Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2016; 4(6): 471-477

Received: 17-09-2016
Accepted: 16-10-2016

Israrul Hoque Mondal
University of Gour Banga,
Mokdumpur, Malda,
West Bengal, India

Kaushik Chakraborty
University of Gour Banga,
Mokdumpur, Malda,
West Bengal, India

Correspondence
Israrul Hoque Mondal
University of Gour Banga,
Mokdumpur, Malda,
West Bengal, India

Relative efficiency of some selected insecticide formulations on yellow stemborer, *Scirpophaga incertulas* (walk.) In rice field at Murshidabad, West Bengal, India

Israrul Hoque Mondal and Kaushik Chakraborty

Abstract

Experiment in field condition was carried out to assess the relative efficacy of three selected plant extracts *i.e* neem, tobacco, akando and two selected chemical insecticides *i.e* Dursban 20 EC and Fipronil against the incidence of yellow rice stem borer (YSB), *Scirpophaga incertulas* (Walk.) at Murshidabad, West Bengal, India, during three consecutive *kharif* crop seasons of 2013-2015. Grossly the experiment had six treatments that were replicated four times in each year in randomized complete Block Design (RCBD). Plant extracts significantly control *S. incertulas* population that is comparable with chemical insecticides. Fipronil showed the reduction of 56.28% dead hearts (DH) and 65.27% white head (WH) over control after 35 days of spraying. While the result for dursban was 30.01% DH and 40.27% WH. Neem extract reduced DH and WH by 38.33% and 48.14% respectively. The result from tobacco (22.18% DH and 24.30% WH), akando (15.33% DH and 16.89% WH) are appreciable. Fipronil and Dursban treated plot showed yield of 3.18 and 3.04 t/ha respectively. While in neem, tobacco and akando extracts treated plot the yield was 3.07, 2.86 and 2.68 t/ha respectively. The result indicates that out of the insecticides of plant origin, application of neem formulation effectively reduces *S. incertulas* infestation in consideration to chemical insecticides.

Keywords: RCBD, Yellow stem borer, Plant extracts, Yield, Botanicals

Introduction

Rice (Oryza sativa L.) is regarded as an important food crop supporting food security for 50% of the global population [22, 27]. In Asia, about 2.5 billion people depends on rice as principal food source [23]. Globally, about 90% of the rice cultivable land is in Asia [38]. Rice shares one fifth of the world crop land that is employed for cereal production [51].

Damages by the insect pests are considered as one of the prime causes of low yield generation of rice in the tropical Asian countries [41]. Grossly 128 species of insects are recorded to damage the rice fields. Out of these, in consideration of crop damage, 15 to 20 insect species are economically important [34]. Stem borers (SBs) are regarded as key group of insect pests of rice [21]. Yellow stem borer (YSB), *Scirpophaga incertulas* Walker is reported throughout India and is considered as the most dominating and destructive pest species out of the all species of stem borers [40]. West Bengal tops the list in consideration of rice production in India. YSB is reported to ravage in all of the agro-ecological regions of West Bengal sharing about 89.50% of the total rice borer population [12]. Yellow stem borer, *Scirpophaga incertulas* (Walker) (Lepidopter: Pyralidae) is a monophagous rice pest. Larval infestation during reproductive growth stage of rice causes the damage of the growing panicle resulting in 'white head'' symptoms. After entering within the stem by successful boring/tunnelling, the larvae matures and subsequently pupates [58]. Severe infestation by YSB often results in complete crop failure [39].

Conventionally control of rice stem borer is generally done by the application of different insecticides of newer brands [37]. However recurrent resistance in the insect pest species, repeated insect pest resurgence, [44] and wide spread environmental hazards [60], residual toxicity of synthetic pesticides [68, 71] have indulge us to trust upon insecticides of plant origin [37, 39, 57]. Several brands of inorganic insecticides had been tested to check YSB menace which conceives no definite plant protection schedule appropriate for all of the Indian agro-ecological zones.

In spite of that synthetic insecticides are still the most trusted way to control YSB incidence [53, 59].

Under this situation pesticides of biological origin are reported to be harmless to human [4] and also imparts no ecological toxicity [36, 37]. Research on medicinal plants as an alternative source of insecticides for insect pest management gets momentum because threat to the environment from their application or to human health is insurmountable [1]. Further plant extracts are non-pollutant [6], less toxic [68] and easily bio-degradable [28]. Experiment on the efficacy of neem and its derivatives and few other bio-pesticides on YSB incidence have tested with variable range of success [18, 25]. The neem seed kernel extract (NSKE) suppresses the feeding, growth and reproduction of insects [47]. Neem products can be recommended for many programmes for integrated pest management [33, 13]. Similarly application of tobacco and akando as insecticide is used at restricted scale. Miranpuri [42] have also reported the efficacy of some bio-pesticides for pest suppression. *Calotropis procera* belongs to family Asclepiadaceae and has very wide range of ecological amplitude. The akando plant extract is effective against lepidopterous and sucking pest of several crop [43]. Extract of akando plant containing insect toxic components such as cardenolides, cardiac glycosides, flavonoids, giganticine and other cytotoxic components which are effective against an array of insect pest [19]. A lectin called Nicotaina tabacum agglutinin (NICTABA) was explored from the leaves of tobacco [16]. Nictaba-related proteins have been studied and characterized for their biological properties and physiological role. Nictaba may be utilized for the crop as it has entomotoxic effects on Lepidopteran larvae [26].

Considering the above facts the present three consecutive years (2013-2015) research work is designed to determine relative efficacy of different insecticides and plant extracts to control yellow stem borer.

Materials Methods

Field layout and outline of experiment: Field experiment was conducted with transplanted 35-day old healthy seedlings of widely cultivated variety *Swarna mashuri* (MTU 7029) during three consecutive *kharif* seasons of 2013-2015 at Murshidabad [24º22´90´´(N) – 88º24´61´´(W)], West Bengal. The soil of the field was sandy loam with pH value 6.8 and EC value 0.31mmhs/cm. Field N, P_2O_5 and K_2O was 363, 67 and 368 kg/ha respectively. Triple super phosphate (TSP), Muriate of potash (MOP), gypsum and zinc sulphate was added basally to the main field at the rate of 120, 80, 60 and 10 kg/ha as and when needed.

Experiment was conducted by randomized block design at 15x10 cm seedling spacing during 2013-2015. There were six treatments, each with four replications for each year. Each plot was 26.75x 10.50 m in size and is separated from the nearby plot by a distance of 0.60 m. Insecticide formulation in the main field was applied at two times; during 35 and 60 days after seedling transplantation (DAT) respectively. Fertilizer inputs, irrigation, weeding and other necessary field management were carried out in due course of time following the national protocol with necessary modification as and when required.

Observation of stem borer population (SBs): Randomly selected 15 plots, 3 from each of the 5 insecticide treated fields, having no history of insecticide application were periodically inspected to register the incidence of stem borers (SBs). SBs were collected by a fine nylon cloth sweep net of 35 cm in diameter. Sweeping was carried out at the plant canopy level including the interspaces between the rice hills and the basal region of the plants as far as possible. In each field, 10 complete sweeps for each plot were made. A complete sweep includes one forward and one reverse sweep. Sweeping was mostly conducted at the early morning and early evening. There are five replications for each of the four rice growth stages namely (i) seedling, (ii) tillering (iii) milk maturation stage (iv) grain hardening stage from the randomly selected rice hills in each fields. SBs that were collected from each field were separated and accordingly counted.

Preparation of plant extracts pesticide formulation (Table 1): Leaves and barks of neem (*Azadirachta* sp.) of about 5kg in weight were cut into small pieces and mixed with 10 liter water. The water was then boiled for 30-50 minutes. The solution was then cooled and then filtered. The stock solution is diluted and applied in the field (T1). Similarly, 3 kg tobacco (*Nicotiana* sp.) leaf were cut into small pieces and mixed with 8 liters of water and subsequently boiled for 30-50 minutes which was then cooled for another 2 hours. The solution was then filtered through muslin cloth and the stock solution was thus prepared (T2). In the same manner akando (*Calotropis* sp.) formulation was also prepared (T3). Grades of inorganic pesticide formulations were prepared following standard protocol for field application (T4 and T5). Same volume of water without the insecticides was applied in the control field (T6).

Table1: Pesticide formulation, type and the application dose

Treatments	Generic and/or Scientific name of insecticide	Active substance for insect pest control	Source	Mode of application	Type	Applied dose/ha	Total volume applied
T1	Neem (*Azadirachta indica*)	Azaridactin	Leaf and bark	spray	---	15ml/L	1.5L
T2	Tobacco (*Nicotiana tabacum*)	Nicotin	Leaf	spray	---	15ml/L	2.3L
T3	Akando (*Calotropis procera*)	Calotropin-	Leaf and stem	spray	---	15ml/L	2.5L
T4	Dursban	Chlopyrifos		spray	20EC	4ml/L	3.2L
T5	Fipronil	Fipronil	---	spray	0.3G	1.0 kg	4.5Kg
T6 (control)	Water	---	---	---	---	---	2.3L

(--):not applicable

Assessment on pest incidence following insecticidal input

Incidence and occurrence of pest population was taken from three growth stages, *i.e.* (i) seedling (ii) tillering (iii) milk maturation stage (iv) grain hardening stage and was averaged. Infestation of YSB results in dead hearts (DH) and white head (WH) during vegetative and reproductive growth stages of rice plant respectively. Incidence of DH (%) and WH (%) was recorded from 50 hills that was diagonally selected from each plot during vegetative and panicle formation stage of rice plant respectively. percentage of damage is calculated following formula as described by Singha [67].

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

Statistical analysis: The pooled data was statistically analyzed by programme-software INDOSTAT- ANOVA and accordingly CD value was calculated. Nature of correlation was worked out between the extent of yield loss with the field incidence of DH (%) and WH (%). Chandel [15].

Results and Discussion

Observation of major stem borer species of rice crop (Table 2, 3 and 4 & Fig 1): Observation for three consecutive years (2013-2015) in rice eco-system reveals a number of insect pests are associated with rice field. The stem borer species are Yellow stem borer (*Scirpophaga incertulas*), Pink stem borer (*Sesamia inferens*), Dark headed stem borer (*Chilo partellus*), Stripped stem borer *(Chilo suppressalis*), White stem borer *(Scirpophaga innotata*). Maximum and minimum incidence of all of the stem borer species was recorded at tillering stage and grain hardening stage of rice plant respectively. Numerically, yellow stem borer tops the list (24.67%) out of the borer species. This is respectively followed by pink stem borer (8.08%), white stem borer (4.91%), dark headed borer (3.36%) and stripped stem borer (1.75%) in descending order.

Yellow stem borer (YSB): The incidence of YSB differed considerably among different rice growth stages. Grossly the relative abundance is 24.67%. Maximum number of YSB incidence was recorded at tillering stage (2.66 individuals/ sweep) and lowest at grain hardening stage (1.26 individuals/ sweep) respectively.

Pink borer (PSB): Occurrence of PSB population differ significantly in consideration of different growth stages of rice plant. The relative abundance was 8.08%. The mean population ranges from 1.26 to 0.98/sweep. Maximum and minimum number of PSB population was recorded at tillering (1.26 individuals/sweep) and grain hardening stage (0.65 individuals/ sweep) respectively.

White borer (WSB): Incidence of WSB is very low throughout the growth stages of rice plant. The relative abundance is 4.91%. Tillering growth stage of rice plant had supported maximum number of WSB population (0.68 individuals/sweep) while the least is noted at grain maturation stage (0.39 individuals/sweep).

Dark headed stem borer (DHSB): The relative abundance of DHSB is 3.36%. Numerically maximum number of DHSB was recorded at tillering stage (1.54 individuals/ sweep) and lowest was recorded in grain hardening stage (0.91 individuals/sweep).

Stripped stem borer (SSB): Incidence of SSB differed considerably among different rice growth stages. The value of relative abundance is 1.75%. The highest number of stripped stem borer was found at tillering stage (0.47 individuals/sweep) and lowest in seedling stage (0.15 individuals/ sweep).

Ragini [55] had recorded three rice stem borer species, *i.e*. the YSB (*Scirpophaga incertulas*), PSB (*Sesamia inferens*) and DHB (*Chilo partellus).* Out of that YSB was the most predominant species during June to September (60.0%) followed by October to January (48.43%). PSB was the second most dominant species during June-September (35.21%). During October to January incidence of PSB was least (18.23%). However throughout the season DHSB was least abundant (4.29-7.18%).

Table 2: Extents of yellow stem borer infestation and yield generation of paddy cultivar *Swarna Mashuri* under different pesticide treatments.

Insecticide formulations	Extent of infestation (%)										Yield(t/ha)				Application Efficacy (%) (In consideration of yield increase over control)
	DH					WH					2013	2014	2015	Mean	
	2013	2014	2015	Mean	Suppression of incidence (%)	2013	2014	2015	Mean	Suppression of incidence (%)					
T1	3.81 (1.95)	3.68 (2.04)	3.85 (2.08)	3.78 (2.06)	38.33	2.24 (1.65)	2.30 (1.67)	2.18 (1.63)	2.24 (1.65)	48.14	3.04	3.08	3.10	3.07	27.38
T2	4.72 (2.72)	4.78 (2.29)	4.81 (2.30)	4.77 (2.29)	22.18	3.12 (1.90)	3.27 (1.92)	3.43 (1.98)	3.27 (1.94)	24.30	3.12	2.72	2.74	2.86	18.67
T3	5.24 (2.28)	5.15 (2.37)	5.19 (2.38)	5.19 (2.38)	15.33	3.44 (1.98)	3.62 (2.02)	3.72 (2.05)	3.59 (2.02)	16.89	2.61	2.81	2.61	2.68	11.20
T4	4.31 (2.07)	4.21 (2.17)	4.37 (2.20)	4.29 (2.18)	30.01	2.52 (1.73)	2.56 (1.74)	2.68 (1.78)	2.58 (1.75)	40.27	3.08	3.02	3.06	3.04	26.14
T5	3.21 (1.92)	2.12 (1.45)	2.62 (1.76)	2.68 (1.76)	56.28	1.38 (1.37)	1.60 (1.44)	1.54 (1.42)	1.50 (1.41)	65.27	3.18	3.12	3.24	3.18	30.29
T6 (no application)	6.20 (2.48)	6.12 (2.57)	6.08 (2.56)	6.13 (2.57)		4.18 (2.16)	4.42 (2.21)	4.38 (2.20)	4.32 (2.19)		2.51	2.42	2.32	2.41	
SE(±)	0.11	0.17	0.21	0.16	-	0.08	0.14	0.19	0.14	-	015	0.12	0.09	013	-
CD (P=0.05)	0.35	0.34	0.45	0.27	-	0.21	0.26	0.37	0.39	-	0.21	0.17	0. 17	0.19	-

Table 3: Important insect pests of rice at Murshidabad, West Bengal

Common English name	Scientific name	Family	Order	Extent of incidence (%) (in consideration of numerical abundance)
Yellow stem borer	*Scirpophaga incertulas* (Walker)	Pyralidae	Lepidoptera	24.67
Pink stem borer	*Sesamia inferens* (Walker)	Pyralidae	Lepidoptera	8.08
White stem borer	*Scirpophaga innotata*(Walker)	Pyralidae	Lepidoptera	4.91
Dark headed stem borer	*Chilo partellus* (Walker)	Pyralidae	Lepidoptera	3.36
Striped stem borer	*Chilo suppressalis* (Walker)	Pyralidae	Lepidoptera	1.75

Table 4: Incidence and abundance of different stem borer species at different growth stages in rice crop field without insecticide input

Growth stage of rice	Different species of stem borer				
	YSB	PSB	WSB	DHSB	SSB
Seedling	1.68 (1.48)	0.98 (1.22)	0.54 (1.02)	1.22 (1.27)	0.16 (0.82)
tillering	2.66 (1.78)	1.26 (1.33)	0.68 (1.09)	1.54 (1.43)	0.47 (0.99)
Milk maturation stage	1.82 (1.52)	0.7 (1.10)	0.44 (0.97)	1.092 (1.26)	0.378 (0.94)
Grain hardening stage	1.26 (1.33)	0.658 (1.08)	0.39 (0.94)	0.91 (1.19)	0.15 (0.81)

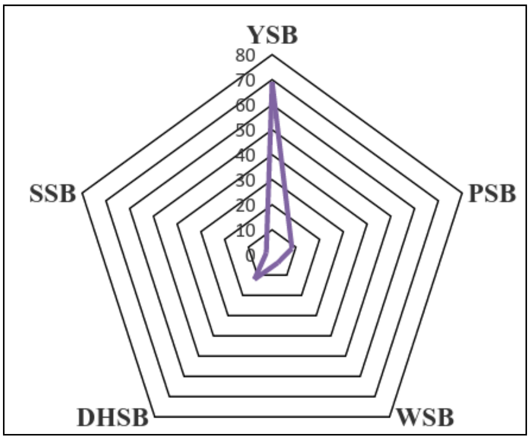

Fig 1: Incidence of YSB in relation to other stem borer species in rice field

In consideration of yield generation (Table. 2): Maximum yield generation was noted from T5 (3.18t/ha). This was followed by T1 (3.07t/ha), T4 (3.04t/ha), T2 (2.86 t/ha), T3 (2.68t/ha) respectively in descending order. The lowest yield of 2.41 t/ha was registered from insecticide untreated field (T6). In consideration of yield increase over control, maximum efficacy was calculated for T5 (30.29%). This was then followed by T1 (27.38%), T4 (26.14%), T2 (18.67%), T3 (11.20%) in descending order.

In consideration of yield economics (Table 5): Cost of input and value of return per hectare for rice production was considered in the value of rupees. Expenditure was done primarily due to the cost of insecticide and other usual field management procedure. Grossly, field management cost for all the treatments remained more or less constant except for the 'control' fields. As there was no insecticidal input in the 'control' field, thus the expenditure related to insecticide application was merely 'nil'. In consideration of input cost, the maximum value is noted in T4 (Rs. 31,230**).** The next highest input cost was registered in T5 (Rs. 30,930). This was respectively followed by T2 (Rs. 28,710), T3 (Rs. 28,610), T1 (Rs. 28,330), T6 (Rs. 27,730) in descending order. But, in consideration of gross return maximum value was noted in T5 (42,165). The next highest return was possible from T4 (Rs. 40,690). This was followed by T1 (Rs. 38,250), T2 (Rs. 37,065), T3 (Rs. 35,910), T6 (Rs. 33,005) in descending order. In consideration of monetary return, 'net profit' was maximum in T5 (10,235). It was seconded by T1 (Rs. 9,920).This was followed by T4 (Rs. 8,460), T2 (Rs. 8,355), T3 (Rs. 7300), T6 (Rs. 5,275) in descending order. Maximum cost benefit value (CBR) was noted case of T5 (1.36). This is followed by T1 (1.35), T4 (1.30), T2 (1.29) and T3 (1.25) in descending order. The least CBR value was noted in case of control field (1.19).

Table 5: Yield economics showing Cost Benefit value under different treatments

Treatment	Field management expenditure (a)			Income(Rs/ha)				CBR value
				Gross (b)			Net	
	A	B	Total	Grain	Fodder	Total	(a-b)	
T1	600	27,730	28,330	30,200	8,050	3,8250	9,920	1.35
T2	980	27,730	28,710	28,200	8,865	37,065	8,355	1.29
T3	880	27,730	28,610	27,500	8,410	35,910	7,300	1.25
T4	3,500	27,730	31,230	31,400	9,290	40,690	8,460	1.30
T5	3,200	27,730	30,930	32,500	9,665	42,165	10,235	1.36
T6	-	27,730	27,730	26,155	6,850	33,005	5,275	1.19

No definite observation on the impact of insecticide formulations on YSB incidence adjacent to Gangetic plains of West Bengal was carried out earlier. Works had done mostly superficial covering the assessment of efficacy of different newer inorganic insecticidal brands and side by side the estimation of YSB population in relation to high yielding cultivars. In the present study the extent of YSB infestation was on average 6.13% DH and 4.32% WH respectively in pesticide untreated field. Assessment on the relative efficacy of insecticidal formulations in relation to YSB incidence was also accounted at different agro-climatic zones [17, 37, 45, 46, 49, 52, 66]. Field experiments on the efficacy of synthetic pesticides of different newer brands have also been documented [37, 39, 53, 57, 59]. But no definite plant protection schedule applicable for all the agro-ecological zones could be evolved. Over dependence on synthetic pesticides causes' ecological difficulty and health related problems [39, 70]. All of the results varied considerably in consideration of the ranges of success. In such back drop bio-pesticides are reported to be safer to human health imparting no ecological toxicity [36, 37].

In the present experiment best result in consideration of the extent of pest suppression was found when Neem extract (@15ml/L) was applied. This was followed by fipronil 0.3G(1kg/ha), Dursban 20 EC(4ml/L), Akanda extract (15 ml/L), Tobacco extract (15ml/L) respectively in descending order. In parity to the pest suppression efficacy, best yield was obtained from fipronil formulation treated plot while the least was noted from tobacco applied field. Somewhat similar results from inorganic insecticide application were also documented [24, 50, 57]. Akondo formulation extract showed a reduction of 18.67% which statistically similar with the result when Akondo formulation. Prasad [52] from India had documented that in consideration of insect pest suppression capacity, monocrotophos expressed good result out of the six selected pesticides they had tested. Dash [18] have documented that in Orissa condition efficacy of pesticide formulations differ considerably to suppress YSB incidence. In general for all of the rice cultivars, a limit of 10% tiller damage (DH+WH) is considered as ETL value of YSB incidence at pre harvest condition [63].

Though efficacy of neem derivatives and few other bio-pesticides on YSB incidence have tested elsewhere, it has resulted in only a variable range of success [18, 25]. The neem seed kernel extract (NSKE) is known to suppress the feeding, growth and reproduction of insects due to its bio-chemicals [47]. Neem products can be recommended for many programmes on integrated pest management [13, 33]. Miranpuri [42] have also reported the efficacy of some bio-pesticides for pest suppression. In this consideration efficacy of different pesticide formulation on the YSB incidence in diverse agro-ecological zone is needed to be explored [20, 39].

Conclusions

Botanical source insecticides may serve as alternatives to popularly used synthetic chemical insecticides. The result of the study on the effectiveness of different botanical extract and insecticides for the controlling of yellow stem borer of rice. The treatment viz. Dursban 20 EC, Fipronil, Tobacco, Akando, Neem extract and untreated control were included in this field test. Among the treatments Neem extract showed the best result which was statistically similar with Fipronil. Among the treatments Fipronil treated plot yielded highest amount of rice. Though the effectiveness of the botanicals was low than chemical insecticides. So Farmer may use neem based insecticide to produce rice which will ensure better yield and the conservation of beneficial insect in rice field ecosystem.

References

1. Ahmed S, Saleem MA, Rauf I. Field Efficacy of Some Bioinsecticides against Maize and Jowar Stem Borer, *Chilo partellus* (Pyralidae: Lepidoptera). International Journal of Agriculture Biology. 2002; 3:332-334.
2. Ahmed A, Sultana P. Comparative efficacy of some indigenous plant material as repellents against *Sitophilus oryzae* Linn. Bangladesh Journal of Agricultural Research. 1980; 5(2**)**:31-35.
3. Ali SI, Singh OP, Misra US. Effectiveness of plant oils against pulse beetle, *Callosobruchus chinensis* Linn. Indian Journal of Entomology. 1983; 45:6-9.
4. Anchal SVD, Diwevidi, Smita Singha, Khsitiz Kumar Pawar, Mahesh Jerman, Singh LB *et al.* Biological Control & its important in Agriculture. International Journal of Biotechnology & Bioengineering Research. 2013; 4:175-180. ISSN 2231-1238.
5. Anis Joseph R, Premila KS, Nisha VG, Soorya S, Rajendran M, Sarika. Safety of neem products to tetragnathid spiders in rice ecosystem. Journal of Biopesticides. 2010; 3(1)088-089.
6. Annie Melinda Paz-Alberto, Gilbert C. Singha Phytoremediation. A Green Technology to Remove Environment. American journal of climate change. 2013, 2:71-86.
7. Ascher KRS, Eliahu M, Nemny NE, Meisner J. Neem seed kernel extracts an inhibitor of growth and fecundity in Spodoptera littoralis. In: H. Schmutterer and K.R.S. Ascher (Editors), Natural Pesticides from the Neem Tree and Other Tropical Plants. Proceedings of the Third International Neem Conference, Nairobi, Kenya, Rottach-Egern, Eschborn. 1984, 331-344.
8. Barrion AT, Litsinger JA. Rice land spiders of South and South-East Asia. CAB International, UK & International Rice Research Institute (IRRI), Philippines. 1995, 700.
9. Bhanu KV, Reddy PS. Field evaluation of certain newer insecticides against rice insect pests. Journal of applied. Zoology Research. 2008; 19(1):11-14.
10. Bhanukiran Y, Panwar VPS. *In vitro*, efficacy of neem products on the larvae of maize stalk borer *Chilo partellus* (Swin.). Annals of Plant Protection Sciences. 2000; 8:240-2.
11. Bhardwaj D, Panwar AD. Predator of rice insect pests in Chhatrtishgarh region, Madhya Pradesh, India. International Rice Research Notes. 1987; 12(4):35.
12. Biswas S. 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. 2006, 1-46.
13. Calvo D, Molina JM. Effects of a commercial neem (*Azadirachta indica*) extract on *Streblotepanda* larvae. Phytoparasitica. 2003; 31:365-370.
14. Catling HD, Islam Z, Patrasudhi. Assessing yield losses in deepwater rice due to yellow stem borer *Scirpophaga incertulas* (Walker) in Bangladesh and Thailand. Crop Protection. 1987; 6(1):20-2.
15. Chandel SRS. A handbook of Agricultural Statistics. Achal Prakashan Mandir, Kanpur (UP.) India. 1984, 149-318.
16. Chen H, Wilkerson CG, Kuchar JA, Phinney BS, Howe GA. Jasmonate inducible plant enzyme degrade herbivore midgut. Proceeding of the National Academy of Science USA. 2005; 102:19237-19242.
17. Das T, Baqui MA. Aromatic Rice of Bangladesh. In: Aromatic Rice. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi. 2010, 184-87.
18. Dash D, Mukherjee SK. Evaluation of insecticides against rice yellow stem borer, *Scirpophaga incertulas* (Walker). Journal of insect Science. 2010; 23(2):184-187.
19. Deepika S, Singh Padma. *In vitro* Fungitoxic Evaluation & GCMS analysis of *Calotropis procera*. World Journal of pharmaceutical Research. 2015; 4(3):1123-1135.
20. Dent DR. The effect of *Bacillus thuringiensis* as an insecticide. In: Exploitation of Microorganisms (Ed. Gareth Jones), Chapman and Hall, London. 1993, 19-44.
21. Dhaliwal GS, Arora R. An estimate of yield losses due to insect pests in Indian Agriculture. Indian Journal of Ecology. 1996; 23:70-73.
22. FAO. Food & agricultural commodities production. Food & Agriculture Organization of the United Nations, 2011.

23. FAO. Food & Agriculture Organization of the United Nations. Quartely Bulletin of statistics.1995; 8:1-2.
24. Firake DM, Rachna-Pande, Karnatak AK. Evaluation of microbial and some chemical insecticides against yellow stem borer and leaf folder of rice. Journal of Insect Science. Ludhiana, India. Indian Society for the Advancement of Insect Science. 2010; 23(2):150-153.
25. Ganguli RN, Ganguli J. Residual toxicity of insecticides and neem based formulations against *Chilo partellus* (Swin.) infesting maize. Indian Journal Agricultural Research. 1998; 32:227-32.
26. Gianni, V, Groten K. *Nicotiana tabacum* agglutin is active against Lepidopteran pest insect. Journal of Experimental Biology. 2010; 61(4):1003-1014.
27. Garris AJ, Tai TH, Coburn J, Kresovich S, Mccouch S. Genetic structure & diversity in *Oryza sativa* L. Genetics. 2005; 169:1631-1638.
28. Gujar MS, Ali S, Aktar M, Singh KS. Efficacy of plant extract in plant disease Management. Journal of Agriculture Science. 2012; 3:423-425.
29. Heong KL, Aquino GB, Barrion AT. Arthropod community structures of rice ecosystems in the Philippines. Bull. Entomology. Res. 1991; 81:407-416.
30. Hern´andez MM, Heraso C, Villarreal ML, Arispuro IV, Aranda E. Biological activities of crude plant extracts from *Vitex trifolia* (Verbenaceae). Journal of Ethnopharmacology. 1999; 67:37-44.
31. ICAR. Report of research review committee for establishment of National Agricultural Research Project (NARP) under Bidhan Chandra Krishi Viswa vidhyalaya. Pundibari, Cooch Behar, West Bengal. 1982.
32. Imayavaramban V, Thanunathan K, Thiruppathi M, Singaravel R, Dandapani D, Selvakumar P. Effect of combining organic and inorganic fertilizers for sustained productivity of traditional rice cv. Kambanchamba. Res.crops. 2004; 5(1):11-13.
33. Juan A, Sans A, Riba M. Antifeedant activity of fruit and seed extracts of *Melia azedarach* and *Azadirachta indica* on larvae of *Sesamia nonagrioides*. Phytoparasitica. 2000; 28:311-319.
34. Kalode MB. Insect pest of rice and their management in Rice in Indian Perspective edited by SD. Sharma and BC. Nayak. Today and Tomorrow Printers and Publishers (India). 2005; 819-854.
35. Kamal NQ, Karim ANM, Rand Alam S. Some common predators of rice insect pests. International Rice Research Notes. 1987; 12(3):34.
36. Ketkar CM. Utilization of neem (*Azadirachta indica* Juss) and its bye-products. Directorate of Non-edible Oils & Soap Industry, Khadi & Village Industries Commission, Bombay, India. 1976, 234.
37. Khan I, Khaliq A. Field evaluation of some granular insecticides for the control of rice stems borers. Pakistan Journal of Scientific and Industrial Research. 1989; 32(12):824.
38. Khush GS, Brar DS. Biotechnology for rice breeding. In proceeding of the 20th session of the International Rice Commission. 2002.
39. Kushwaha KS. Chemical control of Rice stem borer, *Scirpophaga incertulas* (Walker) and leaf folder *Cnaphalocrocis medinalis* Guenee on Basmati. Journal of Insect Science. 1995; 8(2):225-226.
40. Mahar MM, Bhatti IM, Dhuyo AR. Stem borer infestation and yield loss relationship in rice and cost-benefits of control. Paper presented at 5th National Seminar on Rice and Production. Kalashakaku. 1985, 23-25.
41. Matteson PC. Insect pest management in Tropical Asian Irrigated rice. Annual Review of Entomology. 2000; 45:549-574.
42. Miranpuri GS, Kachatourian GG. Role of bio insecticides in integrated pest management and insect resistance management. Journal of Insect Science. 1993; 6:161-72.
43. Muhammad FM, Mohammad Nawaz, Zahid Hafeez. Efficacy of synthetic insecticide & botanical infusion against onion thrips of in Baluchistan, Pakistan I, Asian Journal Plant of Science. 2003; 2(10):779-781.
44. Muhammad Nawaz, Juma Ibrahim Mabubu, Hongxia Hua. Current status and advancement of bio pesticides: Microbial & botanical pesticides. Journal of Entomology and Zoology Studies. 2016; 4(2):241-246.
45. Mustafa G, Razzaq MA. Efficacy of different doses of granular insecticides against rice borers. Ann. Rept. AARI, Faisalabad. 1990-91, 42-43.
46. Mustafa G, Razzaq MA, Munir M. Comparative efficacy of some emulsifiable concentrates applied in paddy water as sand mix against rice borers. Ann. Rept. AARI., Faisalabad. 1989-90, 44-46.
47. Natarajan K, Sundaramurthy VT. Effect of neem oil on cotton white fly *(Bemisia tabaci*) Indian Journal Agriculture Science.1990; 60(4):290-291.
48. Ooi PAC, Shepard BM. Predators and parasitoids of rice insects. In E.A. Heinrich (ed.) Biology and Management of Rice Insects, Wiley Eastern Ltd. India & International Rice Research Institute (IRRI), Manila, Philippines. 1994; 613-656.
49. Panda SK, Samalo AP, Shi N. Effect of insecticidal protection of stem borers and gall midge on rice yield in Orisha, India, *Oryza*. 1989; 25:57-61.
50. Panda BM, Rath L-K, Dash D. Effect on fipronil on yellow stem borer *Scirpophaga incertulas* (walker) & certain plant growth parameters in rice, Indian Journal of Entomology. 2004; 66(1):17-19.
51. Pathak MD, Khan ZR. Stem borers In: Insect pest of rice. IRRI & ICIPE.1994, 5-17.
52. Prasad R, Prasad D. Evaluation of bio-efficiency of newer insecticides against major lepidopterous insect pests of rice ecosystem at Ranchi. Journal of Applied. Zoology Research. 2010; 21(1):25-27.
53. Prasad R, Prasad D. Account of insect pests problem in rice-system in Ranchi. Indian Journal of Entomology. 2006; 68(3):240-246.
54. Prasad R, Kumar SS, Prasad D. Evaluation of newer molecules of insecticides for management of major insect pests or rice. In: Abstract research papers. National Symposium on IPM strategies to combat emerging pests in the current scenario of climatic change, held at Passi Ghat at Arunachal Pradesh. 2009, 62.
55. Ragini JC, Thangaraju D, David PMM. Relative abundance of rice stem borer species in Tamilnadu, Madras Agriculture Journal. 2000; 87(4-6):228-234.
56. Raju VR, Jaggannatham A, Rao RS. Performance of scented rice *(Oryza sativa*) varieties under different levels of nitrogen in Andhra Pradesh. Indian. Journal of Agriculture Science.1990; 60(10):694-696.
57. Saljoqi AUR, Khan M, Abdullah K, Latif A. Evaluation of Fipronil for the management of rice stem borer. Sarhad Journal of Agriculture. 2002; 18(1):59-61.
58. Sarwar M. Management of rice stem borers (Lepidoptera: pyraridae) through host plant resistance in early, medium

and late planting of rice (*Oryza sativa*. L).Journal of cereals and oil seeds. 2012; 3(1):10-14.

59. Sasmal A, Bhattacharya DK, Nanda LR. Eco-friendly management of rice leaf folder and case worm in Odisha. National Symposium on sustainable pest management of safer environment organized by OUAT, Bhubaneswar. 2007; 33-34.
60. Sen D. Threatened indigenous rice biodiversity of old alluvial region of North and South Dinajpur, West Bengal. Asian Agri-History. 2008; 12(2):109-127.
61. Sen D, Bhatt A, Kar CS. Tulaipanji: An indigenous scented rice genotype of West Bengal. Asian Agri-History. 2005; 9(2):153-156.
62. Senapati B, Panda SK. Rice stem borers. Insect pests of cereals and their management. Eds. Anand Prakash and Jagadiaswami Rao. AZRA publs. Cuttack. India. 1999, 2-18.
63. Senthil Nathan S, Murugan K, Kalaivani K. Effect of azadirachtin and *Bacillus thuringiensis* (Berliner) on the behavioral and physiological response of *Cnaphalocrocis medinalis* Guen´ee (Rice leaf folder). In: Murugan, K. [Ed.] Proc. National Symp on Biological Control of Insects in Agriculture, Forestry, Medicine and Veterinary Science Coimbatore, India. 1999; 1:31-35.
64. Shepard BM, Barrion AT, Litsinger JA. Friends of the rice farmers: helpful insects, spider and pathogens. International Rice Research Institute. Los Banos. Laguana. Philippines. 2000, 127.
65. Siddiq EA. Export prospects for Indian ‘Basmati’rice. Indian Fmg. 1990; 40:45-47.
66. Singh PP, Rao R, Singh KM. Efficacy and economics of some insecticides against rice stem borer *Scirpophaga incertulas* Walker. Journal of Applied Biology. 1995; 3(1-2):36-41.
67. Singha SS, Pandey V. Relative susceptibility of rice germplasm to yellow stem borer, *Scirpophaga incertulas*. Indian Journal of Entomology. 1997; 59(3):257-262.
68. Ramesh S, Kumar T, Arumugam CR. Ananda kumar, Balakrishnan S, Rajavel DS. Use of Plant species Controlling Environment Pollution-A Review. Bulletin of Environment, Pharmacology and Life Science. 2013; 2(2):52-53.
69. Thakur NSA. Insect pests of rice in Sikkim hills. International Rice Research Notes. 1984; 9(6):16.
70. Wakil W, Hussain M, Akbar R, Gulzar A. Evaluation of different insecticides against rice stem borer and rice leaf folder. Pakistan Journal of Agricultural Science. 2001; 38:49-50.
71. Way MJ, Heong KL. The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice a review. Bulletin of Entomology Research. 1994; 84:567-587.