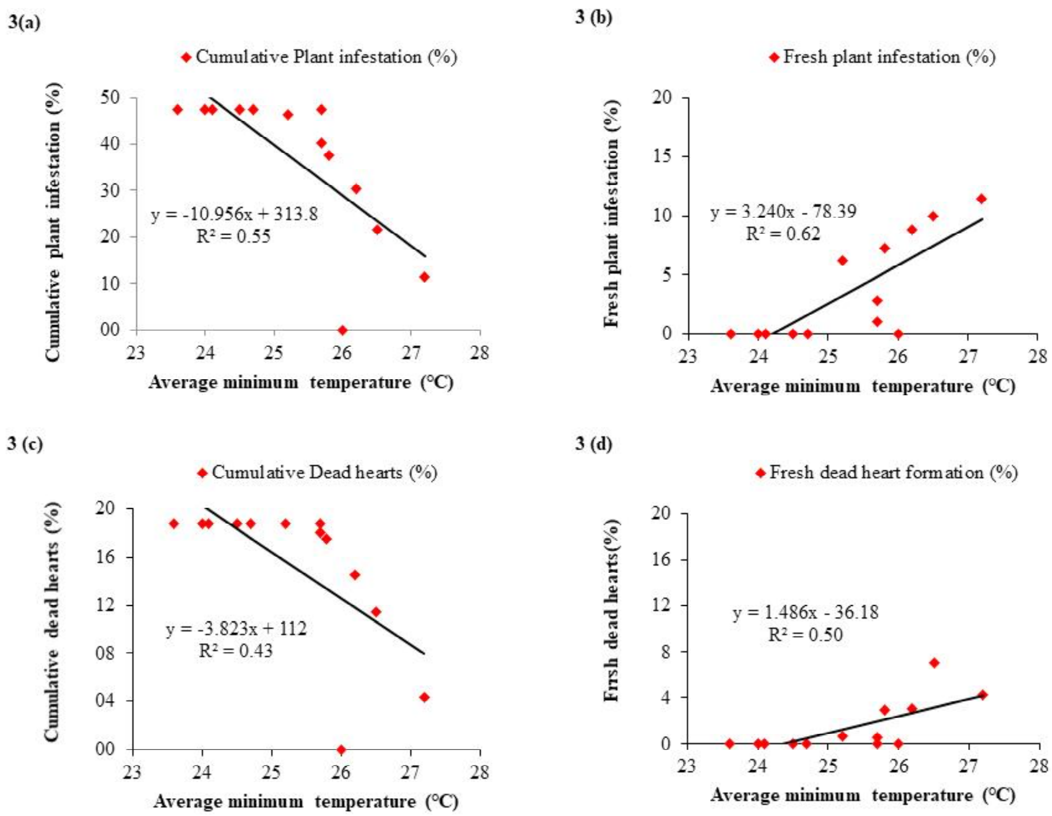

Fig.3: Linear regression line plots of *C. partellus* cumulative plant infestation (3a), fresh plant infestation (3b), cumulative dead heart formation (3c) and fresh dead heart formation (3d) with average minimum temperature.

significant positive correlation (r=0.591) was reported between larval population of *C. partellus* and parasitisation by *C. flavipes* (Table 3) which is in complete agreement with Patel *et al.* (2016).

Pupal population of C. partellus and weather parameters

Pupae of *C. partellus* were recovered from maize stem, under the leaf sheath, from mid-rib of leaves and even from maize cob. Larvae of *C. partellus* attained maturity and started transforming into pupae during 31st SMW. The pupal population was maximum (1.5 pupae/plant) during 35th SMW (last week of August) and declined thereafter (Table 1). Besides this, pupal population had a non-significant negative correlation with maximum temperature, minimum temperature and non-significant positive correlation with all other weather parameters (Table 2). Only one study regarding pupal density of *C. partellus,* where maximum number of pupae (19/50 plants) were recorded during 44th SMW (Divya *et al.,* 2009), was found in the literature.

In addition to egg and larval parasitoids, parasitisation by two pupal parasitoids, *Tetrastichus* sp. and *Sturmiopsis* sp. was also observed but their rate of parasitisation was very low (1.40-5.20 % and 0.80-2.40%, respectively) (Rao *et al.,* 2001).

Plant infestation and dead heart formation by C. partellus

Plant infestation by neonate larvae started during 28th SMW (second week of July) and increased up to the maximum (47.5 %) during 34th SMW (third week of August). No further plants were infested after this point due to the decrease in number of larvae and transformation of larval population into pupal stage (Table 1). However, maximum fresh plant infestation (11.5%) was recorded during 28th SMW which followed a declining trend afterwards up to 34th SMW when only one per cent of fresh plants were infested.

Dead hearts were first observed during 28th SMW (4.3%) and increased gradually to the peak value (18.8 per cent) during 33rd SMW (Table 1), and no further increase in dead hearts was observed. On the other hand, maximum fresh dead hearts (7.1%) were recorded during 29th SMW and declined afterwards up to 33th SMW when only 0.7 per cent of fresh dead hearts were observed.

Table 1: Population dynamics of *C. partellus* in relation to different weather parameters on maize hybrid, HM 10 during *Kharif,* 2017

SMW	DAG	Egg masses plant^{-1}	*C. partellus* eggs per mass	Egg parasitisation (%)	Larvae plant^{-1}	Larval Parasitisation (%)	Pupae plant^{-1}	CPI	FPI	CDH	FDH	T (Max)	T (Min)	RH (M)	RH (E)	SSH	R
27	5	0.30	34.56	4.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.4	26	90	70.9	4.5	85.6
28	12	0.75	43.78	6.53	1.10	0.00	0.00	11.50	11.50	4.30	4.30	33.6	27.2	84.3	70.6	6.1	12.0
29	19	0.64	42.12	4.88	3.10	3.79	0.00	21.50	10.00	11.40	7.10	32.9	26.5	88	71.1	6.3	10.6
30	26	0.24	38.96	4.55	3.60	16.14	0.00	30.30	8.80	14.50	3.10	33.0	26.2	89.9	75.6	2.7	17.0
31	33	0.08	24.26	0.80	3.80	20.20	0.10	37.50	7.20	17.50	3.00	32.3	25.8	88.3	72.6	6.5	59.8
32	40	0.00	0.00	0.00	3.00	26.58	0.40	40.30	2.80	18.10	0.60	31.8	25.7	92.4	80.6	4.3	05.4
33	47	0.00	0.00	0.00	2.60	31.64	0.60	46.50	6.20	18.80	0.70	31.5	25.2	92	77.6	4.7	83.8
34	54	0.00	0.00	0.00	1.40	28.57	0.90	47.50	1.00	18.80	0.00	33.1	25.7	89	69.4	6.5	59.3
35	61	0.00	0.00	0.00	0.20	20.16	1.50	47.50	0.00	18.80	0.00	32.0	24.7	93.3	77.4	4.9	55.0
36	68	0.00	0.00	0.00	0.00	0.00	0.70	47.50	0.00	18.80	0.00	32.6	24.5	87.9	67.1	9.5	00.0
37	75	0.00	0.00	0.00	0.00	0.00	0.40	47.50	0.00	18.80	0.00	33.4	24.1	87.9	62.4	9.9	01.8
38	82	0.00	0.00	0.00	0.00	0.00	0.40	47.50	0.00	18.80	0.00	34.0	24.0	88	59	7.0	00.0
39	89	0.00	0.00	0.00	0.00	0.00	0.30	47.50	0.00	18.80	0.00	33.8	23.6	91	59	4.0	00.0

SMW= Standard Meteorological Week; DAG= Days After Germination; CPI=Cumulative Plant Infestation (%); FPI=Fresh Plant Infestation (%); Cumulative Dead Hearts (%); Fresh Dead Hearts (%); T (max)= Average Maximum Temperature (°C); T (min)= Average Minimum Temperature (°C); RH (M)= Morning Relative Humidity (%); RH (E)= Evening Relative Humidity (%); SSH = Sunshine Hours; R= rainfall (mm per week)

Table 2: Correlation of *C. partellus* with different weather parameters

Weather parameters	Egg masses $plant^{-1}$	Larvae $plant^{-1}$	Pupae $plant^{-1}$	Cumulative plant infestation (%)	Fresh plant infestation (%)	Cumulative dead hearts (%)	Fresh dead hearts (%)	*Trichogramma* sp.	*Cotesia flavipes*
Maximum temperature (^{0}C)	0.282	-0.515	-0.404	-0.256	-0.140	-0.329	-0.015	0.309	-0.741^{**}
Minimum temperature (^{0}C)	0.775^{**}	0.594^{*}	-0.453	-0.739^{**}	0.789^{**}	-0.659^{*}	0.709^{**}	0.797^{**}	0.225
Morning relative humidity (%)	-0.593^{*}	0.088	0.509	0.362	-0.400	0.384	-0.454	-0.506	0.520
Evening relative humidity (%)	0.114	0.635^{*}	0.151	-0.198	0.409	-0.109	0.227	0.174	0.695^{**}
Sunshine hours	-0.118	-0.397	0.150	0.283	-0.268	0.226	-0.116	-0.280	-0.377
Rainfall (mm/week)	-0.213	0.356	0.174	-0.141	-0.045	-0.108	-0.220	0.083	0.622^{*}

*: Significant at P=0.05%; **: Significant at P=0.01%

Similar level of plant infestation by *C. partellus* has been reported in different parts of India and the world (Farid *et al.,* 2007; Naz *et al.,* 2003; Patel *et al.,* 2016; Segeren *et al.,* 1995). Maximum plant infestation was recorded during 33rd SMW in Gujarat, however, dead hearts were maximum (62%) in the month of July (Biradar *et al.* 2011).

Fresh plant infestation and fresh dead hearts exhibited positive correlation with minimum temperature, however, cumulative plant infestation and cumulative dead hearts had a negative correlation with minimum temperature (Table 2). Mahadevan and Chelliah (1986) also suggested positive relation between minimum temperature and plant infestation. Likewise, negative correlation (r=-0.527) of *C. partellus* plant infestation with minimum temperature was reported by Patel *et al.* (2016). Both cumulative and fresh plant infestation had a non-significant correlation with all other weather parameters, like Jeengar *et al.* (2010). Pragati *et al.* (2014) and Dhaliwal *et al.* (2018) also found similar relations between plant infestation and dead hearts, and different weather parameters. However, literature is silent on relation of fresh plant infestation and fresh dead heart formation with weather parameters.

Multiple linear regressions

Weather parameters accounted for 86 per cent variability in egg density of *C. partellus* over the entire duration of crop (R^2=0.86) and 82 per cent of this was contributed by average minimum temperature and rainfall *i.e.* these two were the most important factors responsible for fluctuations in egg density of *C. partellus* (Table 4 and Fig 1a, 1c). Evening relative humidity accounted for significant 40 per cent variability (Table 5 and Fig 1e) in larval population of *C. partellus* out of the total variation of 68 per cent (R^2=0.68) (Table 4). Similarly, all meteorological parameters accounted for 57 per cent variability in pupal population of *C. partellus* (R^2=0.57) but no single weather factor explained it significantly (Table 4).

On the other hand, average minimum temperature was the single most important factor governing cumulative plant infestation by contributing 55 per cent of the total variability (Table 5 and Fig 3a). Abiotic factors were responsible for significant 93 per cent variability (R^2=0.93) (Table 4) in fresh plant infestation (regression equation Y5) and minimum temperature accounted for 62 per cent variability (Table 5 and Fig 3b). Average minimum temperature was reported to be the most important factor responsible for 43 and 50 per cent variability in cumulative (Fig 3c) and

Table 3: Correlation between *C. partellus* and its egg and larval parasitoids

Parasitoids	Egg masses/plant	Eggs per mass	Larvae/plant
Egg parasitoid, *Trichogramma* sp.	0.941**	0.957**	-
Larval parasitoid, *C.flavipes*	-	-	0.591*

*: Significant at P=0.05%; **: Significant at P=0.01%

Table 4: Multiple linear regression of *C. partellus* with weather parameters

	Multiple linear regression equations	R^2
Egg masses (Y1)	Y1 = - 10.175 - 0.023X1 + 0.341X2 + 0.045X3 - 0.022X4 + 0.008X5 - 0.003X6	0.86
Larvae (Y2)	Y2 = 88.228 - 2.732X1 + 1.232X2 - 0.095X3 - 0.240X4 - 0.420X5 - 0.008X6	0.68
Pupae (Y3)	Y3 = - 17.809 + 0.293X1 - 0.242X2 - 0.101X3 + 0.070X4 + 0.135X5 - 0.002X6	0.57
Cumulative Plant infestation (Y4)	Y4 = 1023.06 - 12.722X1 - 14.597X2 - 2.285X3 + 0.199X4 - 0.972X5 - 0.073X6	0.74
Fresh plant infestation (Y5)	Y5 = 288.830 - 6.388X1 + 2.877X2 - 1.208X3 - 0.411X4 - 1.531X5 - 0.055X6	0.93
Cumulative dead hearts (Y6)	Y6 = 404.595 - 6.720X1 - 4.195X2 - 0.536X3 - 0.141X4 - 0.454X5 - 0.046X6	0.69
Fresh dead hearts (Y7)	Y7 = - 16.407 - 3.279X1 + 4.122X2 + 0.674X3 - 0.523X4 - 0.057X5 - 0.050X6	0.88

X1: Average maximum temperature (^{0}C) ; X2: Average minimum temperature (^{0}C); X3:Morning relative humidity (%); X4: Evening relative humidity (%); X5: Sunshine hours; X6: Rainfall(mm/week)

Table 5: Step wise multiple linear regression showing the contribution of major weather parameters in variability of different stages and damage of *C. partellus*

	Step-wise multiple linear regression equations	R^2
Egg masses (Y1)	Y1 = - 4.590 + 0.187X2	0.60
	Y1 = - 5.392 + 0.224X2 -0.003X6	0.82
Larvae (Y2)	Y2 = - 8.550 + 0.142X4	0.40
Cumulative Plant infestation (Y4)	Y4 = 313.804 – 10.956X2	0.55
Fresh plant infestation (Y5)	Y5 = - 78.39 + 3.239X2	0.62
Cumulative dead hearts (Y6)	Y6 = 112 – 3.823X2	0.43
Fresh dead hearts (Y7)	Y7 = - 36.178 + 1.486X2	0.50

X2: Average minimum temperature (^{0}C); X4: Evening relative humidity (%)

fresh dead hearts (Fig 3d) respectively (Table 4 and 5). Contrary to this, Dhaliwal *et al.* (2018) reported 33.48 per cent variation in dead heart formation due to maximum temperature and evening relative humidity.

CONCLUSION

Peak egg and larval population occurred during 28th and 31st SMW, respectively whereas maximum cumulative plant infestation (47.5%) and dead hearts (18.8%) were recorded during 34th and 33rd SMW, respectively suggesting control measures should be initiated during early stages of crop growth. Larval population exhibited significant positive correlation with minimum temperature and evening relative humidity (r= 0.635) but cumulative plant infestation and cumulative dead heart formation had a highly significant negative correlation with minimum temperature. *Trichogramma* sp. and *Cotesia flavipes* exhibited highly significant positive correlation with egg and larval population of *C. partellus,* respectively suggesting a positive density dependent response. Further studies are required to ascertain potential of egg and larval parasitoids at different release rates and this thorough knowledge of population dynamics studies of *C. partellus* in relation to biotic and abiotic factors will strengthen the development of efficient pest management strategies in future.

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