World Applied Sciences Journal 17 (4): 532-539, 2012
ISSN 1818-4952

Consequences of Feeding by Yellow Stem Borer (*Scirpophaga incertulas* Walk.) On Rice Cultivar *Swarna mashuri* (MTU 7029)

[1]C.R. Satpathi, [2]Kaushik Chakraborty, [1]D. Shikari and [1]P. Acharjee

[1]Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalay (University) Mohonpur, Nadia, 741252, West Bengal, India
[2]Department of Zoology, Alipurduar College, Alipurduar, Jalpaiguri.736122. West Bengal, India

Abstract: Feeding by yellow stem borer (*Scirpophaga incertulas* Wlk.) larvae and the consequences of damage to internode was assessed on the paddy cultivar *Swarna mashuri* (MTU 7029) at the *Chakdah* Regional Research Station of *Bidhan Chandra Krishi Viswavidyalaya* (University) for three consecutive years (2007-2009) by randomized block design. Grossly there were five larval instars. All the morphs varied considerably in both size and shape. The relative length of 1st, 2nd, 3rd and 4th instar larvae was 17.01±0.09mm, 18.72±0.62mm, 19.13±0.27mm and 19.54±0.54 mm respectively. The full grown larvae was 20.32±1.23 mm. Considerable difference regarding the relative position and number of damaged internodes'(s)/plant, larval individual(s)/plant, nature of feeding and the incidence of damaged tiller(s)/hill was assessed. The entire incidence was expressed in percentage. Incidence of 1 larvae/tiller (75.72%) and 2 damaged internodes/plant (63.32%) were more common. 62.26% of larval population was found to penetrate through the topmost internodes' while the remaining 25.88% and 11.86% larvae bore through the second and third internodes' respectively. Deep circular stem feeding was observed for 81.94% larvae. Incidence of partially emerged white head (59.19%) dominated the field. In insecticide untreated field 3.61% and 13.01% tillers got larval infestation at vegetative and reproductive growth stage respectively. While external symptoms of dead heart were only 1.50% and 13.07% respectively for these two growth stages.

Key words: *Swarna mashuri* · Paddy yellow stem borer · Larva · Larval damage

INTRODUCTION

India is the second largest producer of rice in the world. A number of insect pests are reported to ravage the rice fields in tropics [1]. Stem borers (SBs) are key group of insect pests of rice [2, 3]. The yellow stem borer (YSB), *Scirpophaga incertulas* Walker (Pyralidae: Lepidoptera) is one of the major pests in all rice producing areas of Asia [4], in south east Asia [3, 5] and India in particular [6, 7]. YSB shares about 89.50% of the total rice borer population in West Bengal which is considered as the prime rice growing centre of India [3, 8]. Recurrent rice grain loss due to this pest attack is a reported phenomenon [9-11]. Larval feeding and subsequent internodal penetration during vegetative and reproductive stage cause severing of the growing apical plant part and finally results in the characteristic symptom of dead heart (DH) and whitehead (WH) at vegetative and reproductive growth stage of rice plant respectively. Formation of DH and WH is responsible for yield loss [12, 13]. The extent of borer induced yield losses have been estimated to range from 30 to 70% in outbreak years and from 2 to 20% in non outbreak years in Bangladesh [7] and in India [6, 14] respectively. Though due to physiological compensatory mechanism rice plant can tolerate a low level of DH formation without any final yield loss. But for the increase of every percent of WH there was 1.3% yield loss [15-17]. Adoption of integrated pest control methodology under modern IPM mostly relies on the bio-ecology of the pest species, *i.e*, identification of the most vulnerable developmental stage of pest life cycle and side by side its interaction with the growing crop plant.

Thus a suitable management protocol befitted to the bio-ecology of the pest is urgently needed. In this contemplation and in order to visualize the damage

Corresponding Author: C.R. Satpathi, Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalay (University) Mohonpur, Nadia, 741252, West Bengal, India.

potentiality of YSB on rice cultivar *Swarna mashuri* (MTU 7029), a study for three consecutive years (2007-2009) was undertaken at Chakdah, a regional experimental station of *Bidhan Chandra Krishi Viswavidyalaya* (University), West Bengal, India.

MATERIALS AND METHODS

Geographic Location and Agro-Climatic Conditions: Experiment was conducted at the regional research station of *Bidhan Chandra Krishi Viswavidyalaya* (University) located at *Chakdah* [20°31´ (N) - 85°53´ (E)], Nadia, West Bengal. The region belongs to new alluvial zone. The climate of this zone is sub-tropical humid in nature. The season of this area is broadly classified in three groups, *viz*, dry and warm (March-May), wet and warm (June-October), dry and cool (November-February) respectively. The monsoon generally sets in by the middle of June and recedes by middle of October. The average annual rain fall varies from 1500 to 2000 mm, the maximum rainfall occurs during the rainy months of June to September amounting to more than 80% of the total rain fall. The mean maximum temperature is usually high 36.9°C in April and low 9.1°C in the early part of January. The relative humidity at 8:30 hours is 65% and 95% in March and July respectively. The relative humidity in the afternoon at 17:30 hours is 55% and 90% in March and November respectively.

Experimental Layout: Field experiment was conducted in randomized block design with 35 days old transplanted seedlings of widely adopted paddy cultivar *Swarna mashuri* (MTU 7029) at 15x10 cm seedling spacing during three consecutive crop seasons of 2007-2009. The soil of the experimental field was sandy loam with PH-6.5 and EC-0.29 mmhs/cm. Before starting the experiment, field N, P_2O_5 and K_2O was 332, 57 and 357 kg/ha respectively. Triple super phosphate (TSP), Muriate of potash (MOP), gypsum and zinc sulphate was applied basally to the main field and at the rate of 120, 85, 60 and 10 kg/ha.

Assessment on Larval Behavior: In each plot, both the incidence and the behavior of YSB larva on rice plant covering the early vegetative growth stage till to the yellow maturation growth stage was noted by visual observation. Observation was done mostly in the early morning and sometimes in late evening. For this purpose, 50 hills in each plot were selected diagonally and the relative distribution of larval population in relation to the alteration crop phenology due to progressive plant growth was noted. In each occasion fresh rice hills was considered.YSB covers 5 larval stages in a single life cycle and 2 such life cycle on *Swarna mashuri* crop during *kharif* season. Observation encompasses all the larval stages; however attention was more given to 5th instar mature larvae.

Assessment on Larval Induced Damage: YSB infestation results in dead heart (DH) and white head (WH) during vegetative and reproductive growth stages respectively. Extent of larval infestation was assessed at two growth stages (vegetative and reproductive stages respectively) in both insecticide treated and untreated plots in three replications for three consecutive years. Insecticide was applied at 25 and 75 days after seedling transplantation (DAT) respectively to the main field. For insecticide application table 1 was followed.

Incidence of DH (%) and WH (%) was assessed from 50 hills diagonally selected from each plot during vegetative and panicle formation stage respectively and from that percentage was calculated following the formula as described below:

$$\text{DH and WH (\%)} = \frac{\text{Number of DH and WH x 100}}{\text{Total number of tillers counted}}$$

Average number of tillers was calculated from 50 hills, selected diagonally in each plot and the incidence of both infested and uninfected tillers/hill was assessed.

Statistical Analysis: The pooled data was statistically analyzed by programme-software INDOSTAT- ANOVA and accordingly CD value was determined. Correlation was also done between the field incidence of larval population and the consequences of DH (%) and WH (%).

Table 1: Pesticide formulation, type and the application dose

	Insecticide treatment schedule		
Growth stage of rice	*Generic name*	*Type*	*Applied dose/ha*
Seedling root dip treatment	Carbandizm	50 WP	2.5gm/L
Vegetative	Fipronil	0.3 G	0.045 kg
Early reproductive	Monocrotophos	36 WSC	1125 ml

RESULTS AND DISCUSSIONS

Morphometric changes during larval development, roaming behavior during migration from tiller to tillers and the extent of damage by yellow stem borer (*Scirpophaga incertulas* Wlk.) larvae in relation to crop phenology was assessed on the rice cultivar *Swarna mashuri* (MTU 7029) at the *Chakdah* Regional Research Station of *Bidhan Chandra Krishi Viswavidyalaya* (University) for three consecutive years (2007-2009) by randomized block design. The Results are delineated below:

Observation on the Morphometric Changes in Relation to Larval Development (Table 2): The newly hatched larvae of *S.incertulas* are pale white in colour whereas; last instar (fifth instar) was dirty white in colour. In *Swarna mashuri* field the larvae pass four molts before attaining the mature 5th instar stage. The first instar larva is small in size with restricted movement and was non-gregarious in feeding habit. Second, third and fourth instar larva were creamy white in colour with black head and comparatively more gregarious. The relative length of 1st, 2nd, 3rd and 4th instar larvae was 17.01±0.09mm, 18.72±0.62mm, 19.13±0.27mm and 19.54±0.54 mm respectively (Fig. 2a). The relative length of head capsule of 1st, 2nd, 3rd and 4th instar larvae was 0.25±0.02 mm, 0.48±0.05mm, 0.78±0.05 mm (Fig. 2a) and 0.97±0.06 mm respectively. The larva becomes full grown in about 34-42 days. Full grown larvae measures about 20.32±1.23 mm long with a head capsule of 1.28±0.03mm. It is mostly white and in some occasional cases yellowish white with a well developed prothoracic shield. Before pupation it covers the exit hole with thin webbing and then forms a white silken cocoon in which it pupates.

Observation on the Larval Dispersal: Dispersal depends on the extent of YSB larval congregation. Adoption of high number of *Swarna mashuri* seedlings per hill accommodates and protects more YSB larval population.

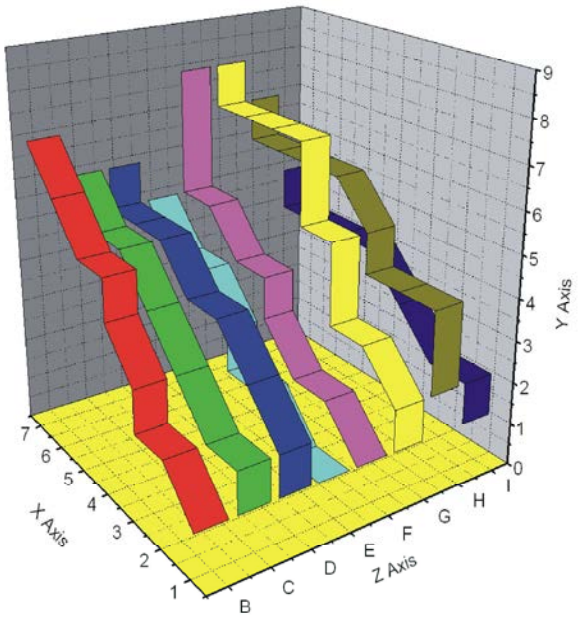

Fig. 1: Spatial distribution of *Scirpophaga incertulas* larvae over time, in experiments conducted in the field of *Swarna mashuri*

For this 2-3 rice seedling per hill during transplantation is thus found optimum for the cultivar *Swarna mashuri*. The first instars are invariably non-motile and do not migrate; the second and fourth instars show moderate migration. But the third instar migrates actively. The fifth instar, on the other hand, hardly moves. Most larvae disperse by ballooning shortly after egg hatch, a process highly influenced by wind. During dispersal larvae themselves hang down by silken thread and get blown to adjoining plants or may fall on water and swim freely till they get to rice plant. Average migratory period for third instar larvae in *Swarna mashuri* field at 10x15 cm seedling spacing ranges from 10 to 19 minutes. For migration, the larva usually come out of the stem whorl, encloses within a case of leaf bits, dropped themselves on field water and subsequently attacks a fresh tender rice plant.

Table 2: Measurement on total body length + head capsule width (mm) of five different YSB larval instars in relation to the instar duration (period) of *Scirpophaga incertulas* from the field of *Swarna mashuri* (MTU 7029)

	Morphometric measurement		
Larval instars	Mean larval length (mm±SE)	Head capsule (mm±SE)	Duration (days)
1	17.01±0.09	0.25±0.02	6.41±0.58
2	18.72±0.62	0.48±0.05	5.62±0.72
3	19.13±0.27	0.78±0.05	4.72±0.84
4	19.54±0.54	0.97±0.06	5.53±1.21
5	20.32±1.23	1.28±0.03	7.34±1.02

High deposition of silica in the rice cultivar *Swarna mashuri* helps the larvae to decorate a silken treat and their firm attachment during areal undulation for subsequent dispersal. However depth of field water and hill to hill distances of rice plant influences the searching capability of the newly non-infested plant at positive (r: 0.782) and negative (r:-0.574) manner respectively. Greater proportion of neonates dispersed from vegetative plants than booting plants. Further neonates from vegetative plants disperse more than booting plants. This is related to the phenological alteration of rice crop in relation to growth. Number of tiller increases during the vegetative stage and the maximum number were attained before the booting stage. Rice tillers at booting stage have greater stem diameter and therefore ensures comparatively higher amount of food resources and offers greater survival value to larval population. In field condition, it is noted, if 9 batches of 3rd instar larvae each with 10 individuals (A-I) was placed on a centre hill, within 48 hours as single larvae could cross the 7 hill distance (Fig. 1).

Observation on the Niche Specification: In healthy YSB egg masses, all the eggs hatch within a few minutes of each other, usually in early or midmorning. Newly emerged *S. incertulas* larvae crawl out to the leaf tips. No definite territorial boundary or the niche size for the larvae of *S.incetulas* on the rice cultivar *Swarna mashuri* was noted. However, usually one larva on one tiller is found but in occasional case 2 to 4 larvae may also be reported. It probably depends on the length of the tiller and vegetative growth potentiality of the rice cultivar relating to larval forage. Observation showed that about 61% larvae remained at the top most internodes' while the second and third node accommodated 25% and 14% larvae respectively. This may be due the low mechanical rigidity and more palatability of the plant tissue due to relatively low rate of silica deposition at the apical growing area of the plant than the rest portion of the plant tissue. The larvae generally hibernate during October-March. This follows a pupa stage lasting up to April.

Observation on the Nodal Penetration by Larva: The newly hatched larva enters in to the leaf sheath, feeds voraciously for 2-3 days and then bores into the stem near the nodal region. Some larvae do not leave the plant on which they enclose, but instead crawl back from the leaf tip and congregate at the nodal area. Most of the larvae migrate to the nodal area within 50-72 minutes of egg hatch. Almost all of the *S. incertulas* larvae will have either entered the leaf sheaths of the plant on which they enclosed or will have dispersed to other plants. In about 6-8 days after hatching some larvae move to other plants or other tillers of the same plant leaf sheath through a common hole. Searching for a suitable node is supposed to be manifested through chemoreception. In such case rice plant odour acts as definite queues to the larvae for suitable plant node selection. Usually only one larva is recorded inside a single stem but occasionally 2-4 larvae may also be noticed. Larval penetration is primarily guided by the plant growth stage and the climatic conditions specially the ambient temperature. To offer better protection from the adverse climatic conditions, probability of more than one larva in a stem was higher for the later larval broods.

Observation on the Rice Plant Tissue Necrosis and Expression of Damaged Symptoms Due to Larval Feeding (Fig2, b, c and d): Nature and extent of feeding by YSB larvae is rice cultivar specific and variety dependent. In general two types of feeding on *Swarna mashuri* were noted, *i.e.,* deep circular (feeding on a particular area) and random feeding (feeding irregularly throughout the stem). Larval feeding was observed only in insecticide untreated plots. The borers generally make deep circular cuts near the base of the upper internodes', mostly the topmost internodes'. 38.11% tillers of the total harbored YSB larvae while the rest are infestation free. Among the infested tillers 75.72% contained only one larva. Incidence of 2 larval individuals is occasional and was noted from 22.06% tillers. Occurrence of more than 2 larvae in a single hill is rare and is recorded from only 2.22% tillers. Grossly 81.94% tillers showed deep circular cuts at the nodal base. Random feeding was noted from 18.06% infested tillers only. Feeding resulted in the formation of DH+WH. But for 31.95% tillers fully expressed symptoms of DH+WH was noted. 59.19% infested tillers did show partial expression of DH+WH while there was no visible external symptom of DH+WH for 8.87% infested tillers.

In insecticide treated plots (control), incidence of DH+WH was far below than the insecticide untreated plots. However in both the fields all the infested tillers did not necessarily showed the symptom of DH+WH. At vegetative growth stage of rice the number of un-infested tillers/hill were 11.01 and 7.41 in insecticide treated and un-treated field respectively. Further, at reproductive growth stage of paddy the number of un-infested tillers/hill were 13.80 and 12.81 in insecticide treated and un-treated field respectively.

Fig. 1.2a: mature third instar larvae of *Scirpophaga incertulas*, 1b: full grown fifth instar larvae of *S. incertulas,* 1c:external symptom of DH, 1d: hibernated *S. incertulas* larvae in stubble

The average value of total infested tillers and the tillers with external symptom of DH was 3.51 and 1.50 respectively in insecticide untreated plot. The respective values were 00.00% and 00.00% for insecticide treated plots. The average value of total infested tillers and the tillers with external symptom of WH was 13.17 and 13.07 respectively in insecticide untreated plot. The respective values were 12.50 and 12.01 for insecticide treated plots. However the number of tillers/hill did not differed significantly under YSB infestation. So, feeding by larvae on *Swarna mashuri* did not inevitably produce DH and WH symptoms. The incidence of WH (%) and DH (%) was positively correlated (r: 0.675) with the ovipositional preference of the moth. Contrary to this deduction, a few plants at the middle of the plot though received higher number of eggs but showed less expression of damage symptoms.

There is evidence that ecologically specialized monophagous YSB have been favoured by crop intensification that involves changes in cultural practices such as (a) an increase in the number of crops grown per year, (b) an increase in the use of agricultural chemicals (fertilizer and pesticides), (c) increased area under irrigation and (d) increased plant densities. Modern rice- IPM put stress on the management of the insect pest through judicious cultural management which includes optimum dose of insecticide and fertilizers in consideration of the life cycle of the pest.

The present observation on larval behaviour is also supported by the findings of Abraham [18], Islam *et al*. [19] and Dhaliwal *et al*. [20]. Present observation is supported by Bora *et al*. [21] who have reported five larval instars of YSB which lasted for 27.30 days. But larval duration and body size in their observation differed considerably, which may be attributed due to the differences in microclimate and cropping practices. However Panda *et al*. [22] on contrary have noted six larval instars on Basmati 370.Grossly, YSB larvae mostly spend the time in the upper part of the rice canopy. So during field scouting attention should the accordingly taken to remove the larval population in order to minimize the subsequent insecticidal input. Further shifting the planting date will disadvantage the YSB larvae and make it vulnerable to air or water temperature extremes, heavy rainfall, a non-preferred crop growth stage or the abundance of natural enemies [23, 24]. Planting time interactions are greatest if carried out over large areas and against a monophagous pest like YSB. Further, an early planted rice crop may also take the advantage of flush of mineralized nitrogen which could either mean greater tolerance to YSB damage due to active crop growth.

On the other hand, Chen *et al*. [25] and Sun *et al*. [26] have reported that the damage due to YSB attack may extend up to 8th internodes' from the top though top three internodes are more badly affected. Further they have noted that the length (cm) of stem damage varied from 10.5 to 118.0, 9.0 to 88.0 and 7.0 to 104.5 in three rice cultivars *i.e. Bayahonda*, *Patnai* and *Panikoui* respectively. They have deduced that every one centimeter increase in stem damage resulted in increasing 0.186, 0.209 and 0.210 per cent chaffy grains respectively. Israel *et al*. [15] and Singha *et al*. [27] have estimated that the yield loss was 0.28 and 0.624 per cent for every unit per cent increase in DH and WH respectively; the combined effect being 0.355 per cent loss due to 1 per cent borer attack. Romena *et al*. [28] and Rai *et al*. [29] have reported almost proportional yield reduction in paddy due to WH formation. For this a judicious management system for YSB is urgently required [30].

Table 3: Nature of stem borer feeding associated with damage in high yielding rice cultivar *Swarna mashuri* during *kharif* season of 2007-2009

	Observation in relation to years							
	2007		2008		2009		Average	
Factors	A	B	A	B	A	B	A	B
Depending on position of inter node at which larvae bores								
Top most internode	47.98	64.29	40.02	60.93	42.00	61.56	43.33	62.26
Second top most internode	18.42	24.68	17.45	26.57	18.01	26.40	17.96	25.88
Third top most internode	8.23	11.03	8.21	12.50	8.22	12.05	8.22	11.86
Total	74.63	100.00	65.68	100.00	68.23	100.00	69.51	100.00
Depending on the number of damaged internode(s)								
One internode	28.01	29.87	29.02	29.01	30.02	28.01	29.02	28.96
Two internodes	63.21	63.12	62.81	63.82	62.4	63.01	62.81	63.32
Three internodes	8.23	7.01	8.21	7.17	8.22	8.98	8.22	7.72
Total	99.45	100.00	100.04	100.00	100.64	100.00	100.04	100.00
Depending on the type of YSB larval feeding								
Deep circular (at the base)	39.89	83.10	40.01	81.60	43.02	81.12	40.97	81.94
Random	8.11	16.90	9.02	18.40	10.01	18.88	9.05	18.06
Total	48.00	100.00	49.03	100.00	53.03	100.00	50.02	100.00
Depending on the types of white head symptoms								
Fully expressed	31.01	32.05	32.00	32.62	30.11	31.16	31.04	31.95
Partially expressed	57.31	59.24	57.50	58.61	57.71	59.72	57.51	59.19
Remain confined	8.42	8.70	8.61	8.78	8.81	9.12	8.61	8.87
Total	96.74	100.00	98.11	100.00	96.63	100.00	97.16	100.00
Depending on the occurrence of YSB larval individuals/hill								
One larvae	69.12	75.79	70.01	74.29	71.01	77.09	70.05	75.72
Two larva	20.01	21.94	22.22	23.58	19.02	20.65	20.42	22.06
More than two larva	2.07	2.27	2.01	2.13	2.08	2.26	2.05	2.22
Total	91.2	100.00	94.24	100.00	92.11	100.00	92.52	100.00

A-Number of tillers observed (Average of 5 plots), B-% of the number in A

Table 4: Nature and extent of infestation to the tillers under insecticide protected and unprotected field in relation to two important growth stages of rice cultivar *Swarna mashuri*

			Extent of infestation in consideration of growth stage							
			Vegetative				Reproductive			
Nature of infestation and the field protection status		Average number of tillers/hill	2007	2008	2009	Average	2007	2008	2009	Average
A	I	11.21	7.41	7.61	7.21	7.41	13.60	13.80	14.01	13.80
	II	10.91	11.01	11.01	11.02	11.01	12.71	12.91	12.81	12.81
B	I	11.01	0.00	0.00	0.00	0.00	12.61	12.51	12.40	12.50
	II	10.21	3.41	3.50	3.61	3.51	13.30	13.20	13.01	13.17
C	I	11.02	0.00	0.00	0.00	0.00	12.51	12.01	11.50	12.01
	II	10.02	1.61	1.50	1.40	1.50	13.01	13.20	13.01	13.07

I- insecticide protected, II- insecticide untreated A- un-infested tillers, B- infested tillers, C- infested tillers with expressed symptoms

From the result it may be concluded that all infested paddy tillers by YSB did not necessarily exhibit the external damage symptoms of DH and WH. Only about half and one third of total damage showed DH and WH symptoms in rice cultivar *Swarna mashuri* (MTU 7029). Further pattern of life cycle and behavior of YSB larvae is cultivar dependent. Development of knowledge of damage mechanisms associated with YSB feeding can be of great value to farmers in enabling strategies to tackle it. This study provided some information on the bio-ecology of YSB more precisely the nature of feeding and the final expression of DH and WH in the field. This could be valuable to develop a suitable YSB management strategy in rice cultivar *Swarna mashuri* (MTU 7029) to monitor of the pest and helps to validate the existing cultivation practices with appropriate alternation.

REFERENCES

1. Pathak, M.D., 1968. Ecology of common insect pests of rice. Annl. Rev. Entomol., 13: 257-294.
2. Alam, N., R. Sing, R.P. Yadav and S.C. Goel, 1992. Population dynamics of borer complex in deep water rice. Bioecology and control of insect pests. Proc. Of the Natl. Symp. On Growth development and control Technology of Insect pests, pp: 95-99.
3. Bandong, J.P. and J.A. Litsinger, 2005. Rice crop stage susceptibility to the rice yellow stemborer *Scirpophaga incertulas* (Walker) (Lepidoptera: Pyralidae). Int. J. Pest Manag., 51: 37-43
4. Cohen, M.B., A.M. Romena and F. Gould, 2000. Dispersal by larvae of the stem borers *Scirpophaga incertulas* (Lepidoptera: Pyralidae) and *Chilo suppressalis* (Lepidoptera: Crambidae) in plots of transplanted rice. Environ. Entomol., 29: 958-971.
5. Pathak, M.D., 1968. Ecology of rice pests. Annl. Rev. Ent., 13: 257-294.
6. Chelliah, A., J.S. Benthur and P.S. Prakasa Rao, 1989. Approaches to rice management - Achievements and opportunities. Oryza., 26: 12-26.
7. Catling, H.D., Z. Islam and R. Patrasudhi, 1987. Assessing yield losses in deepwater rice due to yellow stem borer *Scirpophaga incertulas* (Walker) in Bangladesh and Thailand. Crop Prot., 6(1): 20-27.
8. Biswas, S., 2006. Studies on the stem borer, leaf folder and gall midge under *terai* agro-ecology of West Bengal. M.Sc (Agriculture) Thesis submitted to the *Uttar Banga Krishi Viswavidyalaya*, Pundibari, Cooch Behar, West Bengal, India, pp: 1-46.
9. Mustafa, G., M.A. Razzaq and M. Munir, 1990. Comparative efficacy of some emulsifiable concentrates applied in paddy water as sand mix against rice borers. Ann. Rept. AARI., Faisalabad, 1989-90: 44-46.
10. Malhi, B.S. and D.S. Brar, 1998. Biology of yellow stem borer, *Scirpophaga incertulas* Walker on Basmati rice. J. Insect Sci., 11: 27-129.
11. Senapati, B. and S.K. Panda, 1999. Rice stem borers : insect pests of cereals and their management. Eds. Anand Prakash and Jagadiswami Rao. AZRA publs. Cuttack. India, pp: 2-18.
12. Senapati, B., A.P. Samalo and B.P. Das, 1994. Relationship between extent of stem damage by yellow stem borer and grain yield of rice under semi-deepwater situation. Oryza., 31: 313-314.
13. Sherawat, S.M., M. Inayat, T. Ahmad and M.K. Maqsood, 2007. Determination of economic threshold level (ETL) for the chemical control of rice borers. J. Agric. Res., 45: 55-59.
14. Imayavaramban, V., K. Thanunathan, M. Thiruppathi, R. Singaravel, A. Dandapani and P. Selvakumar, 2004. Effect of combining organic and inorganic fertilizers for sustained productivity of traditional rice cv. Kambanchamba. Res. Crops., 5(1): 11-13.
15. Israel, P. and T.P. Abraham, 1967. Technique for assessing crop losses caused by stem borers in tropical areas. Proc. Symp. Major insect pests of rice plant, IRRI, John Hopkins Press, Baltimore, Maryland, pp: 266-275.
16. Litsinger, J.A., 1979. Major insect-pests of rain-fed wetland rice in tropical Asia. Int. Rice Res. Newsl., 16: 25- 26.
17. Krishanaiah, K., 1995. Technology for rice production. DRR. ICAR, Rajendranagar, Hyderabad 500030, India Pathak, M.D. 1968. Ecology of common insect pests of rice. Annl. Rev. Entomol., 13: 257-294.
18. Abraham, C.C., B. Thomas, K. Karunakaran and R. Gopala Krishnan, 1972. Effect of planting season and associated weather conditions on the incidence of rice stem borer *Tryporyza incertulas* (Walkar). Agric. Res. J. Kerala., 10(2): 141-151.
19. Islam, Z., 1994. Key factor responsible for fluctuations in rice yellow stem borer populations in deepwater rice ecosystems. Insect. Sci. Applic., 15: 461D 468.
20. Dhaliwal, G.S. and R. Arora, 1996. An estimate of yield losses due to insect pest management. Ind. J. Ecol., 23(1): 70-73.
21. Bora, D.K., D. Saharia and S. Hussain, 1994. Biology of yellow stem borer, *Scirpophaga incertulas* (Wlk.). Crop Res. Hissar., 8: 366-370.
22. Panda, N., A.P. Samalo, N.C. Patra and T.G. Reddy, 1976. Relative abundance of Lepidopteran stalk borers of rice in Bhubaneswar, Indian. J. Ent., 38: 301-304.
23. Teetes, G.L., 1981. The environmental control of insects using planting time and plant spacing. In: Handbook of Pest Mgt, Vol. 1, Pimentel, D. (ed.). CRC Press Florida, USA. pp: 209-221.
24. Dirie, A.M., M.B. Cohen and F. Gould, 2000. Larval dispersal and survival of *Scirpophaga incertulas* (Lepidoptera: Pyralidae) and *Chilo suppressalis* (Lepidoptera: Crambidae) on cry1Ab-transformed and non-transgenic rice. Environ. Entomol., 29: 972-978.

25. Chen, H.Y. and R. Angelita, 2006. Feeding pattern of Scirpophaga incertulas (Walker), (Lepidoptera, Crambidae) on wild and cultivated rice during booting stage Environ. Entomol., 35(4): 1094-1102.
26. Sun, J. and Z. Du, 1992. The structure and dynamics in space, number and time of damaged rice in paddy fields infested by striped rice borer *Chilo suppressalis* Walker. Acta Entomol. Sin., 35: 187 D194.
27. Singha, S.S. and V. Pandey, 1997. Relative susceptibility of rice germplasm to yellow stem borer,*Scirpophaga incertulas*. Indian J. Entomol., 59(3): 257-262.
28. Romena, A.M., F.L. Gould and M.B. Cohen, 1997. A method for estimating the number of eggs in egg masses of the yellow stem borer. Int. Rice Res. Notes, 22(2): 50.
29. Rai, A.K., A.K. Singh and M.A. Khan, 2002. Influence of weather factors on light trap Catches of yellow Stem borer in *kharif* season. Indian J. Ent., 64(4): 510-517.
30. Prasad, R. and D. Prasad, 2010. Evaluation of bio-efficacy of newer insecticides against major lepidopterous insect pests of rice ecosystem at Rachi. J.Appl. Zool. Res., 21(1): 25-27.