Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S
Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(3): 1495-1499
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Received: 21-03-2018
Accepted: 22-04-2018

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Effect of organic and inorganic silicon amendments against yellow stem borer (*Scirpophaga incertulas* Walker) and leaf folder (*Cnaphalocrocis medinalis* Guenee) of rice in Costal Odisha

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Abstract
Field experiment on the effect of organic and inorganic silicon amendments against yellow stem borer and leaf folder in rice revealed the superiority of $CaSiO_3$ (Calcium silicate) @ 2t/ha and DAE (Diatomaceous earth) @ 0.45t/ha in arresting stem borer damage *i.e.* (0.00- 3.09%) dead heart and (0.35% & 0.69%) white ear head as against 2.34-11.43% dead heart and 4.47% white ear head in control. At vegetative and heading stages treatments resulted upto 92.17 and 84.56% reduction in borer damage in comparison to control. Similarly, in case of leaf folder, $CaSiO_3$(Calcium silicate) @ 2t/ha and DAE (Diatomaceous earth) @ 0.45t/ha was successfully supress the infestation with a record of (0.00- 4.17% damaged leaf) in peak vegetative stage and (1.84% & 2.03%) damaged leaf in reproductive stage as against 3.73-8.55% damaged leaf in untreated control during the entire growth stage of the crop. Both the treatments are able to achieve 65.84 and 64.86% reduction in damage over control. In grain yield point of view both the treatments yielded more than 45.0q/ha which is significantly higher than untreated control (36.66q/ha).

Keywords: Silicon amendments, yellow stem borer (*Scirpophaga incertulas* Walker), leaf folder (*Cnaphalocrocis medinalis* Guenee)

1. Introduction
Rice (*Oryza sativa* (L.)) is one of the most important staple food crops in the world. Among the rice growing countries of the world, India has the largest rice acreage and ranked second in production [1]. Rice yield is either stagnating/declining in post green revolution era due to several factors of which insect pests are of major concern [2].

In India losses incurred by different insect pests of rice are reported to the tune of 15,120 million rupees which in turn works out to 18.60 per cent of total losses [3]. The current scenario of rice pests in the country causes severe yield reduction of which the stem borer and leaf folder are considered as major insect pests. Yellow Stem Borer *Scirpophaga incertulas* (Walker) is the dominant one among the stem borers infesting rice [4] because of its ubiquitous distribution and chronic pattern of infestation [5, 6]. It infests rice plant from seedling to flowering stage causing dead heart at vegetative stage and white ear heads during the flowering stage [6]. The extent of yield losses due to borers have been estimated to range from 30 to 70% in outbreak years and from 2 to 20% in non-outbreak years [7]. Paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee) is one of the most important insect pests in Indian subcontinent [8]. In India, *Cnaphalocrocis medinalis* is distributed in most regions of the country and considered as a migratory pest with 1 to 11 generations per year [9]. The Leaf Folder (*Cnaphalocrocis medinalis*) is known to cause grain yield loss range from 25-30%. Second instar LF larvae glues the growing paddy leaves longitudinally for accommodation and feeds on green foliage voraciously which results in papery dry leaves [10].

For management of these notorious insect pests, over reliance on highly toxic and hazardous pesticides has created higher magnitude of environmental pollution leading to imbalance in natural ecosystem. Development of resistance in insects, resurgence and residues becomes major problems due to indiscriminate use of pesticides. Hence the use of less toxic compounds of natural plant origin, host plant resistance, bioagent, and adoption of cultural practices are given priority as important components for implementation of IPM programme. In the absence of natural heritable resistance in rice varieties, resistance could be induced by alternate strategies to suppress certain insect pests. One such strategy of induced resistance is enrichment of silicon in plants to defend insect pests.

Silicon (Si) is the second most abundant element in soil (following oxygen) and comprises ~28% (wt/wt) of Earth's crust [11]. Although Si is not considered an essential element for the majority of plants, the beneficial effects of this element on plant growth, development, stress resistance, and defense against insect pest and diseases have been well documented in many plant species [12]. An increased physical barrier produced by the deposition of Si beneath the leaf cuticles as opaline phytoliths has long been considered to represent a major component of underlying Si-mediated plant resistance to insect pests [13, 14]. Recent studies also have shown that Si treatment induces the activities of plant defensive enzymes [15, 16] and leads to increased accumulation of defensive compounds such as phenolics, phytoalexins, momilactones [17-19] and also increased release of plant volatiles that attract natural enemies of herbivorous insects [20].

As the Si- induced resistance in plants against insect pest was considered as a novel strategy for biologically based, environmentally friendly and durable insect pest management. Keeping these concept in view, the present investigation was undertaken.

2. Materials and Methods

A field experiment was carried out in randomized block design with three replications in the Central research farm, OUAT during *kharif*, 2013 to test the effect of exogenous application of organic and inorganic sources of silicon to rice plant grown under irrigated condition. Twenty one day old seedlings of rice variety "Swarna" were transplanted in 20 m^2 plots at 15x20 cm^2 spacing. Fertilizers were applied at 100:50:50 kg NPK/ha and crop was grown following all recommended agronomic practices. Treatments comprised of diatomaceous earth (DAE) at 150, 300& 450 kg/ha doses, Calcium silicate at 2, 3& 4t/ha and rice hull ash @ 2,3, 4t/ha. All treatments were imposed as basal application during puddling. Enough care was taken to prevent seepage of water from one plot to the other by separating plots with bunds and channels.

Observations on stem borer damage was recorded from 10 randomly selected hills from each plot at 10 days interval starting from 30 DAT onwards till harvest of the crop. At vegetative stage dead heart (DH) damage was estimated by counting total tillers and the infested ones and at heading stage white ear head damage was accessed by counting the total panicle bearing tillers and the damaged ones.

Observations on leaf folder damage was recorded from 10 randomly selected hills from each plot at 20 days interval starting from 30 DAT onwards till harvest of the crop. At both vegetative and reproductive stage of the crop % leaf damage was estimated by counting total leaves and the infested leaves. Plot wise grain yield was recorded leaving two border rows from all sides. Data generated were then subjected to statistical analysis after stable transformation for drawing meaningful conclusion.

3. Results

Rice Yellow Stem borer and Leaf folder are considered as the major insect pests in all rice growing areas of Odisha. Both the insects are found in both *kharif* and *rabi* season in rice. During the period of investigation, the borer damage at an intensity of 11.43% DH and 4.47% WEH was recorded at vegetative and reproductive stage respectively. Similarly, the leaf folder damage was 8.55% damaged leaf in vegetative stage and 5.31% damaged leaf in reproductive stage of the crop.

3.1 Effect of silicon sources against Yellow stem borer (*Scirpophaga incertulas*)

The data presented in Table 1 revealed the effect of exogenous application of different sources of silicon at different doses against yellow stem borer during *kharif*, 2013. The basal application of treatments bring about significant difference in stem borer damage in the treated plots *i.e.* (0.00-0.95% DH) as against 2.34% DH in untreated control even after 30 days after application. The organic silicon source *viz.*, diatomaceous earth at 0.45t/ha and Calcium silicate, an inorganic source of silicon at 2.0t/ha exhibited best performance amongst all other test products. The damage was almost nil (0.00) in both the treatments in early tillering stage. However, in maximum tillering stage superiority of these two molecules were marked with perceptible difference in damage *viz.*, (0.00- 3.09% DH) as against (4.55- 11.43% DH) in untreated control.

The lowest dose of Calcium silicate (*i.e.* $CaSiO_3$ @ 2.0t/ha) which proved most effective but with an exception of highest dose of calcium silicate (*i.e.* 4.0t/ha) which proved ineffective. In future some in-depth research is required to clarify the ineffectivity of calcium silicate (*i.e.* 4.0t/ha). In case of RHA (Rice Hull Ash), a moderate level of performance was shown at vegetative growth stages of crop with a record of (0.00- 8.56% DH) as against (2.34-11.43% DH) in control. Mean data revealed a direct negative relation of borer damage with test doses of DAE whereas a positive relation with doses of $CaSiO_3$ and rice hull ash. Thus, a maximum decline (87.39%) in borer damage were observed in plots receiving lowest dose of $CaSiO_3$ and highest dose of DAE (80.45%).

Similar trend was also observed during reproductive stage of the crop with a lowest record of 0.35% WEH in plots receiving lowest dose of calcium silicate *i.e.* 2.0t/ha and highest dose of DAE (0.69% WEH) as against moderate severity *viz.*, (1.24-2.76% WEH) in rest of treatments. In both the crop growth stages i.e. vegetative and reproductive stage of the crop, the superiority of $CaSiO_3$ at 2.0t/ha and DAE at 0.45t/ha dose were established with lowest incidence of DH and WEH respectively. According to grain yield, lowest dose of $CaSiO_3$ yielded highest with a record of 50.50q/ha as against 36.0q/ha in untreated control.

3.2 Effect of silicon sources against Leaf folder (*Cnaphalocrosis medinalis*)

Data presented in Table 2 revealed the effect of exogenous application of different silicon sources at different doses against leaf folder during *kharif*, 2013. Significant difference in % damage was marked among different silicon treatments applied basally in both vegetative and reproductive stage of the crop *viz.*, (0.00 to 7.03% damage leaf) as against (3.73-8.55% damage leaves) in untreated control. Among the different silicon sources tested, Diatomaceous earth (DAE), an organic silicon source at 0.45t/ha and Calcium silicate, an inorganic silicon source at 2t/ha performed best in suppressing the leaf folder damage. In early tillering stage *i.e.* at 30 DAT(days after transplanting), a marked difference in effectiveness of both the treatments was observed *i.e.* 0.00% and 1.04% damaged leaves as against 3.73% in untreated control. Similar trend in effectivity of both the treatments was also observed in maximum tillering and reproductive stage of the crop *viz*., 2.08 and 2.14 mean percentage damage leaf as against 6.09 in untreated control.

In case of DAE, other treatments shows moderate level of infestation and the mean data reveals a direct negative relation of leaf folder damage with the test doses of DAE. Similarly, in case of $CaSiO_3$, a direct positive relation of folder damage with the test doses was observed with an exception of highest dose of $CaSiO_3$ which found ineffective. In case of Rice Hull Ash (RHA), another organic source of silicon performed at moderate to low level against leaf folder infestation with a record of (1.26-7.03%) damaged leaf as against (3.73-8.55%) in untreated control.

Two best treatments *viz.*, $CaSiO_3$ @ 2.0t/ha and DAE at 0.45t/ha registered 65.84% and 64.8 percent decrease in damage by leaf folder over control. In grain yield point of view, all the treatments yielded more than 39.0q/ha as against 36.66q/ha in untreated control. $CaSiO_3$ @ 2.0t/ha was the highest yielder with a record of 50.50q/ha which was closely followed by DAE @ 0.45t/ha with a record of 47.66t/ha.

3.3 Discussions

Rice is one of the typical Si-accumulating plant species, and Si accumulation in rice is an active process [21]. As reported for crops within the family Poaceae, increased resistance associated with Si addition may result from a cuticle-silica double layer, which is formed in the leaf blade and acts as a mechanical barrier to insect herbivores [22]. Furthermore, rice varieties resistant to the rice leaf folder have closer silica chains, heavy deposition of silica in the intercostal area, high epidermal silica deposition and a single or double row of silica, in contrast to susceptible rice varieties [23]. In the present study, basal application of silicon in rice increases resistance against yellow stem borer and leaf folder which may be attributed by application of silicon amendments. The increased Si content from Si amendment plots conferred resistance to the rice stem borer and leaf folder, as indicated by reduced rate of infestation by the insects on plants.

The present findings on impact of silicon amendments against yellow stem borer are in close conformity with reports of Han and Hou [24] who reported similar impact of Calcium silicate ($CaSiO_3$) on rice with fairly high level of efficacy against stem borer. The present results are also in agreement with Fallah *et al*. [25] who found 10-20% less stem borer infestation in silicate fertilizer treated plants as compared to control plants and less incidence was attributed to silica deposition in shoot, leaf and panicle.

Similarly in case of leaf folder, the present findings on impact of silicon amendments against leaf folder are supported by Chandramani *et al.* [26] they found a negative correlation between increase in silica content and infestation by leaf folder. They also reported that reduced leaf folder incidence was attributed to wearing of mandibles and lack of feeding which was an antixenotic (non-preference) mechanism induced by silica. Similarly, the present findings are in accordance with Jawahar *et al.* [27] who established that soil application of Silixol Granules @ 37.5 kg /ha along with 100% recommended dose of fertilizers reduced the infestation of leaf folder and stem borer in rice by enhancing silicon content in plants.

4. Conclusion

Thus, considering all the facts and figures discussed in the present study, it is evident that overall impact of the organic and inorganic sources of silicon *viz.*, Diatomaceous earth (450kg/ha) and Calcium silicate (2t/ha) may be recommended for integration into the IPM system in rice.

5. Acknowledgement

Authors are thankful to the Orissa University of Agriculture & Technology, Bhubaneswar for providing necessary facilities and for requisite funding towards this research study.

Table 1: Effect of organic and inorganic Silicon amendments on stem borer damage in rice during *kharif*, 2013

Tr. No.	Test product	Dose	Vegetative stage (% DH)							Pre harvest (% WEH)		Grain yield (q/ha)
			30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	Mean	% decrease over control	90 DAT	% decrease over control	
T1	Diatomaceous Earth	0.15	0.95 (1.20)	2.16 (1.61)	1.63 (0.92)	3.41 (1.97)	7.56 (2.83)	3.14	49.27	2.68 (1.77)	40.04	40.83
T2	Diatomaceous Earth	0.30	0.39 (0.92)	1.34 (1.35)	1.36 (1.36)	2.90 (1.83)	6.87 (2.70)	2.57	58.48	1.96 (1.56)	56.15	42.91
T3	Diatomaceous Earth	0.45	0.00 (0.70)	0.42 (0.94)	0.83 (1.14)	1.75 (1.49)	3.09 (1.89)	1.21	80.45	0.69 (1.08)	84.56	47.66
T4	Calcium Silicate	2.0	0.00 (0.70)	0.00 (0.70)	0.19 (0.82)	1.35 (1.34)	2.38 (1.69)	0.78	87.39	0.35 (0.90)	92.17	50.50
T5	Calcium Silicate	3.0	0.00 (0.70)	1.25 (1.31)	1.37 (1.35)	2.96 (1.85)	5.57 (2.45)	2.23	63.97	1.93 (1.65)	56.82	43.00
T6	Calcium Silicate	4.0	0.20 (0.81)	1.46 (1.39)	1.38 (1.36)	3.46 (1.98)	7.02 (2.73)	2.70	56.38	2.43 (1.70)	45.63	41.49
T7	Rice Hull Ash	2.0	0.00 (0.70)	1.30 (1.33)	2.19 (1.63)	2.99 (1.86)	4.98 (2.33)	2.29	63.00	1.24 (1.31)	72.25	43.83
T8	Rice Hull Ash	3.0	0.21 (0.82)	1.34 (1.35)	2.43 (1.69)	3.23 (1.92)	6.26 (2.59)	2.69	56.54	1.68 (1.46)	62.41	42.00
T9	Rice Hull Ash	4.0	0.00 (0.70)	1.52 (1.41)	3.07 (1.88)	4.56 (2.24)	8.56 (3.00)	3.54	42.81	2.76 (1.80)	38.25	39.83
T10	Untreated Control	-	2.34 (1.67)	4.55 (2.24)	5.06 (2.35)	7.59 (2.83)	11.43 (3.45)	6.19		4.47 (2.22)		36.66
	S.E.(m)± C.D.(0.05)		0.068 0.20	0.084 0.25	0.158 0.46	0.068 0.20	0.058 0.17			0.117 0.34		1.604 4.76

*Figures in parenthesis are square root transformation value

Table 2: Effect of organic and inorganic sources of silicon on leaf folder damage in rice during *kharif*, 2013

Tr. No.	Test product	Dose(t/ha)	% Damaged leaf						Grain yield (q/ha)
			30 DAT	50 DAT	70 DAT	90 DAT	Mean	% decrease over control	
T1	Diatomaceous Earth	0.15	1.68 (1.46)	5.10 (2.36)	4.62 (2.25)	3.67 (2.03)	3.76	38.25	40.83
T2	Diatomaceous Earth	0.30	1.37 (1.35)	4.97 (2.33)	3.61 (2.02)	3.04 (1.87)	3.24	46.79	42.91
T3	Diatomaceous Earth	0.45	0.00 (0.70)	4.17 (2.15)	2.39 (1.69)	2.03 (1.58)	2.14	64.86	47.66
T4	Calcium Silicate	2.0	1.04 (1.22)	3.36 (1.96)	2.11 (1.61)	1.84 (1.52)	2.08	65.84	50.50
T5	Calcium Silicate	3.0	1.38 (1.36)	4.35 (2.19)	2.86 (1.82)	2.64 (1.77)	2.80	54.02	43.00
T6	Calcium Silicate	4.0	1.90 (1.54)	6.03 (2.55)	4.22 (2.16)	3.30 (1.94)	3.86	36.61	41.49
T7	Rice Hull Ash	2.0	1.26 (1.32)	4.76 (2.28)	3.39 (1.96)	2.66 (1.76)	3.01	50.57	43.83
T8	Rice Hull Ash	3.0	1.99 (1.57)	5.54 (2.45)	4.54 (2.20)	3.64 (2.03)	3.92	35.63	42.00
T9	Rice Hull Ash	4.0	2.48 (1.72)	7.03 (2.73)	5.10 (2.36)	3.82 (2.07)	4.60	24.46	39.83
T10	Untreated Control	-	3.73 (2.05)	8.55 (3.00)	6.77 (2.69)	5.31 (2.40)	6.09		36.66
	S.E.(m)±		0.067	0.076	0.052	0.067			1.604
	C.D.(0.05)		0.20	0.22	0.15	0.19			4.76

*Figures in parenthesis are square root transformation values.

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