



Influence of summer weather on prevalence of rice yellow stem-borer in central India: Monitoring and biocontrol strategy



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ABSTRACT

Light and pheromone trap-catches of yellow stem-borer (YSB) [*Scirpophaga incertulas* (Walker)] were monitored in low-land rice during summer 2017 in the Chhattisgarh, India region to develop biological control management strategies for areas with low winter temperatures. High catches of males and females in light trap started during March 05 to 11th, 2017, in association with 8.5% dead-heart symptom, indicative of YSB damage to the central shoot, which continued during May 14 to 20th, 2017 and, thereafter declined. Male moth catches in pheromone traps started during the same time as in light trap and peaked from May 07 to 13th, 2017. White ear, due to YSB causing empty panicles in the ear-bearing stage, appeared during April 23rd to 29th, 2017 and reached a peak of 22.8% during May 21st to 27th, 2017. Increase of temperature coupled with reduction of relative humidity and scanty rainfall were favourable to the multiplication of YSB and trap catches in summer rice. These data are helpful for planning biological control against YSB in rice during the Chhattisgarh summer.

1. Introduction

Rice (*Oryza sativa* L.) is grown on 3.6 million hectares in Chhattisgarh, India, with the productivity ranging between 1.2 to 1.6 t/ha depending upon the rainfall (Anonymous, 2009). It is estimated that more than hundred species of insects feed on rice and caused severe damage (Pathak, 1977; Muralidharan and Pasalu, 2006). Most of them are minor, sporadic and they occasionally produced economic loss. However some insects significantly damage the rice growth and yield and they are considered as major pest of the rice and are predominantly important (Senthil-Nathan, 2015).

The rice stem borers in the order Lepidoptera are very serious pests. In India, 18 stem borer species in the family Pyralidae and three species in the family Noctuidae have been recorded (Muralidharan and Pasalu, 2006; Annamalai et al., 2018). The rice stem-borers are reported to cause economic crop losses up to 60% (Daryaei, 2005; Muralidharan and Pasalu, 2006; Rahaman et al., 2014; Manikandan et al., 2016; Annamalai et al., 2018) by inducing symptoms of dead heart and white ear (empty ear panicles) during active tillering and reproductive stages of the crop, in all the seasons, respectively. The Yellow Stem-Borer (YSB), *Scirpophaga incertulas* (Walker) has been found to be a predominant insect pest of rice in the Chhattisgarh region.

Climate change, will affect insect behaviour as well as distribution and abundance, evidenced by increasing in the number of generations a year, increasing survival rates in winter, and the earlier appearance of majority of the insects (Patel and Singh, 2017). Further meteorological factors play an important role in seasonal abundance, distribution and population build-up of stem-borer (Pandey et al., 2001). YSB causes significant yield loss in lowland rice grown during November to March season (Hugar et al., 2010). The maximum damage to rice was reported during 36 and 37th meteorological standard week (MSW) for YSB (Kakde and Patel, 2014; Murali-Baskaran et al., 2017). The maximum incidence of stem-borer was reported in lowland rice during summer, especially in March, at Karaikal, India (Adiroubane and Raja, 2013). A 3-year study on light trap catch of YSB in lowland rice of Raichur, Karnataka indicated that the maximum activity of adults was during March in summer crop that recorded 1764 mean trap catches (Naganagoud et al., 1999). In the *rabi* [winter (October to March)] growing season, dead heart or white ear per cent showed significant positive correlation with morning and afternoon relative humidity and non-significant positive correlation with the mean sunshine hours per day (Hugar et al., 2010). According to Mishra et al. (2005), stem-borer damage had a positive significant correlation with maximum and minimum daily temperatures, and a negative correlation with relative humidity. Acknowledged of abundance and

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distribution of pests in relation to weather parameters will be helpful for developing any pest management programme for a specific agro-ecosystem including the use of *Trichogramma* sp. for biological control during the peak time of YSB egg production (Patel and Singh, 2017). A typical knowledge of the seasonal abundance and population dynamics is vital important to ensure timely awareness to handle the pest problems and prevent crop losses (Das et al., 2008; Patel and Singh, 2017). Hence the monitoring was made in summer rice (2017) with the help of light and pheromone traps in Central India to find out how YSB prevalence including male and female moth catches on standard meteorological week basis, damage potential and number of broods varied in response to the weather parameters, carryover of YSB population from rainy season (July to October) rice to summer (March to May) rice via winter season (November to February) and how such information could be used to ascertain the time of availability of maximum egg load of YSB and further release of its egg parasitoid, *Trichogramma japonicum* for management.

2. Materials and methods

2.1. Installation and monitoring of traps

Rice yellow stem-borer (YSB) sex pheromone traps @ 5/acre and one light trap (160 W mercury bulb) @ 1 per ha were erected on 1st March 2017 (Summer 2017) in lowland rice (Cv. MTU 1010) at Baronda farm of ICAR-National Institute of Biotic Stress Management, Raipur (Latitude 21° 23' 0" N Longitude 81° 49' 36" E), Chhattisgarh, India region. YSB lure (Scirpolure) was mounted in a trap, manufactured by Pest Control of India Ltd., Bengaluru, India and installed in transplanted rice field, one in each corner (10 m away from bund) and a fifth one at the centre of the field. Adults of male YSB caught in the pheromone trap counted and collected throughout the monitoring period (10 to 24 MSW) were killed. The lure was replaced once in a fortnight for six times during the experiment. Light trap was operated from 7 pm to 5 am and YSB adults of both sex were collected, immobilized at -80 °C and counted, daily. Date of first appearance of adults and number of peak catches were recorded. Damage caused by YSB including dead-heart and white-ear were recorded once in a week.

2.2. Observation

Damage potential of YSB was observed in five hills, selected randomly in five different places in an acre area and calculated as per the formulae, given below.

$$\text{Percent dead heart} = \frac{\text{Number of dead hearts/hill}}{\text{Number of total tillers/hill}} \times 100$$

$$\text{Percent white ear} = \frac{\text{Number of white ears/hill}}{\text{Number of productive tillers/hill}} \times 100$$

The weather data on maximum and minimum temperature, rainfall and relative humidity from 10 to 24 MSW were collected from automatic weather station at Baronda farm. A correlation coefficient and multiple linear regression were calculated by taking per cent dead-heart, white-ear, light and pheromone trap catches as dependent variables with the weekly mean meteorological data as independent variables once in a fortnight. Rice was cultivated under lowland condition, following all agronomic practices and maintained under unprotected condition throughout the experimental period during summer 2017.

2.3. Statistical analysis

Correlation coefficient (r) was estimated by the formula given by Gomez and Gomez (1985) as (IRSTAT).

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2) - (\sum x)^2][n(\sum y^2) - (\sum y)^2]}}$$

Where x = Independent variable (Climatic factors), y = Dependent variable (trap catches, % dead-heart, % white-ear), n = No. of observations.

3. Results and discussion

3.1. Light and pheromone trap catches of YSB during summer 2017

The first male (100/trap) and female (104/trap) YSB light-trap catches appeared during March 05 to 11th, 2017 (10th MSW) which induced 8.5% dead-heart. Thereafter, the catches per trap declined from 73 (March 12 to 18th, 11th MSW, 2017) to 22 (May 14 to 20th, 20th MSW, 2017) for males while female catches per trap declined from 101 (March 12 to 18th, 11th MSW, 2017) to 65 (May 14 to 20th, 20th MSW, 2017). During this period, dead-heart increased (12.7%); attained peak (17.4%; 14th MSW) and declined to 4.1% at 20th MSW ($F_{6,28} = 47.08$, $P \leq 0.001$) (Table 1). The first white-ear (4.5%) appeared on 17th MSW (April 23rd to 29th, 2017) when the light trap catch of male and female were 13 and 66/trap, respectively, and the white-ear peaked to 22.8% (21st MSW; May 21st to 27th, 2017) with catches of 5 and 26 per/trap, respectively. White-ear then declined to 4.3% by 24th MSW. The two peak catches of female ($F_{6,28} = 387.58$, $P \leq 0.001$) adults of YSB in light traps were indications for the presence of broods, one at 10th MSW (104/trap) and another at 16th MSW (74/trap) (Table 1) which might indicate the presence of maximum egg load i.e., 5–7 days (pre-mating period + mating period + pre-oviposition period + oviposition period) from the day of each peak catch when the release of egg parasitoid, *Trichogramma* spp. would be optimum for the management of YSB at egg stage itself. Data on light trap catch (female) were useful to identify the number of broods of YSB that would lead to the development of biological control strategies.

Pheromone trap catches of male YSB initiated on 4th day after installation of traps in transplanted rice field and 18/5 traps were caught from March 05 to 11th, 2017 (10th MSW) with dead-heart of 8.5%, which reached to the maximum of 85/5 traps (19th MSW; May 07 to 13th, 2017) with 4.8% dead-heart and 12.6% white-ear, thereafter it declined to 54, 40, 28 and 5 numbers/5 traps during 19th to 23rd MSW.

The maximum light trap catches of YSB was recorded during 3rd week of April with peak dead-heart incidence during 1st week of April (Summer 2017) whereas in another study conducted at Tungbhadra project area of Karnataka (Naganagoud et al., 1999), the peak incidence and trap catches were recorded during 1st week of May. Pheromone and light trap used as monitoring tools in the present study were on competition in attraction of male moths of YSB. Initially, the males were attracted to the light trap in greater numbers than to the pheromone (Table 1). The differential performance of both traps in luring male moths was due to the influence of climatic conditions especially an increase of temperature coupled with reduction of relative humidity and non-interference by rainfall, which ultimately enhanced the efficiency of pheromone trap through increasing the evaporation rate of the volatile chemicals impregnated inside the rubber septa (Murali Baskaran et al., 2017).

3.2. Infestation level of rice YSB

The dead-heart symptoms produced by the feeding of YSB larva on rice during summer 2017 ranged from 2.2 (May 21st to 27th, 2017; 21st MSW) to 17.4% (April 02nd to 08th, 2017; 14th MSW). The symptom started during 10th MSW (8.5%); reached the maximum of 17.4% during 14th MSW and declined to 2.8% during 22nd MSW. As the crop matured, the first white-ear (4.5%) appeared during 17th MSW; reached maximum (22.8%) during 20th MSW and declined to 4.3% during 24th MSW. The abundance of YSB in terms of trap catches noticed in the early stage of summer rice crop of the present study (nursery itself as well as 3–5 days after transplanting) is mainly due to the climatic condition of Chhattisgarh state, India region which is peculiar and characterized by the temperature, ranging from 6 °C and 16 °C during the winter from

Table 1

Damage potential and trap catches of rice stem-borer and meteorological parameters in wet land rice during summer 2017.

Meteorological Standard Week	Period	Yellow stem borer		Pheromone Trap catches Male YSB (Nos./5 trap)	Light trap catches (Nos./trap)		Max. Temp (°C)	Min. Temp (°C)	RH (%)	Rain fall (mm)
		Dead heart (%)	White ear (%)		Female YSB	Male YSB				
10	March 5 to 11, 2017	8.5	0	18	104	100	27.9	17.8	71.9	4.8
11	March 12 to 18, 2017	12.7	0	18	101	73	27.3	15.3	65.0	0
12	March 19 to 25, 2017	15.2	0	24	96	45	30.6	18.0	61.3	0
13	March 26 to April 1	13.1	0	27	69	39	34.4	22.1	44.4	0
14	April 2 to 8, 2017	17.4	0	32	52	32	35.2	24.9	47.9	1.7
15	April 9 to 15, 2017	7.5	0	38	48	21	34.3	21.1	33.5	0
16	April 16 to 22, 2017	7.1	0	44	74	13	37.7	25.3	39.8	0
17	April 23 to 29, 2017	5.3	4.5	60	66	13	35.1	23.3	31.1	0
18	April 30 to May 6, 2017	5.3	7.7	65	61	14	37.1	26.8	37.9	0
19	May 7 to 13, 2017	4.8	12.6	85	52	18	36.6	25.4	54.7	0.2
20	May 14 to 20, 2017	4.1	18.1	54	65	22	40.6	28.6	39.6	0
21	May 21 to 27, 2017	2.2	22.8	40	26	5	39.2	28.7	35.2	0
22	May 28 to June 3, 2017	2.8	15.2	28	19	6	35.7	27.1	65.0	1.2
23	June 4 to 10, 2017	0	8.1	5	6	0	35.6	28.1	54.8	0
24	June 11 to 17, 2017	0	4.3	2	2	1	33.0	26.4	71.3	0

November to February, as reported by [Amit Kumar et al. \(2015\)](#) in most of the rice growing areas of North India. Due to the extreme low temperature during winter, the larvae of YSB which infest the lowland rice in later stage of crop (late tillering or flower initiation stage), being grown during *khariif* (June to October monsoon season) have the habit of entering into pupal diapause in the remnants of rice plant (culm) until adequate climatic conditions revive. Whenever, the rice fields are brought into cultivation during summer (March) through ploughing the remnants along with diapause stages of YSB and further irrigation to cultivate short duration rice cultivars, the diapaused YSB pupae start emerging due to revival of conducive conditions (optimum temperature & moisture) and congregate on the summer rice nursery itself or on 3 to 5-day-old transplanted seedlings for laying eggs. This is uncommon in rice, grown from June to October (*khariif* season) where they appear in 25–30 days-old transplanted crops, as pointed in several studies ([Adiroubane and Raja, 2013](#); [Hugar et al., 2010](#); [Murali Baskaran et al., 2017](#)).

In previous studies to investigate the crop yield-stem borer relationships, the percent incidence of white ear head, dead heart and injury has been used as an analytical set of independent variables for estimating losses ([Israel and Abraham, 1967](#); [Muralidharan and Pasalu, 2005](#); [Reji et al., 2008](#); [Yang et al., 2009](#); [Shi et al., 2008](#); [Manikandan et al., 2016](#)). The potential yield of the rice cultivars has also often been derived from a plot with maximum protection against the YSB ([Pathak, 1969](#); [Waibel, 1996](#); [Muralidharan and Pasalu, 2005](#)). Accordingly, in this study, the severity of dead-heart was noticed from initial stage of transplanted rice (8.5%) which continued and reached the maximum of 17.4% (ETL is 10% dead-heart) on 14th MSW, because of revival of conducive climate, provided by continual increase of maximum and minimum temperature from 27.9 to 35.2 °C and 17.8–24.9 °C, respectively. Thereafter, gradual reduction of dead-heart was noticed due to the advancement of crop to reproductive stage and tolerance mechanism of the plant by compensating the dead-hearts with new tillers.

3.3. Correlation of weather parameters with damage and trap catches of YSB

The maximum temperature ($F_{7,32} = 5.98$, $P \leq 0.001$), ranging from 27.3 to 40.6 °C during the period of study had significant positive correlation with white-ear ($r = + 0.672$) ($F_{7,32} = 65.88$; $P \leq 0.001$) and pheromone trap (male YSB) catch ($r = + 0.540$) ($F_{7,32} = 123.77$; $P \leq 0.001$) while it was negatively correlated with light trap catches [$r = - 0.496$ (male YSB) ($F_{7,32} = 354.40$; $P \leq 0.001$); $r = - 0.772$ (female YSB) ($F_{7,32} = 266.16$; $P \leq 0.001$) and dead-heart ($r = - 0.456$) ($F_{7,32} = 146.07$; $P \leq 0.001$) with $R^2 = 0.81$ which explains 81% of total variability in the dead heart produced by YSB and trap catches ([Table 2](#)). Researchers have reported that the development time is positively correlated with temperature ([Pathak and Khan, 1994](#)). [Manikandan et al. \(2016\)](#) has pointed out survivorship of the YSB was decreased with increasing temperature. The time taken for fifty percent mortality also decreased with increasing temperature. It was proved that most of the insects reared under higher temperature has very low survivorship and died earlier as they were not able to tolerate higher temperatures. It was previously proved with other insect pest. [Kuo et al. \(2006\)](#) reported less than 15% of *Tetraneura nigriabdominalis* nymphs survived when the temperature increased from 10 °C to 35 °C.

In general, it was reported that high temperature is positively correlated and favourable for the growth and development of borers of rice ([Kumar and Sudhakar, 2001](#)), however this statement holds good to the Southern states of India where, extreme reduction of temperature is uncommon during winter while in central India, like Chhattisgarh state, the temperature ranging from 6 °C to 16 °C during winter season reduces insect activity. Hence the correlation between maximum and minimum temperature and dead-heart, in the present study was significantly negative ([Table 2](#)) which was supported by [Adiroubane and Raja \(2013\)](#) and contradicted by the results of [Mishra et al. \(2005\)](#) and [Hugar et al. \(2010\)](#) who found that temperature had positive correlation with

Table 2
Correlation between weather parameters and damage and trap catches of yellow stem-borer in wet land rice during summer 2017.

Independent factor	Dependent factor	Correlation coefficient (r)	Co-efficient of determination (R ²)
Maximum Temp. (°C)	Dead heart (%)	- 0.456	0.81
	White ear (%)	+0.672	
	Pheromone Trap catches (Nos.)	+0.540	
	Light trap catches-Female (Nos.)	- 0.496	
	Light trap catches-Male (Nos.)	- 0.772	
Minimum Temp. (°C)	Dead heart (%)	- 0.667	0.83
	White ear (%)	+0.714	
	Pheromone Trap catches (Nos.)	+0.265	
	Light trap catches-Female (Nos.)	- 0.767	
	Light trap catches-Male (Nos.)	- 0.835	
Relative humidity (%)	Dead heart (%)	- 0.040	0.55
	White ear (%)	- 0.202	
	Pheromone Trap catches (Nos.)	- 0.590	
	Light trap catches-Female (Nos.)	+0.031	
	Light trap catches-Male (Nos.)	+0.436	
Rainfall (mm)	Dead heart (%)	+0.194	0.65
	White ear (%)	- 0.205	
	Pheromone Trap catches (Nos.)	- 0.225	
	Light trap catches-Female (Nos.)	+0.307	
	Light trap catches-Male (Nos.)	+0.660	
Light trap catch of female stem-borer	Dead heart (%)	+0.693	0.48
Light trap catch of female stem-borer	White ear (%)	- 0.492	
Light trap catch of male stem-borer	Dead heart	+0.609	0.39
Light trap catch of male stem-borer	White ear	- 0.499	
Pheromone trap male stem-borer	Dead heart	- 0.060	0.16
Pheromone trap male stem-borer	White ear	+0.346	

dead-heart.

The relative humidity had non-significant correlation with damage (dead-heart & white-ear) caused by YSB and light trap catches, however, it had significant negative correlation with pheromone trap catches (male YSB) ($F_{7,32} = 123.77$; $P \leq 0.001$) which envisaged the increase of the efficiency of pheromone lure, as the relative humidity decreased. The periodical tapering of relative humidity from 71.9% (10th MSW) to 35.2% (21st MSW) was unfavorable to dead-heart caused by YSB, however, it could not be noticed to have any impact on white-ear and further reduction of it beyond 22nd MSW was due to the reach of the crop into physiological maturity stage.

The total rainfall of the entire summer 2017 was scanty (8 mm) that could not have significant impact on YSB damage and trap catches (Table 1). Similar observations were also reported by Mishra et al.

(2012) and Patel and Singh (2017) as *S. incertulas* moth exhibiting their peak activity in the month of September. However, Varma et al. (2000) reported three peak periods viz., July, August and September of *S. incertulas* moth activity during *kharif* season. Also depending upon the weather conditions, particularly the amount of rainfall during the cropping period starting from June to October could influence the pest occurrence to a great extent. The warm temperature is also an important criteria for the pest. The relative humidity had shown negative correlation with dead-heart and white-ear as in the case of results enumerated by Bhatnagar and Saxena (1999) and Hugar et al. (2010) but it was non-significant with damage caused by YSB (Table 1). Rainfall during summer 2017 was insufficient to have significant correlation with most of the dependent factors (Table 1), as also observed by Kumar and Sudhakar (2001).

However, Rehman et al. (2002) found that low temperature, high relative humidity and rainfall resulted in *S. incertulas* outbreak. Rai et al. (2002) reported that *S. incertulas* adult population had no significant correlation with temperature while it was positively correlated to maximum relative humidity and sunshine. Padhi and Saha (2004) also reported that maximum temperature, rainfall and relative humidity were negatively correlated while minimum temperature, evaporation and sunshine were positively correlated to *S. incertulas* adult population. Our findings also in agreement with Adiroubane and Raja (2013) and Patel and Singh (2017) reported a negative correlation of dead heart percentage with temperature. In contrast, Rao (1996) and Rehman et al. (2002) reported no influence of temperature and relative humidity on pheromone trap catches while Padhi and Saha (2004) reported YSB moth population had positive correlation with temperature, rainfall and relative humidity.

3.4. Correlation between trap catches and damage by YSB

The male ($r = + 0.693$) ($F_{6,32} = 259.63$; $P \leq 0.001$) and female ($r = + 0.609$) ($F_{7,32} = 152.22$; $P \leq 0.001$) of YSB trapped in light trap were positively correlated with dead-heart ($r = 0.693$, 0.609) ($F_{6,28} = 47.08$; $P \leq 0.001$) and negatively with white-ear ($r = - 0.492$, $- 0.499$) ($F_{6,28} = 473.57$; $P \leq 0.001$) which explains 48 and 39% of total variability in the incidence of YSB, respectively (Table 2). The correlation of numbers of male YSB caught in the pheromone trap ($F_{6,28} = 89.99$; $P \leq 0.001$) was negative with dead-heart ($r = - 0.060$) ($F_{6,28} = 50.55$; $P \leq 0.001$) and positive with respect to white-ear ($r = + 0.346$) ($F_{6,28} = 84.00$; $P \leq 0.001$) which were *vice versa* with male YSB caught in light trap (dead-heart = + 0.609; white ear = - 0.499) and explains only 16% of total variability (Table 1).

4. Conclusion

Monitoring of rice YSB with light and pheromone traps from 10 to 24th standard meteorological week of summer 2017 in lowland rice at Central India region provided information about YSB peak abundance, number of broods and their enabled correlation of trap captures with weather parameters. Further the information on two broods of YSB indicated the presence of maximum egg load in rice fields on which first release of egg parasitoid, *T. chilonis* can be initiated for efficient biocontrol of YSB. The data generated in these studies could be supportive to biological control of rice yellow stem borer.

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