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Effect of Organic and Inorganic Sources of Silicon against Yellow Stem Borer (*Scirpophaga incertulas* Walker) of Rice in Odisha, India

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A B S T R A C T

Field studies on the effect of organic and inorganic sources of silicon against yellow stem borer in rice revealed the superiority of calcium silicate at 2t/ha and diatomaceous earth at 0.45t/ha in arresting stem borer damage with a record of average 5.84 – 11.97 % dead heart (DH) and 2.56 – 8.84% white ear head (WEH) as against 14.75 – 21.34 % DH and 8.35-14.93% WEH in control. At vegetative and heading stages both the treatments resulted in up to 60% and 69% decline in borer damage. The cumulative accumulation of silicon in rice plant was 8.39 and 10.25 % respectively as against 4.15% in control. Higher grain yield (33.64 – 34.99 q/ha) was recorded from plots receiving above treatments as compared to 24.24 q/ha in untreated check.

Introduction

Rice is life and considered most important among the cereals, the staple food of 65% of the total population in India. India is the largest rice growing country and contributes 157.90 MT annual production with 22% share of world's production and 24% of Asian countries rice production (FAO, 2011). In Odisha, all the ten agro-climatic zones are favourable for cultivation of rice but still the productivity of rice in Odisha is below national average. Since the onset of green revolution in the country, there has been a constant increase in the productivity but there is also increase in number of insect pests and also a concomitant shift in their pest status/intensity, diversity, and spread in rice. Several insects feeds on rice, but stem borers are considered to be the most important rice pest of which Yellow Stem Borer *Scirpophaga incertulas* (Walker) (Sigsgaard, 2000) is the dominant one because of its ubiquitous distribution chronic pattern of infestation (Salim and Masir, 1987) and (Senapati and Panda, 1999). Stem borer *S. incertulas* usually comprised more than 90% of the borer population in rice ecosystem of Odisha. 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. It infests rice plant from seedling to flowering stage causing dead heart at vegetative stage and white ear heads during the flowering stage.

Currently, the yellow stem borer populations are principally managed with chemical insecticides. However, because of pest resistance, resurgence and residue on food stuff chemical failed to give adequate control measure and hence its use is being highly discouraged. Moreover, poor control by chemical is due to the insect's shelter inside the stem and its migratory behaviour, the latter necessitating precise timing and repeated insecticide applications. Therefore, it is imperative to develop an alternative approach to control this pest.

One crop management tactic that can benefit the control of insect pests is the amendment of silicon (Si) fertilizer. Silicon, after oxygen, the second most abundant element in the Earth's crust and soil (27.70%) (Ma and Yamaji, 2006; Yamaji *et al.*, 2008 and Fauteux *et al.*, 2005). Silicon (Si) is considered as a "quasi-essential element for plant growth", because it is directly not involved in growth of higher plants and no visible symptoms of Si deficiency or toxicity do appear on plants. Deposition of Si in rice plant tissue enhances its strength and rigidity protecting the plants in a passive way. Specifically, in rice up to 10% Si accumulation occurs on a dry weight basis in the shoot. High accumulation of Si in rice has been demonstrated to be necessary for healthy growth and high and stable production with protection from economically important insect pests viz., stem borer, brown planthopper etc., and non-insect pests such as mites (Ma and Yamaji, 2006), (Liang,1998) and (Savant *et al.*,1997).

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 concepts in view, the present investigation was undertaken.

Materials and Methods

Field experiments were carried out in randomized block design with three replications in the Central research farm, OUAT during *rabi*, 2014 and 2015 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 "Khandagiri" 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 ($CaSiO_3$) at 2, 3& 4t/ha and rice hull ash(RHA) @ 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 days after transplanting(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. Plot wise grain yield was recorded leaving two border rows from all sides. At harvest plant samples were collected from each plot for estimating the silicon (Si) accumulation following procedure laid out by (Wieman *et al.*, 2005). Data generated were then subjected to statistical analysis after stable transformation for drawing meaningful conclusion.

Results and Discussion

Yellow stem borer inflicts heavy damage to rice crop in the state with five broods in a year. Comparatively the severity is more in *rabi* season during which the field experiments were carried out. Borer damage to the tune of 29.84 % DH and 14.93 % WEH was recorded at vegetative and reproductive stages respectively. Data presented in Table 1 revealed the importance of exogenous application of different sources of silicon at different doses during *rabi* 2014. The basal application of test products could bring about a perceptible effect even 30 days after its application with a distinctly lower borer damage (4.63-8.13 % DH) in silicon treated plots compared to that of control (10.87% DH). Diatomaceous earth, an organic source of silicon, at 0.45 t/ha and calcium silicate, an inorganic source at 2.0t/ha exhibited better performance in arresting the stem borer damage at this early tillering stage with a record of 4.3 – 4.6 % DH over rest of the treatments exhibiting a moderate level of borer damage (6.84-8.13% DH) with the exception of highest dose of calcium silicate which proved ineffective. Almost similar effects were noticed in subsequent observations with little deviations but without compromising the superiority of $CaSiO_3$ at 2t/ha and DAE at 0.45t/ha in arresting stem borer damage (10.0 – 20.43 % DH) during its peak activity. A moderate to low level of performance was shown by rice hull ash at different stages of crop growth with a record of 6.72 – 25.97 % DH as against 10.87 – 29.84 % 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 (43.90%) in borer damage were observed in plots receiving highest dose of DAE, and lowest dose of $CaSiO_3$ (44.75%) and rice hull ash (34.06%) during the vegetative stage of the crop. Similar trend was also observed at the heading stage with a record of lowest white ear head damage(3.38% WEH) in plots receiving highest dose of DAE and lowest dose of $CaSiO_3$ (2.56 % WE) as against a moderate severity (3.95- 4.59 % WE) in rest of the treatments. Like vegetative stage, the superiority of DAE at 0.45t/ha and $CaSiO_3$ at 2.0 t/ha was observed in reproductive stage resulting in 59-69 % decline in white ear head damage during this season. The graphical representation on effect of different silicon treatments against yellow stem borer infestation during *rabi* 2014 was shown in Fig 1. Grain yield, which is manifestation of cumulative impact of different treatments, was maximum (36.3 q/ha) in plots receiving $CaSiO_3$ at 2.0t/ha followed by DAE at 0.45t/ha and rice hull ash at 2.0t/ha with a record of 32.4 and 30.9 q/ha respectively as against 20.70 q/ha in control.

Result of the second season trial presented in Table 2 further strengthened our finding and substantiated the fact that basal application of different sources of silicon in rice could effectively restrict the stem borer damage as reported earlier by Sawant *et al.,* (1994). Like previous season, the superiority of highest dose of DAE over other treatments could be demonstrated at different growth stages of the crop. At vegetative stage borer damage to the extent of 0.35 to 13.64 % DH (Avg 5.84%) registered by this treatment as against 7.42 to 25.8% DH (Avg 14.75% DH) in untreated check resulting in 60.40 % reduction in damage. Correspondingly, 40.80 % reduction in white ear head damage was exhibited by this treatment. $CaSiO_3$ on the other hand at 2t/ha exhibited similar performance and resulted in about 52.0 % reductions in borer damage at both vegetative and reproductive stages. Interestingly during second trial also incremental damage by borers at both vegetative and heading stage was observed with increase in doses of this test product.

Table.1 Effect of organic and inorganic sources of silicon on stem borer damage in rice during *rabi*, 2013-14

Tr. No.	Test product	Dose (t/ha)	Vegetative stage (% DH)						Pre harvest (% WEH)	
			30 DAT	40 DAT	50 DAT	60 DAT	Mean	% decrease over control	90 DAT	% decrease over control
T1	Diatomaceous Earth	0.15	8.13 (2.92)	17.14 (4.19)	23.07 (4.84)	21.05 (4.63)	17.34	18.74	4.59 (2.23)	45.02
T2	Diatomaceous Earth	0.30	7.60 (2.83)	16.90 (4.16)	22.73 (4.81)	20.49 (4.57)	16.93	20.66	4.17 (2.14)	50.05
T3	Diatomaceous Earth	0.45	4.34 (2.16)	10.04 (3.23)	19.08 (4.42)	14.42 (3.85)	11.97	43.90	3.38 (1.96)	59.52
T4	Calcium Silicate	2.0	4.63 (2.25)	10.30 (3.27)	20.43 (4.57)	11.83 (3.50)	11.79	44.75	2.56 (1.73)	69.34
T5	Calcium Silicate	3.0	8.36 (2.97)	13.26 (3.70)	24.43 (4.98)	17.13 (4.19)	15.79	26.00	4.41 (2.21)	47.18
T6	Calcium Silicate	4.0	9.44 (3.14)	16.14 (4.07)	26.13 (5.15)	17.88 (4.28)	17.39	18.50	6.38 (2.61)	23.59
T7	Rice Hull Ash	2.0	6.72 (2.68)	11.04 (3.39)	22.11 (4.78)	16.42 (4.10)	14.07	34.06	4.00 (2.10)	52.09
T8	Rice Hull Ash	3.0	6.84 (2.69)	11.92 (3.52)	23.14 (4.85)	18.72 (4.37)	15.15	29.00	3.95 (2.10)	52.69
T9	Rice Hull Ash	4.0	7.40 (2.79)	13.84 (3.78)	25.97 (5.14)	19.97 (4.51)	16.79	21.32	5.78 (2.48)	30.77
T10	Untreated Control	-	10.87 (3.36)	21.23 (4.65)	29.84 (5.50)	23.45 (4.89)	21.34		8.35 (2.97)	
	SE (m) ± $C.D._{0.05}$		0.142 0.42	0.091 0.27	0.071 0.21	0.085 0.25			0.123 0.37	

*Figures in parentheses are square root transformed values.

Table.2 Effect of organic and inorganic sources of silicon on stem borer damage in rice during *rabi* 2014-15

Tr. No.	Test product	Dose (t/ha)	Vegetative stage (% DH)						Pre-harvest (% WE)	
			30 DAT	40 DAT	50 DAT	60 DAT	Mean	%decrease over control	90 DAT	% decrease over control
T1	Diatomaceous Earth	0.15	5.31 (2.40)	4.21 (2.16)	13.71 (3.76)	21.14 (4.64)	11.09	24.81	11.00 (3.38)	26.32
T2	Diatomaceous Earth	0.30	1.17 (1.28)	3.2 (1.93)	12.31 (3.57)	19.06 (4.41)	8.94	39.38	11.71 (3.48)	21.56
T3	Diatomaceous Earth	0.45	0.35 (0.90)	0.00 (0.70)	9.37 (3.12)	13.64 (3.75)	5.84	60.40	8.84 (3.05)	40.79
T4	Calcium Silicate	2.0	0.69 (1.05)	0.00 (0.70)	10.77 (3.34)	16.78 (4.15)	7.06	52.13	6.99 (2.71)	53.18
T5	Calcium Silicate	3.0	3.04 (1.88)	1.02 (1.22)	12.06 (3.53)	21.21 (4.65)	9.33	36.74	9.91 (3.21)	33.62
T6	Calcium Silicate	4.0	3.37 (1.96)	1.62 (1.45)	14.90 (3.91)	21.23 (4.65)	10.28	30.30	10.70 (3.34)	28.33
T7	Rice Hull Ash	2.0	0.69 (1.05)	3.98 (2.11)	12.72 (3.63)	18.21 (4.32)	8.90	39.66	11.56 (3.46)	22.57
T8	Rice Hull Ash	3.0	2.72 (1.79)	3.92 (2.18)	13.12 (3.67)	19.29 (4.35)	9.76	33.83	11.68 (3.47)	21.76
T9	Rice Hull Ash	4.0	3.31 (1.94)	4.12 (2.31)	14.50 (3.66)	19.98 (4.52)	10.47	29.01	11.90 (3.51)	20.29
T10	Untreated Control	-	7.42 (2.81)	8.63 (3.01)	17.12 (4.19)	25.84 (5.12)	14.75		14.93 (3.92)	
	SE(m)± C.D.(0.05)		0.095 0.28	0.094 0.28	0.127 0.38	0.094 0.28			0.128 0.38	

Figures in parenthesis are square root transformed values.

Table.3 Cumulative accumulation of silica in rice plants as influenced by sources of silicon during *rabi'* 2014-15

Tr. No.	Test product	Dose(t/ha)	Silicon Content (%) At harvest	Grain yield(q/ha) *rabi*, 2013-14	Grain yield(q/ha) *rabi*, 2014-15	Mean
T1	Diatomaceous Earth	0.15	4.73 (2.28)	27.84	30.55	29.19
T2	Diatomaceous Earth	0.30	6.03 (2.55)	29.44	31.63	30.54
T3	Diatomaceous Earth	0.45	8.39 (2.97)	32.36	34.91	33.64
T4	Calcium Silicate	2.0	10.25 (3.24)	36.25	33.72	34.99
T5	Calcium Silicate	3.0	9.49 (3.13)	28.72	31.74	30.23
T6	Calcium Silicate	4.0	7.63 (2.84)	26.54	30.15	28.35
T7	Rice Hull Ash	2.0	8.19 (2.94)	30.87	32.93	31.90
T8	Rice Hull Ash	3.0	5.94 (2.53)	26.08	31.34	28.71
T9	Rice Hull Ash	4.0	5.32 (2.40)	25.68	29.94	27.81
T10	Untreated Control	-	4.15 (2.15)	20.72	27.76	24.24
	SE(m) ±		0.025	1.173	0.580	
	$CD_{0.05}$		0.07	3.48	1.723	

Figures in parentheses are square root transformed values.

The reason for this peculiar behavior of the test product is not clear and needs to be ascertained. Lowest panicle damage (6.99% WE) observed with lowest dose of $CaSiO_3$ and remained on par with that of highest dose of DAE. Rice hull ash did not show any variations in borer damage at different test doses during the heading stage of the crop. The graphical representation on effect of different silicon treatments against yellow stem borer infestation during *rabi* 2015 was shown in Figure 2. Maximum yield to the tune of 34.91 q/ha was obtained from plot receiving DAE at 0.45t/ha followed by 33.72 q/ha and 32.93 q/ha in lowest dose of $CaSiO_3$ and rice hull ash compared to 27.80 q/ha in control. All other treatments yielded lower but significantly more than control which may be attributed to the level of resistance induced against the borers.

Silicon content in plant sample

Laboratory estimation of silicon in plant samples revealed a marked variation in level of "Si' accumulation during entire period of crop growth with a record of 4.73 to 10.25 % in different treatments compared to 4.14% in control. $CaSiO_3$ applied at 2t/ha resulted in highest silicon accumulation (10.25%) which in turn imparted greater level of resistance to borer damage. With its increased dose, silicon accumulation in plants decreased which is also observed with rice hull ash with a variation of 5.32 to 8.19%. However, in case of DAE, the silicon content in plant samples increased from 4.73% to 8.39% with increase in dose from 0.15 to 0.45 t/ha dose. This higher accumulation of silicon is the reason for low borer damage in plots receiving higher doses of DAE. It has been hypothesized that "Si" deposited on the tissue surface acts as a physical barrier and it prevents physical penetration and / or makes the plant cells less susceptible to enzymatic degradation by insect pests (Salim and Saxena 1992) and (Kvedaras and Keeping, 2007). This mechanism is supported by the positive correlation between the Si content and the degree of suppression of insect pests which is well established through this investigation (Table 3).

The present findings are in close conformity with reports of Han and Hou (2011) who reported similar impact of calcium silicate on rice with fairly high level of efficacy against stem borer. Similarly, Fallah *et al.,* (2011) also noticed 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. Thus, considering all the facts and figures discussed above and the overall impact of different sources of silicon, diatomaceous earth at 0.45 t/ha and calcium silicate at 2t/ha may be recommended for use by the rice farmer as a holistic approach in stem borer management in rice.

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