Studies on reproductive biology of yellow stem borer, *Scirpophagaincertulas*walker (Lepidoptera: Pyralidae) in the changing climate scenario

Abstract

Studies on reproductive biology of yellow stem borer, *Scirpophagaincertulas*walker in the changing climate scenarioconducted at Agriculture Research Station, Gangavathi during 2020-22.Results on post eclosion~~behaviour~~behavior of yellow stem borer revealed that themaximum female moths emerged between 18:00 and 21:00 hrs from among the emerged moth the female calling was observed between 23:00 and 02:00 hrs. The time of mating commenced after the calling period and was observed between 23:00 and 03:00 hrs. The average pre-oviposition period, oviposition period and post-oviposition period were completed in 1.09 ± 0.09, 1.28 ± 0.17, and 0.85 ± 0.25 days, respectively. The longevity of adult ~~female~~ females and ~~male~~ males was about 3.23 ± 0.29 and 2.66 ± 0.33 days, respectively. The total number of eggs laid varied from 68 to 221 in number with an average of 146.95 ± 43.98 per female.The Operational and intrinsic sex ratio of YSB were observed to be ~~female biased~~female-biased with 1:1.35 and 1:1.44 of male to female moths, respectively.

~~**Key words**~~**Keywords:** Biology, climate,female calling, operational sex ratio, yellow stem borer

Introduction

The biotic stresses such as insect pests, nematodes, diseases, and weeds limit ~~the~~ food production globally. Among the biotic stresses, insect pests constitute the major yield limiting factors throughout the ~~rice growing~~rice-growing countries. All together 21 species of lepidopteran stem borers have been recorded as rice pests throughout the world. Of these, 8 species are known to occur in India (Rao, 1965 and Pathak, 1975). Among these lepidopteran insect pests attacking on rice, yellow stem borer, *S. incertulas*, white stem borer, *Scirpophagainnotata*(Walker), stripped stem borer, *Chilosuppressalis* (Walker), dark headed borer, *Chilopolychrysus*(Meyrick) and pink stem borer, *Sesamiainferens*(Walker) are economically important.

The yellow stem borer (YSB) infests rice plant throughout the cropping period. At tillering stage, the stem borer larva enters in the tiller and feeds inside resulting in “dead heart”. Whereas, in the central leaf whorl does not unfold, turns brownish and dries out although the lower leaves remain green and healthy. The affected tillers do not bear panicles. At reproductive stage, the damage is characterized by conspicuous whitish empty panicles which are called “white ear head” (Dutta and Roy, 2018). YSB causes 1 to 19 per cent yield loss in early planted and 38 to 80 per cent in late transplanted rice crops (Choudhary et al., 2017). Being associated closely with paddy due to its monophagous nature, reported to cause 20-70 per cent yield loss (Sharma et al., 2018).

In Karnataka, the incidence and damage level of yellow stem borer varies from region to region. Mysuru, Mandya and Chamrajanagara districts of Karnataka recorded 5-40 per cent damage (AICRP, 2019). In Shivamogga the per cent dead heart and white ear head ranges from 5.70-32.20 and 11.40-38.50, respectively during *kharif* and per cent

dead heart and white ear head ranges from 3.12-36.50 and 12.20-22.80, respectively during summer (Shilpa et al., 2018). In Tungabhadra project area, reported that 1.20 per cent dead heart during vegetative stage and 1.00 per cent white ears at harvest was recorded. Whereas, in Gangavathi <2 per cent dead heart and <5 per cent white ear head damage was recorded due to yellow stem borer (ICAR-IIRR, Progress Report, 2019).

Though the pest is monophagous and closely associated with the crop throughout the cropping period, the available management strategy seems to be inadequate.Current management practices are mainly aimed at chemical approaches, resulting in indiscriminate application with often unsatisfactory results.Better understanding of its reproductive biology in the changing climate scenariocould lead to its effective management. As climate change exacerbates the pest problem, there is a great need for future pest management strategies by understanding its reproductive biology.

Materials and method

The present investigation was carried out in rice growing Tungabhadra command regions of Karnataka during 2021-2022. Studies on the reproductive biology of yellow stem borer was conducted at Agriculture Research Station, Gangavathi.

Post-eclosion~~behaviour~~behavior of yellow stem borer

For this study, 25 days old seedlings were transplanted in pots and grown up to 40 days and cylindrical plastic sheets were covered around the pots to avoid the escape of the moths and 10 per cent honey solution was provided. On each night of observation, one pair of pupa which were ready to emerge with same age were placed on the soil at the base of the rice plant at the center and this was replicated ten times. Observations of adult activity after emergence were recorded at 10-20 min intervals from 18:00 to 06:00 h, using a flashlight fitted with a red cellophane filter paper. The experiment was conducted on four nights. Observations recorded on time of emergence, time of female calling, time of mating, number of mating, duration of mating, pre-oviposition period, oviposition period, post oviposition period, fecundity and longevity.

Operational sex ratio (OSR)

OSR is the ratio of males and females that are available for mating at a given point of time. Moths collected in tray- water light traps were sexed and the sex ratio was noted. Pupae were collected from the field at a particular period when availability is more. After collection of pupae sexing was carried out. Sex ratio was estimated by using the formula:
Sex ratio = Total number of female/ Total number of male

Intrinsic sex ratio (ISR)

For this study 25 days old seedlings of paddy were transplanted in 5×5 m plot and grown up to 40 days. The plots were covered with net throughout the cropping period to avoid the entry of YSB moths. Five pairs of freshly emerge moths were released in netted plot and allowed for egg-laying and then the experimental plots were kept under observation for different developmental stages. After emergence, adults were collected through light trap and pheromone trap and their sex was determined based on presence of a black spot on the wing and a tuft of yellowish hairs at anal end. The analysis was performed to determine the sex ratio.

Results and discussion

Post eclosion~~behaviour~~behavior of yellow stem borer

The results on post eclosion~~behaviour~~behaviorof *S. incertulas* studied at Agriculture Research Station, Gangavathi during *Kharif* 2021 are documented.

There is a definite pattern observed with respect to different reproductive ~~behaviour~~behavior in female such as time of emergence, time of female calling and time of mating. Maximum female moths emerged between 18:00 and 21:00 hrs from among the emerged moth the female calling was observed between 23:00 and 02:00 hrs. The time of mating commenced after the calling period and was observed between 23:00 and 03:00 hrs and duration of mating varied from 60 to 150 minutes (Table 1). The similar observation was made by Cuong and Cohen (2003) who reported that the peak of moth emergence occurred between 19:00 and 21:00 h. The moths become active about 2-3 h after emergence. Female calling was first observed at 22:00 h. The first mating was observed at midnight and the duration of mating was from 1 to 2 h.

The ~~pre- oviposition~~pre-oviposition period was varied from 1 to 2 days with an average of 1.09 ± 0.09 days; the oviposition period was varied from 1 to 2 days with an average of 1.28 ± 0.17 days and post-oviposition period was varied from 0 to 1 day with an average of 0.85 ± 0.25 day. The longevity of adult varied from 3 to 4 days with an average of 3.23 ± 0.29 days in female and 2 to 3 days with an average of 2.66 ± 0.33 days in male. The total number of eggs laid varied from 68 to 221 in number with an average of 146.95 ± 43.98 per female. Similarly,Gautam *et al.* (2020) studied the biology of yellow stem borer. The results revealed that the pre-oviposition, oviposition and post oviposition period of 1.0 ± 0.06, 1.5 ± 0.08 and1.0 ± 0.07 days was recorded in *kharif*, 2015 and 1.3 ± 0.07, 1.7 ± 0.09 and 1.2 ± 0.05 days in *kharif*, 2016. The similar situation has also been shown by Hugar *et al*., (2010) who observed that in aerobic rice, the total no. of egg masses laid 2.3, fecundity (No. of eggs/female) 159.3, no. of eggs hatched on 6^{th} day 73.8, 7^{th} day 71, pre oviposition period (hr.) 25.6, oviposition period (hr.) 23.0, post oviposition period (hr.) 20.3. In transplanted rice the total no. of egg masses laid 2.4, fecundity (No. of eggs/female) 152.2, no. of eggs hatched on 6^{th} day 69.8, 7^{th} day 64.3, pre oviposition period (hr.) 25.2, oviposition period (hr.) 22.0, post oviposition period (hr.) 20.2.

On an average female lived for 3.23 days and male 2.66 days, a shorter adult longevity in YSB is also reported by several other researchers. The present observation is in line with the report of Panigrahi and Rajamani (2008) reported that the male and female longevity of 2.64 and 2.96 days, respectively. The similar situation has been reported by, Sameer (2009) that the male and female longevity of 2.40 and 2.93 days, respectively.

Operational sex ratio of yellow stem borer collected in different locations through light trap

Operational sex ratio (OSR) was determined by collecting moths from light trap which was installed in three different locations during the moth activity period. Of the 741 moths trapped at ARS, Gangavathi during 2021, 319 were male and 422 were female moths; (male: female = 1:1.32; Chi-square test; χ^2 = 7.16; p<0.0002).There were 1905 moths trapped at KVK, Gangavathi, of which 985 were male and 920 were female moths (male: female = 1:0.93; Chi-square test; χ^2 = 1.11; p<0.14). In Ayodhya, 738 moths were trapped and 347 of them were male and 391 female moths (male: female = 1:1.13; Chi-square test; χ^2 = 1.31; p<0.11). Of the 1600 moths sampled in ARS, Gangavathi 2022,

759 were male and 820 were female moths (male: female = 1:1.08; Chi-square test; χ^2 = 1.30; p<0.10).The sex ratio was female biased in all locations except KVK, Gangavathi (Table 2). Sex ratio ranged between 0.93 and 1.32. The present observation is in line with the report of Baskaran et al., 2017, who recorded the sex ratio (male: female) was found to be 1:1:32.

Operational sex ratio of yellow stem borer observed from field ~~collected pupae~~collected pupae from different locations

The OSR was determined by collecting pupae of YSB from various locations and recording the sex of pupae. Total 14 samples were drawn from different locations *viz.*, ARS, Gangavathi, Ayodhya, Kesarahatti, Gonal and Dhadesugur. Collected samples were brought to the laboratory then male and female pupae were separated and sex ratio was determined.

In total, 14 samples were drawn from five different locations during the study period collecting 575 pupae of which 245 were males and 330 were females with sex ratio of 1:1.35 (male: female).Observation revealed the female biased sex ratio in all the locations ranging from 1.09 to 1.44 with an average of 1.35 (Table 3). Interestingly there is a difference in the OSR between light trap catches and the field pupae collected in the present investigation, the sex ratio observed in the light trap catches was an average of 1:1.11 whereas, it was 1:1.35 in the collected pupae. Though the difference is slight but it was less in the light trap catches. The reason could be attributed to the loss of females during flight period towards the light trap.

Intrinsic sex ratio (ISR) of yellow stem borer from laboratory reared moths

A total of 560 moths were recorded from 25 pair of male and female moths. Among 560 moths, 231 were males and 329 were females with a sex ratio of 1:1.44 (male: female~~).The~~). The ISR study was conducted from laboratory reared moth for two seasons in which a total of 560 moths were observed. Interestingly, the sex ratio is also ~~female~~ female-biased biased ranging from 1.34 to 1.53 with an average of 1.44(Table 4). The sex ratio of both lab reared and field collected matched closely. The similar observation was recorded by Sameer (2009), the sex ratio of *S. incertulas*(male: female) under field and laboratory condition was 1: 1.43 and 1: 1.58, respectively.

Conclusion

There is a definite pattern observed with respect to different reproductive ~~behaviour~~behavior in female such as time of emergence, time of female calling and time of mating. Maximum female moths emerged between 18:00 and 21:00 hrs from among the emerged moth the female calling was observed between 23:00 and 02:00 hrs. The time of mating commenced after the calling period and was observed between 23:00 and 03:00 hrs. The average pre-oviposition period, oviposition period and post-oviposition period were completed in 1.09 ± 0.09, 1.28 ± 0.17 and 0.85 ± 0.25 days, respectively. The longevity of adult female and male was about 3.23 ± 0.29 and 2.66 ± 0.33 days, respectively. The Operational and intrinsic sex ratio of YSB were observed to be female biased with 1:1.35 and 1:1.44 of male to female moths, respectively.

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Table 1. Post-eclosionbehaviour of yellow stem borer

Female											Male			
Date of Adult Emergence	No. of moths observed	Time of emergence	Time of Female Calling	Time of mating	Duration of mating (Min)	Pre- Oviposition (Days)	Ovi position (Days)	Post –Oviposition (Days)	Fecundity	Longevity (Days)	Date of male AE	Time of male emergence	Date of male death	Longevity (Days)
12-12-2021	1	18:20	23:10	01:20	70	1.13	1.22	0.84	155	3.18	12-12-2021	18:00	15-12-2021	2.33
	2	19:30	00:00	01:50	130	1.01	1.30	0.83	146	3.14	12-12-2021	19:40	15-12-2021	2.63
	3	20:30	01:50	03:10	90	1.01	1.25	1.06	87	3.34	12-12-2021	20:20	15-12-2021	2.97
	4	21:00	02:10	03:10	100	1.05	1.13	1.29	115	3.48	12-12-2021	21:00	15-12-2021	2.22
	5	18:40	22:50	23:50	130	1.21	1.22	0.88	178	3.30	12-12-2021	18:30	15-12-2021	2.88
13-12-2021	6	18:50	23:30	01:00	140	1.04	1.29	0.84	168	3.17	13-12-2021	18:20	16-12-2021	2.85
	7	18:10	22:50	00:50	90	1.17	0.92	1.00	75	3.08	13-12-2021	18:00	15-12-2021	2.22
	8	19:30	00:10	01:10	110	1.00	1.33	0.83	221	3.17	13-12-2021	19:30	16-12-2021	3.02
	9	20:20	00:20	01:30	100	1.04	1.29	0.31	148	2.65	13-12-2021	20:40	16-12-2021	2.98
	10	19:20	00:10	01:30	90	1.10	1.29	1.17	92	3.55	13-12-2021	19:00	16-12-2021	2.25
14-12-2021	11	20:40	02:10	03:30	60	1.00	1.29	0.88	210	3.17	14-12-2021	20:40	17-12-2021	2.65
	12	19:50	00:20	01:50	70	1.00	1.29	1.08	168	3.38	14-12-2021	19:20	17-12-2021	2.38
	13	20:30	00:40	02:00	100	1.29	1.67	0.84	200	3.80	14-12-2021	20:00	17-12-2021	2.92
	14	19:00	00:20	02:10	120	1.09	1.25	0.35	99	2.69	14-12-2021	19:00	17-12-2021	2.26
	15	19:00	23:00	00:00	90	1.01	1.30	1.00	165	3.33	14-12-2021	19:20	17-12-2021	3.06
15-12-2021	16	18:00	22:50	00:20	140	1.08	1.34	0.84	170	3.26	15-12-2021	18:20	18-12-2021	3.14
	17	19:50	00:40	02:00	90	1.04	1.21	0.88	121	3.13	15-12-2021	19:30	18-12-2021	2.68
	18	20:30	00:30	01:50	130	1.05	1.29	1.13	142	3.47	15-12-2021	20:00	18-12-2021	2.33

	19	19:00	23:40	01:10	60	1.08	1.25	0.81	147	3.15	15-12-2021	19:20	18-12-2021	2.92
16-12-2021	20	21:00	23:10	01:20	120	1.23	1.68	0.30	218	3.22	16-12-2021	21:00	19-12-2021	2.56
	21	20:10	00:00	01:50	100	1.00	1.25	1.01	113	3.26	16-12-2021	20:00	19-12-2021	3.05
	22	19:00	01:50	03:10	140	1.06	1.29	0.38	162	2.73	16-12-2021	19:00	19-12-2021	2.27
25-12-2021	23	19:30	02:10	03:10	70	1.00	1.26	0.84	83	3.10	25-12-2021	19:20	28-12-2021	2.35
	24	20:10	22:50	23:50	80	1.00	1.38	1.17	201	3.55	25-12-2021	20:20	28-12-2021	2.89
	25	19:40	23:40	00:50	120	1.06	1.30	1.00	170	3.38	25-12-2021	19:40	28-12-2021	3.02
	26	19:00	23:50	01:10	110	1.01	1.30	1.00	205	3.33	25-12-2021	18:20	27-12-2021	2.19
26-12-2021	27	18:40	23:20	01:30	80	1.13	1.21	0.88	155	3.22	26-12-2021	18:40	29-12-2021	2.76
	28	18:10	23:10	00:40	110	1.04	1.29	0.92	180	3.25	26-12-2021	18:00	29-12-2021	2.26
	29	18:50	23:40	00:40	80	1.13	1.26	1.00	75	3.39	26-12-2021	18:50	29-12-2021	2.80
	30	19:30	00:00	01:30	90	1.09	1.21	0.88	175	3.17	26-12-2021	19:00	29-12-2021	2.89
	31	20:00	00:50	03:30	60	1.27	0.96	0.39	89	2.63	26-12-2021	20:20	29-12-2021	3.17
	32	21:00	02:00	03:40	90	1.05	1.13	0.75	158	2.94	26-12-2021	20:40	28-12-2021	2.13
27-12-2021	33	18:20	23:00	00:10	110	1.05	1.35	1.26	149	3.67	27-12-2021	18:00	30-12-2021	2.97
	34	18:50	23:30	00:50	70	1.25	0.89	0.80	81	2.96	27-12-2021	19:20	30-12-2021	2.39
	35	20:10	00:10	02:00	100	1.06	1.25	0.81	168	3.14	27-12-2021	20:00	30-12-2021	2.75
	36	19:30	23:50	01:30	150	1.09	1.29	0.88	97	3.26	27-12-2021	19:50	30-12-2021	3.01
	37	20:30	00:20	02:30	90	1.29	1.75	0.67	157	3.71	27-12-2021	20:20	30-12-2021	2.29
28-12-2021	38	21:00	23:30	00:40	100	1.13	1.25	0.35	140	2.74	28-12-2021	21:00	31-12-2021	2.51
	39	18:50	23:40	00:30	90	1.13	1.25	1.00	68	3.38	28-12-2021	19:20	31-12-2021	3.02
	40	19:40	00:10	01:20	120	1.25	1.72	0.84	216	3.83	28-12-2021	20:00	31-12-2021	2.30
	41	20:00	01:20	01:50	100	1.06	1.25	0.79	158	3.10	28-12-2021	20:00	31-12-2021	2.80
Average						**1.09 ±0.09**	**1.28 ±0.17**	**0.85 ±0.25**	**146.95 ±43.98**	**3.23 ±0.29**				**2.66 ±0.33**

Table 2. Operational sex ratio of yellow stem borer collected in different locations through light trap

Sl. No.	Location	Moths observed	Male	Female	Sex ratio	Chi-square
1.	ARS, Gangavathi (2021)	741	319	422	1:1.32	7.16
2.	KVK, Gangavathi	1905	985	920	1:0.93	1.11
3.	Ayodhya	738	347	391	1:1.13	1.31
4.	ARS, Gangavathi (2022)	1600	759	820	1:1.08	1.30
Average		**1246**	**602.50**	**638.25**	**1:1.11**	**2.72**

Table 3. Operational sex ratio of yellow stem borer observed from field collected pupae from different locations

Location	Date	Total Pupae collected	Male	Female	Sex Ratio
ARS, Gangavathi	21-04-2021	61	25	36	1:1.44
	29-04-2021	35	15	20	1:1.33
	29-11-2021	29	12	17	1:1.42
	27-04-2022	31	14	17	1:1.21
	15-05-2022	46	22	24	1:1.09
Ayodhya	22-04-2021	41	19	22	1:1.16
	14-11-2021	24	10	14	1:1.40
	16-04-2022	45	19	26	1:1.37
Kesarahatti	22-04-2021	33	14	19	1:1.36
	13-04-2022	61	25	36	1:1.44
Gonal	15-04-2022	55	23	32	1:1.39
Dadesugur	14-04-2021	56	23	33	1:1.43
	21-04-2021	36	15	21	1:1.40
	22-11-2021	22	9	13	1:1.44
Total		**575**	**245**	**330**	**Average= 1:1.35**

Table 4. Intrinsic sex ratio (ISR) of yellow stem borer from laboratory reared moths

Date of moth release	Total moths	Male	Female	Sex ratio
18.11.2021	122	50	72	1.44
19.11.2021	76	30	46	1.53
19.11.2022	164	70	94	1.34
15.04.2022	83	35	48	1.37
16.04.2022	115	46	69	1.50
Total	**560**	**231**	**329**	**Mean = 1.44**