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Mass culturing of rice yellow stem borer, *Scirpophaga incertulas* W. (Crambidae; Lepidoptera)

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Abstract
Rice is a major crop attacked by several species of stem borers. Among various stem borer species, yellow stem borer *Scirpophaga incertulas* W. is cause considerable damage and severe yield loss in rabi and kharif crops of rice. Host plant resistant and development of durable resistant varieties can provide best alternate to other management strategies. Most of yellow stem borer resistant varieties developed were based on field screening. Artificial screening data provides valid information about the level of resistance in the varieties for long durability of the character in field cultivation. The difficultly in artificial screening is proper mass culturing technique for yellow stem borer and continuous supply of larva or adults for experiments. An attempt has been made on mass culturing of yellow stem borer in susceptible TN-1 and Pusa basmathi-1 plants. During first year mass culturing have been carried out in TN-1 plants and upto III generations was maintained. In the second and third year mass culturing was done with susceptible Pusa basmathi-1 plants. In both years only five generation was maintained continuously. Each year fresh adults were collected from fields to initiate the cultures. In the sixth year there was no adult emergence to continue the mass culture. Various biological parameters like development period, number of male and female emergence in each generation, duration taken for insect emergence, time taken for damage expression, oviposition rate in each generation was recorded and discussed. The first generation data revealed a healthy growth and development of yellow stem borer in the culture. But when the generation progress the parameters showed decline in their growth and development with low emergence of adult insects.

Keywords: Rice, yellow stem borer, *Scirpophaga incertulas*, mass culture, TN-1, pusa basmathi-1

Introduction
Yellow stem borer, *Scirpophaga incertulas* W. is assuming major insect pest in rice. The attack of yellow stem borer on rice is recently in increasing trend and during both kharif and rabi season it attacks the crop. A total of 21 species of lepidopteran stem borers have been reported in rice of which eight species occurs in India [1, 2]. The loss caused by the borers is more than any other insect pest of rice causing 3 to 95 per cent yield losses in India [3]. Yellow stem borer attacks the crop from the seedling up to harvest stage and thus cause complete loss of yield [4]. It attacks at young vegetative stage causes dead hearts as well as at reproductive stage results in white ear formation. The population of stem borer increased in subsequent generation caused serious damage and expectedly is one of the main reasons for successive increases in pest population [5]. Damage by yellow stem borer (YSB), *Scirpophaga incertulas* remained higher at tillering (68.2%) and maximum tillering (72.7%) stage than white stem borer and pink stem borers [6]. Average annual losses to rice borers in China, India, Bangladesh and Southeast Asia were approximately 5–10%, though losses in individual fields may reach 50–60% [7]. The YSB larvae cause serious damage to rice tillers at vegetative stage [4] and at panicle emergence stage [8, 9], although the damage to tillers at vegetative stage is largely compensated. The lowest yields often result from white earhead damage when infestation occurs at or just after the pre-booting stage [10]. The nature of feeding by yellow stem borer prompts its importance in their management. Insecticides are commonly preferred at the farmer level for stem borer management, though often insecticidal applications fail to deliver desired because the insect larvae feed inside the stem pith and remain out of the reach of many insecticides [11]. There are various biological and cultural methods are available for the management of this insect pests.
Development of resistant varieties is also a way to achieve long term management strategies.

However, long back a resistant variety TKM 6 has been released [12] and after there were several attempts were made to screen and identify good source of resistance. The screening of rice varieties for yellow stem borer is achieved upto field level and field resistant in several rice germplasms have been evaluated. But the consistency of resistant can't expect in these entries due to the durability of other problems associated with the evaluation procedures. The field resistance should be confirmed with glass house or artificial screening methods. Most of the varieties evaluated and released are based on field screening only and hence the durability of resistance against yellow stem bore is lacking. The conventional resistance breeding for YSB has not gained much impetus due to the lack of resistance sources in cultivated rice (*O. sativa* and *O. glaberrima*) gene pool [13], want of efficient insect rearing and varietal screening protocols, and inherently complex genetics of resistance [14]. The problem in artificial screening for yellow stem borer is mass culturing methodology. Though International Rice Research Institute (IRRI) published mass culturing methods for different rice insects [15], it is not practically adopted for mass culturing of yellow stem borer. Though controlled screening methods for stem borer resistance is time consuming and laborious, artificial screening provides solid and valid information on varietal resistance [12]. There were little or no attempts were made earlier on mass culturing of yellow stem borer continuously under caged condition in rice plants with their biological factors. With this view an attempt was made to mass culture yellow stem borer under glass house condition. The success and problems in the mass culture of *S.incertulas* and biological parameters was narrated in the research paper.

Materials and methods

Yellow stem borer, *S. incertulas* mass culture was attempted in cages at Entomology glass house, Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore, India. The glass house was maintained with natural condition without any controlled environment. The temperature and relative humidity in the glasshouse ranged from 29º to 37º C and 52 to 80% respectively. The mass culture experiments were initiated during 2016-17 and subsequently during 2017-18 and 2018-19. The universal susceptible variety TN-1 was used during first year experiment. Continuous supply of TN-1 plants of 35 days old was ensured during mass culturing. Plant maintenance has been carried out in a separate room in the glass house. The plants were observed periodically without any insect pests or diseases. Two different types of insect cages were used for rearing of YSB in the glass house. The insect cages used for larval rearing were 2x2x3 ft. size cages and for adult rearing 4x2x3 ft used for oviposition of adult insects on the plants. The initial culture of yellow stem borer egg mass was collected from field during Oct.- Nov. months where the incidence of the stem borer was usually high. The peak incidence of yellow stem borer was reported during October to December months on varieties TN-1 and Pusa basmathi-1 in rice fields of Tamil Nadu [16]. The egg masses were pinned and allowed to hatch on the plants kept in the cages. For each cage 5 plants were kept with one egg mass per plant. Similarly five separate cages were maintained as replication to record the biological parameters of yellow stem borer in each generation. The larval hatching and feeding was ensured by observing the dead heart symptoms. During feeding when the plant dried and shown 60 per cent damage in tillers, the plants were replaced with newer plants. The typical feeding behaviour of YSB in artificial rearing was noticed [17]. During rearing when the plants dried, the third and fourth instar larva came out for another fresh plant to feed. They make holes on the stem of new plants and enter inside. Earlier Satpathi *et al*. [18] also reported the young larval migration within the field on adjacent plants. Most larva disperse by ballooning shortly after egg hatch, a process highly influenced by wind. Hence in the present study at 60 per cent dead heart damage, newer plants are kept for larval migration to fresh plants. The larva pupate inside stem and adults were emerged. The emerged adults were considered as start of first generation and per cage 2 pair of adults were released and the culturing was initiated and followed in all generations. The adult insects laid eggs and larva hatched. Without any disturbance the larva allowed to continue its feeding to pupate. The adults emerged from culture was considered as second generation and allowed for oviposition to proceed to subsequent generation. Likewise the culturing was continued.

The parameters like number of eggs laid, number of male and female adults emerged, duration of emergence, number of days taken for plant damage at 15 and 60%, developmental period in each generation was recorded in five cages. The range and mean of each parameters was observed. In the first year only 3 generation was able to culture continuously. Hence, from second year and third year, 2017-18 & 2018-19, another susceptible variety Pusa basmathi-1 was taken for culturing. Most of the basmathi type aromatic varieties are highly susceptible to yellow stem borer. Several field [19, 20] as well glass house studies [12] have confirmed their susceptible nature. Similar methodology was followed to culture on Pusa basmathi-1 plants in second and third year. The data on biological parameter were collected and mean worked out. The data were subjected to statistical analysis with standard deviation and standard error was calculated.

Results and discussion

Mass culturing of yellow stem borer during first year on susceptible plants TN-1 revealed that continuous culturing was able to done upto three generation (Table 1). The duration from egg laid to adult emergence was considered as development period. The mean developmental period in the first generation was 48.8 days with ranged from 42-60 days. However, in the second and third generation the larva and pupa have taken more time to develop. In the second generation it took 51.2 days where third generation still prolongs to 63.00 days. The range of developmental period was 51-70 days. In general, total duration of life cycle for YSB was 50-70 days [21] for egg to egg period. However another reports stated that average egg to adult period was 45.8 days [22]. Usually prolonged development of larva or pupa is not a favourable factor for insect developmental biology. The duration of development was extended in the third generation in the present study. The total number of male emergence was high in the first generation (11.6), but from second and third generation it was reduced drastically to 5.20 and 8.8 numbers respectively. Similarly, female emergence was maximum in first generation (16.2) and decreasing in second (8.8) and third generation (4.8) on TN-1 plants. The duration of emergence was more in female than male adults. The male adults were emergence at 44.8 days in first generation whereas 48.6 days in second and 58.0 days in third generation. Female took 55.60 days to emerge in the first

generation. In second and third generation, a mean of 57.2 and 64.2 days was taken by the females to emerge. The duration of damage in the plants to reach 15 and 60 per cent was recorded to assess the larval feeding behaviour in each generation. The data indicated that in first generation 15 per cent damage was recorded in 8.8 days whereas second and third generation took 19.6 and 38.6 days. It clearly indicated that larval feeding in advanced generation was relatively low. Similarly 60 per cent plant damage was noticed in 18.6 days in first generation and second and third took 26.0 and 45.2 days. The total number of egg mass laid in each generation was recorded and it was high as 23.2 nos. during first generation and reduced to 5.2 nos. in third generation. There was no adult emergence after third generation. Some of the plants were dissected and observed for the larva inside the stem. Most of larva died in 2 or 3 instar stage. Hence, culturing was discontinued.

In the next season during 2017-18, the culture was initiated with another highly susceptible variety Pusa basmathi-1 plants. The same protocol was followed to continuously culture. The data on biology and development period was recorded. It revealed that comparatively the development period was lower than TN-1 plants and continuously upto V generation the culture was able to maintained. In the first generation the development period was 46.8 days (Table 2). The development period was prolonged to 63.0 days in the fifth generation is almost two month period for egg to adult emergence. The total number of male and female emerged during first generation was 12.0 and 16.0 nos. respectively. During initial generation there was higher female emergence was recorded but when the culturing progress to fifth generation the number of males were more than females. In field normally the male and female ratio was 1:2 [23]. The total number of adult male and female was minimum in fifth generation (3.2 & 2.2 nos.) in the study. The duration of female emergence (48.0 to 59.4 days) was higher than male (43.6 to 53.2 days) in first to fifth generation. The days taken for showing 15 per cent damage in the Pusa basmathi-1 plants was 8 days whereas TN-1 plants also almost took same period. However, Pusa basmath-1 plants took only 13.6 days to express 60 per cent damage in first generation, but TN-1 plants took 18.6 days. It clearly indicates that the variety Pusa basmathi-1 has more susceptible than TN-1 plants. However, the Pusa basmathi-1 plants took 33.8 days to express 60 per cent damage at fifth generation of yellow stem borer mass culture. Oviposition by adult female was also higher in Pusa basmathi-1 in the first generation with 31.4 nos. totally with a mean of 15.7/female adult. However, in the fifth generation the total number of egg mass laid was 1.8 nos. only. The sixth generation adults not emerged and hence the culturing in the second year was discontinued.

Again during 2018-19, fresh culture was started and followed the same procedure to mass culture. The adults were collected from field during Oct.–Nov. and culturing has been carried out. The biological factors indicated as that of last year was observed. The mean development period was 45.4 days in first generation and ended up with 62.2 days in the fifth generation (Table 3). The total male emergence was 6.8 nos. and female emergence was 10.4 nos. in the initial culturing. The adult emergence was poor compared to last year reared on the same Pusa basmathi-1 plants. However, the culturing was done upto fifth generation in the second season with Pusa basmathi-1 plants. The plants took only 7.2 days to show 15 per cent dead heart damage at first generation and took 11.0 days for 60 per cent damage expression. The total number eggs laid by female was higher in first generation with a total of 33.2 and mean of 16.6/adult. But in continuous culturing the female and male emergence become very low and ended with reduced fecundity. A total of 0.8 no. of eggs were recovered from the cages at fifth generation. The total number of female and male emergence was reduced to 2.0 and 2.2 nos. in fifth generation. The normal 1:2 ratio of male and female emergence was not achieved in the glass house rearing which is essential to proceed the generation advancement. The low adult emergence and prolonged duration of development and life cycle hinder the progress of generation.

From three years mass culturing programme it revealed that there are 3 to 5 generations maintained in susceptible rice plants under glass house. Continuous culturing throughout the year was not feasible under glass house condition. Even under field condition reports confirmed that that there are 3 to 5 broods in a year with an average of 4 broods [23]. There may be various factors hinders the continuous mass culturing of yellow stem borer. Normally the susceptible varieties support normal growth and development of insects under artificial condition. Resistant or moderate resistant varieties prolonged development of insect life stages due to antibiosis or biochemical [24, 25]. But when susceptible varieties like TN-1 and Pusa basmathi-1 is not conducive for continuous or normal feeding of stem borer larva clarifies under captivity these insects are not capable for continuous multiplication. There are few reports suggests that during non cropping season yellow stem borers can undergo diapause in the stubbles. During the periods of no crop and the temperature is not optimal the mature larva undergoes diapause in rice stubble [21]. Hibernation or an equivalent period of rest occurs in all but based food supply. The classical Entomologist Lefroy (1909) [26] categories, lepidopteran insects into five groups based on period of rest. The *Scirpophaga* group insects falls in the category that these insects are found to be in food plant throughout the year but the period of hibernation varying with locality and temperature. When the crops are raised the population will develop and reaches its peak. However, in the present study the larva were provided with susceptible varieties for three seasons. There was no artificial diet hitherto developed for *Scirpophaga* group of stem borers. However, diets are developed for other group of stem borers, *Chilo* spp. which attacks sugarcane and millet crops [27,28,29]. The need of self-conscious formalization of rearing insect food science and technology as distinct discipline was put forth by Cohen, 2001 [30]. Artificial diets for *Scirpophga* group can be attempted to further advancement in mass rearing technology.

Table 1: Biological parameters of yellow stem borer on *var*. TN-1 plants (2016-17)

S. No.	Biological parameters	Generation I		Generation II		Generation III	
		Mean (days)	Range (days)	Mean (days)	Range	Mean (days)	Range
1.	Mean developmental period	48.80±1.59	42-60	51.2±1.47	45-61	63.00±1.46	51-70
2.	Total no. males emerged	11.6±0.42	19-24	5.2±0.26	4-7	8.8±0.26	7-10
3.	No. of female emerged	16.2±0.38	15-19	8.8±0.26	7-10	4.8±0.30	3-7
4.	Duration for male emergence	44.8 ±1.14	42-51	48.6±0.64	45-53	58.0±0.89	51-63

5.	Duration for female emergence	55.60±0.91	49-60	57.2±0.96	49-61	64.2±0.97	57-70
4.	Damage symptom expression in days (15%)	8.8±0.29	7-11	19.6±0.46	16-22	38.6±0.77	34-42
5.	Damage symptom expression (60%)	18.6±0.44	16-22	26.0±0.32	24-28	45.2±0.33	43-47
6.	Total egg mass laid	23.2±0.62	20-27	15.4±0.72	12-20	5.2±0.30	3-7
7.	Oviposition rate (egg mass/female)	11.6±0.17	-	7.7±0.23	-	2.6±0.11	-

Values±S.Ed

Table 2: Biological parameters of yellow stem borer in the mass culture on *var*. Pusa basmathi – 1 (2017-18)

S. No.	Biological parameters	Generation I		Generation II		Generation III		Generation IV		Generation IV	
		Mean (days)	Range (days)	Mean (days)	Range	Mean (days)	Range	Mean (days)	Range	Mean (days)	Range
1.	Mean developmental period	46.8±1.05	39-53	49.8±1.56	38-57	53.00±1.60	40-60	58.2±0.68	53-62	63.2±1.17	55-67
2.	Total no. males emerged	12.0±0.42	10-15	8.2±0.17	7-8	13.6±0.46	11-16	8.0±0.11	2-11	3.2±0.22	2-5
3.	No. of female emerged	16.0±0.45	15-19	12.2±0.57	9-16	9.0±0.37	7-12	5.4±0.33	4-8	2.2±0.17	1-3
4.	Duration for male emergence	43.6±0.89	39-49	47.0±1.09	38-52	47.8±0.92	40-52	51.2±1.10	43-57	53.2±0.82	46-56
5.	Duration for female emergence	48.0±0.84	42-53	52.0±1.18	43-57	55.6±1.34	44-60	56.8±1.26	46-62	59.4±1.27	49-65
6.	Damage symptom expression in days (15%)	8.0±0.32	6-10	10.2±0.48	7-13	10.6±0.36	9-13	12.0±0.42	10-15	20.6±0.58	17-24
5.	Damage symptom expression (60%)	13.6±0.46	11-16	17.4±0.42	15-20	20.6±0.58	17-24	27.2±0.38	25-30	33.8±0.29	32-36
6.	Total egg mass laid	31.4±0.56	51.4	19.2±0.89	14-22	7.2±0.29	5-9	5.0±0.24	3-6	1.8±0.29	0-4
7.	Oviposition rate (egg mass/female)	15.7±0.23	-	9.6±0.32	-	3.6±0.26	-	2.5± 0.30	-	0.90±0.24	-

Table 3: Biological parameters of yellow stem borer in the mass culture on *var*. Pusa basmathi – 1 (2018-19)

S. No.	Biological parameters	Generation I		Generation II		Generation III		Generation IV		Generation V	
		Mean (days)	Range (days)	Mean (days)	Range	Mean (days)	Range	Mean (days)	Range	Mean (days)	Range
1.	Mean developmental period	45.4±1.24	35-51	49.4±1.97	36-57	52.4±1.40	40-57	55.4±1.63	41-60	62.2±1.04	54-68
2.	Total no. males emerged	6.8±0.36	5-9	7.0±0.25	5-8	8.2±0.26	7-10	3.8±0.29	4	2.2±0.29	0-4
3.	No. of female emerged	10.4±0.30	8-12	13.4±0.46	10-15	11.4±0.42	9-13	3.2±0.17	2-4	2.0±0.24	0-3
4.	Duration for male emergence	36.6±0.91	30-41	42.4±1.36	32-48	45.8±1.03	37-50	48.2±0.95	40-52	53.6±1.19	44-58
5.	Duration for female emergence	44.5±0.92	37-49	48.0±1.14	38-52	52.8±1.57	39-57	54.0±1.48	41-58	59.2±1.39	47-64
6.	Damage symptom expression in days (15%)	7.2±0.29	5-9	8.4±0.42	6-11	10.8±0.29	9-13	14.8±0.48	12-18	18.4±0.23	17-20
5.	Damage symptom expression (60%)	11.0±0.32	9-13	13.4±0.52	10-16	17.8±0.46	15-20	28.8±0.46	26-31	36.0±0.32	34-38
6.	Total egg mass laid	33.2±0.52	32-37	18.6±0.48	16-22	9.0±0.32	7-11	2.2± 0.29	0-4	0.8±0.16	0-2
7.	Oviposition rate (egg mass/female)	16.6±0.23	-	9.30±0.68	-	4.5±0.11	-	1.1±0.30	-	0.4±0.24	-

Conclusion

It is clearly indicating that yellow stem borer mass culturing for several generations is difficult but which is highly essential for artificial screening for resistance. Mass culturing of yellow stem borer can be done every year freshly to get larva for artificial resistance screening experiments or evaluation of bio control agents and newer insecticides. Yellow stem borer culture can be rejuvenated every year with fresh field population and 4 or 5 generation can be maintained. Within the period the artificial screening experiments can be carried out to evaluate durable resistant sources for YSB. Development for artificial diets for yellow stem borer is an unexplored area of research in rice Entomology.

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