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Silicon induced resistance expression in rice to Yellow stem borer

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Abstract
The field experiment conducted during *kharif* 2014 on the influence of silicon application in rice for induction of resistance against yellow stem borer revealed that application of orthosilicic acid @ 4ml/l as foliar spray four times starting from 15 days after transplanting (DAT) at weekly intervals reduced the yellow stem borer infestation significantly (1.51% dead heart and 3.33% white ear head) as compared to control treatment (5.0% dead heart and 11.44% white ear head). Other silicon based treatments were observed to be less efficacious than orthosilicic acid. Orthosilicic acid treatment improved the yield attributing characters of rice plant and increased the grain yield substantially as compared to other treatments including control treatment. Reduced incidence of stem borer due to application of orthosilicic acid was attributable to reduced stem diameter, reduced feeding and impediment in larval penetration due to higher silica uptake by the rice plants.

Keywords: Rice, Yellow stem borer, Induced resistance, Silicon, Dead heart, White ear head

Introduction
Rice, being the staple food of millions of people in our country, is attacked by a number of insect pests out of which yellow stem borer is the most important one. Due to its monophagous nature and failure of conventional pesticides including some new molecules to control the yellow stem borer, the infestation is still high. Lack of commercial resistant variety against yellow stem borer further compounds the problem. Therefore, exploitation of mechanism of induced resistance in rice through abiotic elicitors is the need of the hour. Silicon is one such abiotic elicitor which improves the resistance of rice plant through jasmonic acid synthesis. Keeping in view the restoration of environmental quality, induction of resistance through application of silicon fertilizer in rice to control a number of rice pest has already been studied by many workers. Panda *et al.* [10] have reported that the larvae of yellow stem borer were unable to attack a resistant rice accession due to higher uptake of silica in their stems. Ranganathan *et al*. [11] also reported that addition of silica in rice led to substantial reduction in stem borer damage. Reduction in stem borer damage due to silicon uptake was attributed to failure in penetration of neonate larvae. Therefore, an attempt was made to find the efficacy of silicon in rice against yellow stem borer, and its influence in increasing the grain yield.

Materials and Methods
Thirty days old seedlings of a rice variety Swarna was transplanted in the field at Central Research Farm, Department of Entomology, OUAT during *Kharif* 2014, with all recommended agronomic practices. Nine treatments including a control (no treatment) were imposed in a randomized block design with three replications. Silicon in form of orthosilicic acid was applied as foliar spray four times at 20, 35, 50 and 65 days after transplanting and calcium silicate, fly ash and steel slag each were applied as basal soil application.
Observation on yellow stem borer in terms of dead heart were recorded at weekly interval starting from 15 DAT and white ear head at 7 days before harvesting. Feeding tunnel produced by feeding of yellow stem borer larvae at maximum dead heart (43 DAT) and white ear head stage (113 DAT) were recorded from 10 random hills/sub-plot, treatment wise. The plant samples at maximum dead heart period and white ear head stage were collected and analysis of silica uptake by the plant was determined in the laboratory of ICAR-NRRI, Cuttack as per the method suggested by Wei-min *et al*. [15]. Various plant morphological parameters like plant height, tillers/hill, number of leaves/hill, effective tillers/hill and stem diameter were recorded treatment wise 7 days before harvesting.

The grain yield was computed from each subplot and converted to q/ha. All the data recorded from various observations were subjected to statistical analysis as per the method suggested by Gomez and Gomez [4] with necessary transformation wherever required.

Results

A. Effect of silicon on yellow stem borer and feeding tunnel

(i) Incidence of dead heart

The data presented in Table 2 revealed that there was no significant difference between the treatments upto 29 DAT, so far the incidence of dead heart was concerned. However, significant difference between the treatments in relation to dead heart was observed from 36 DAT onwards. At 36 DAT, the control treatment registered 7.69% dead heart while orthosilicic acid @ 4 ml/l produced only 1.47% dead heart, remaining at par with orthosilicic acid @ 2 ml/l, calcium silicate @ 1 t/ha and calcium silicate @ 0.5 t/ha and the trend more or less existed for rest of the periods of observation i.e. from 43 DAT to 57DAT. As regards to mean performance, it was observed that treatment T_2 (orthosilicic acid @ 4 ml/l) was the best treatment in recording 1.51% dead heart as against 5% dead heart in control.

(ii) Incidence of white ear head

The data on white ear head (Table 2) revealed that the treatment orthosilicic acid @ 4 ml/l was the best treatment that produced lowest white ear head (3.33%) which remained at par with most of the other silicon treatments excluding T_7 (7.46% white ear head) whereas, control treatment supported 11.44% white ear head.

(iii) Effect of silicon on larval feeding potential

It has been observed that larval feeding was minimum in orthosilicic acid @ 4 ml/l (4.87 cm) which was at par with many other treatments excluding T_5 (fly ash @ 250 kg/ha) (7.42 cm) which indicated that uptake of silicon has definitely interfered in feeding potential by yellow stem borer larvae, whereas, in control treatment feeding tunnel length was found to be 12.60 cm which was significantly different from all the treatments (Table 2). Similarly, at 113 DAT (maximum white ear head stage), it was observed that tunnel length was minimum in T_2 (4.33 cm) which was at par with T_1, T_3, T_4, T_7 and T_8 treatments (4.39-5.37 cm). At this stage the control treatment recorded a tunnel length of 18.70 cm which is significantly different from other treatments.

B. Uptake of silicon by rice plants

It was observed that the plants in T_2 (orthosilicic acid @ 4 ml/l) contained 15.30% silica followed by T_4 (calcium silicate @ 1 t/ha) (15.10%), T_1 (orthosilicic acid @ 2 ml/l) and T_3 (calcium silicate @ 0.5 t/ha), each with 15% silicon content (Table 3). At this stage a corresponding value for control was also 11.20%. Silicon content at white ear head stage (113 DAT) was found to be maximum in T_2 (15.50%) which was significantly different from rest of the treatments. The treatment T_1 and T_4 retained each of 13.50% silica, whereas, control treatment had least amount of silicon (10.20%).

C. Influence of silicon on plant morphological traits

The data presented in Table 3 on plant morphological traits being influenced by various silicon treatments revealed that plant height, number of tillers/hill, number of leaves/hill, number of effective tillers/hill were highest in T_2 (115.90 cm, 25.80, 126.40, 11.20/hill, respectively). The next better treatment in respect of above morphological traits was observed to be T_4 followed by T_3 and T_1. As regards to stem diameter T_2 recorded 3.69cm diameter which was at par with T_1 and remain significantly different from rest of the treatments. Highest stem diameter of 4.93 cm was recorded in control treatment.

D. Effect of silica on rice grain yield

The data on grain yield of rice (Table 3) revealed that highest grain yield of 45.08 q/ha was received from treatment T_2 (orthosilicic acid @ 4 ml/l) which was statistically at par with T_1 (orthosilicic acid @ 2 ml/l) (39.37 q/ha) and T_4 (calcium silicate @ 1 t/ha) (37.78 q/ha). The treatment T_3 (32.54 q/ha) was at par with T_8 (32.06 q/ha) and T_6 (31.43 q/ha) and rest of the treatments. However, the control treatment (T_9) registered the lowest grain yield of 23.97 q/ha.

E. Correlation between silica uptake *Vs* various plant morphological, insect infestation parameters and grain yield

The data on correlation studies between silicon content *Vs* plant morphological character, insect infestation parameters and grain yield is presented in Table 1. The silicon content in plants was found to be negatively and significantly correlated to dead heart (r= -0.72*) and white ear head (r= -0.69*), whereas, it was found to be significantly and positively correlated to grain yield (r= -0.95**). The feeding tunnel length recorded at maximum dead heart stage was also observed to be negatively and significantly correlated with silica content of the plants (r = -0.89), whereas, a non-significant relationship did exist with tunnel length at white ear head stage.

The silicon content in plants was found to be positively and significantly correlated to plant height (r=0.70), tiller number (r=0.77), number of leaves/hill (r=0.83) and number of effective tillers/hill (r=0.80), whereas, it was found to be significantly and negatively correlated to stem diameter (r= -0.81).

Table 1: Correlation between silica uptake *Vs* various plant morphological, insect infestation parameters and grain yield

Parameters	Correlation coefficient (r)
Si content *Vs* plant height	0.70*
Si content *Vs* tiller number	0.77*
Si content *Vs* number of leaves per hill	0.83**
Si content *Vs* stem diameter	-0.81**
Si content *Vs* number of effective tillers per hill	0.80**
Si content *Vs* dead heart (maximum DH stage)	-0.72*
Si content *Vs* white ear head (maximum WEH stage)	-0.69*
Si content *Vs* tunnel length (maximum DH stage)	-0.89**
Si content *Vs* tunnel length (WEH stage)	-0.54
Si content *Vs* grain yield	0.95**

* Significant at 5% level ** Significant at both 1% and 5% level

Table 2. Effect of silicon on the incidence of yellow stem borer and feeding tunnel length in rice

Treatments	Incidence of dead heart (%) at							Mean dead heart (%)	Mean white ear head (%)	Tunnel length (cm) at	
	15 DAT	22 DAT	29 DAT	36 DAT	43 DAT	50 DAT	57 DAT			Maximum Dead heart	Maximum white ear head
Orthosilicic acid @ 2ml/l	0.00 (0.71)	0.33 (0.88)	0.41 (0.91)	1.92 (1.54)	4.07 (2.13)	3.61 (2.03)	2.31 (1.68)	1.81 (1.41)	4.05 (2.13)	5.11 (2.36)	4.39 (2.21)
Orthosilicic acid @ 4ml/l	0.00 (0.71)	0.75 (1.09)	0.83 (1.12)	1.47 (1.39)	3.05 (1.87)	2.88 (1.84)	1.60 (1.44)	1.51 (1.35)	3.33 (1.95)	4.87 (2.30)	4.33 (2.20)
Calcium silicate @ 0.5t/ha	0.00 (0.71)	0.38 (0.90)	0.37 (0.90)	2.11 (1.62)	4.58 (2.25)	3.26 (1.93)	2.41 (1.70)	1.87 (1.43)	4.52 (2.24)	5.92 (2.52)	4.83 (2.31)
Calcium silicate @ 1t/ha	0.00 (0.71)	0.78 (1.10)	1.10 (1.27)	1.91 (1.54)	4.43 (2.21)	2.83 (1.82)	2.12 (1.61)	1.88 (1.46)	4.21 (2.15)	6.03 (2.55)	4.67 (2.27)
Fly ash @ 250kg/ha	0.00 (0.71)	1.05 (1.24)	1.12 (1.27)	2.70 (1.78)	3.95 (2.10)	3.06 (1.88)	2.39 (1.70)	2.04 (1.52)	5.82 (2.49)	7.42 (2.81)	7.10 (2.75)
Fly ash @ 500kg/ha	0.00 (0.71)	1.03 (1.23)	0.75 (1.09)	2.55 (1.74)	3.69 (2.04)	3.33 (1.92)	2.00 (1.57)	1.91 (1.47)	4.82 (2.28)	6.92 (2.72)	6.57 (2.66)
Steel slag @ 250kg/ha	0.00 (0.71)	0.33 (0.88)	0.74 (1.08)	3.15 (1.91)	4.43 (2.22)	3.79 (2.07)	3.32 (1.95)	2.25 (1.54)	7.46 (2.81)	7.23 (2.77)	5.37 (2.42)
Steel slag @ 500kg/ha	0.00 (0.71)	0.86 (1.13)	1.13 (1.28)	2.61 (1.76)	4.37 (2.21)	3.38 (1.96)	2.50 (1.73)	2.12 (1.55)	5.28 (2.39)	6.87 (2.70)	5.03 (2.35)
Control	0.00 (0.71)	1.81 (1.52)	2.79 (1.76)	7.69 (2.89)	10.48 (3.3)	7.56 (2.83)	4.71 (2.27)	5.00 (2.18)	11.44 (3.45)	12.60 (3.61)	18.70 (4.38)
SE_m(±) C.D.(0.05)	0.00 NS	0.16 NS	0.17 NS	0.10 0.30	0.10 0.29	0.13 0.39	0.09 0.28	- -	0.18 0.54	0.17 0.50	0.09 0.28

Figures in parenthesis are $\sqrt{x + 0.5}$ transformed values

Table 3: Effect of different formulation of silica on plant morphological parameters, silica uptake and grain yield

Treatments	Pt. ht (cm)	Tiller/ hill (no.)	Leaves/ hill (no.)	Stem dia (cm)	Effective Tiller/hill (no.)	Silica uptake (%)		Grain yield (q/ha)
						Maximum DH	Maximum WEH	
T_1: Orthosilicic acid @ 2 ml/l	107.60 (10.40)	21.30 (4.67)	95.85 (9.82)	3.89 (2.10)	10.50 (3.32)	15.00 (3.94)	13.50 (3.74)	39.37
T_2: Orthosilicic acid @ 4 ml/l	115.90 (10.79)	25.80 (5.13)	126.40 (11.27)	3.69 (2.05)	11.20 (3.42)	15.30 (3.97)	15.50 (4.00)	45.08
T_3: Calcium silicate @ 0.5 t/ha	105.30 (10.76)	22.10 (4.75)	99.45 (10.00)	4.12 (2.15)	9.80 (3.21)	15.00 (3.94)	12.20 (3.56)	32.54
T_4: Calcium silicate @ 1 t/ha	108.20 (10.43)	23.20 (4.87)	106.72 (10.35)	4.00 (2.12)	9.70 (3.19)	15.10 (3.95)	13.50 (3.74)	37.78
T_5: Fly ash @ 250 kg/ha	110.50 (10.54)	21.70 (4.71)	93.31 (9.69)	4.30 (2.19)	8.90 (3.07)	12.30 (3.58)	10.50 (3.32)	28.89
T_6: Fly ash @ 500 kg/ha	107.40 (10.39)	19.50 (4.47)	87.75 (9.39)	4.25 (2.18)	9.30 (3.13)	13.60 (3.75)	10.60 (3.33)	31.43
T_7: Steel slag @ 250 kg/ha	103.40 (10.19)	19.30 (4.45)	86.85 (9.35)	4.17 (2.16)	9.10 (3.10)	14.00 (3.81)	10.70 (3.35)	31.43
T_8: Steel slag @ 500 kg/ha	106.30 (10.33)	17.80 (4.28)	81.88 (9.08)	4.03 (2.13)	8.80 (3.05)	14.00 (3.81)	11.90 (3.52)	32.06
T_9: Control	100.60 (10.05)	14.60 (3.89)	68.40 (8.27)	4.93 (2.33)	6.50 (2.64)	11.20 (3.42)	10.20 (3.27)	23.97
SE_m(±) CD(0.05)	0.01 0.02	0.01 0.03	0.01 0.02	0.02 0.05	0.03 0.08	0.05 0.16	0.04 0.12	3.21 9.61

Figures in parenthesis are $\sqrt{x + 0.5}$ transformed values

Discussion

A) Effect of silicon fertilizers on yellow stem borer incidence on rice

It was visualized that irrespective of the treatments, the mean DH and WEH incidence was even less than half the value of these parameters in control treatment. Production of less DH and WEH in various silicon treatments may be attributable to failure of neonate larvae to penetrate the leaf sheath and stem due to higher deposition of silica and reduced stem diameter (Saeb and Oskou[12]; Hosseini, *et al.*,[5]). Bandong and Litsinger [1] have also studied excessive stem hardening in rice due to silica mediated lignin and cellulose deposition on leaf sheath cell, which caused less penetration and reduced feeding tunnel length. In the present finding, we also noticed reduced feeding length in silicon treated plants as compared to control. Chandramani *et al.* [2] also suggested that reduction in stem borer incidence in rice was caused due to wearing of mandibles of early larval instars which might have prevented further penetration to cause dead heart and white ear head. Silicon is also regarded as the digestibility reducing component in the insect diet. Hence, higher uptake of silicon by rice plant might have influenced the larval digestion. Such an effect has also been observed by Ranganathan *et al.* [11]. The present finding is well supported by the finding of the above authors.

B) Up take of silica by rice plants

It was indicated from the silicon uptake study that, Orthosillicic acid being a source of well available silicon to rice plants caused higher mobility into plant system as compared to other form of fertilizers. Ma and Takahashi [8] stated that rice is a good silicon accumulator and respond to available form of silicon and when silica level in paddy straw comes below 11% the plants can accumulate more silica. The treated rice plants in the present experiment accumulated more silica than the untreated plants which is well supported from the findings of the above authors.

C) Influence of silicon on morphological traits in rice

The present study revealed that silica enhanced plant height, number of tillers/hill, number of effective tillers/hill and number of leaves/hill. Similar observation has also been made by Hosseini, *et al*. [5] and Moghadam and Heizdarzadech [9]. The above authors stated that application of silica induced the metabolic activity of plants for which the yield attributing characters like plant height, effective tiller number, leaf length, number of leaves/plant were triggered which ultimately produced higher grain yield.

In the present study, reduction in stem diameter due to silica application was observed which might have caused due to compactness in vascular bundles and tight leaf sheath wrapping to provide rigidity. Reduction in stem diameter in rice due to silica application also has been observed by Saeb and Oskou [12] and Hosseini *et al.* [5]. Thus, the present finding derived ample support from the findings of the above workers so far the plant growth parameters of rice plants was concerned.

D) Effect of silica on rice grain yield

Kornodorfer and Lepsch [7] have also observed higher grain yield in rice due to silicon application. They opined that silica application caused vertical leaf positioning; thereby exposing greater leaf area for enhanced rate of photosynthesis for which grain yield was high. Higher grain yield in rice due to silica fertilization also has been observed by Kasturi Thilagam *et al*. [6]. They reported that silica in rice caused vertical positioning of the leaves thus, greater surface of leaf area was exposed to sun which enhanced the rate of photosynthesis and ultimately the grain yield was increased. Hence, the present finding is in line of conformity with the observations of the above authors.

E) Correlation between silica uptake *Vs* various plant morphological, insect infestation parameters and grain yield

Silicon applied through various forms of fertilizers distinctly influenced the degree of plant injury *viz*., incidence of dead heart, white ear head and the feeding potential of the test insect in the present finding.

In the line of present investigation, reports do exist in literature indicating negative correlation of silica with stem borer infestation. Sasamoto [13] found that stems attacked by rice stem borer contain a lower amount of silica. Djamin and Pathak [3] have also observed a negative correlation between silica content of the stem and infestation by Asiatic rice borer.

Role of silica in enhancing the growth parameters of rice ultimately is responsible for higher yield. Takahashi *et al.* [14] have observed that rice being a good silica accumulator showed favourable growth response due to silica application.

Similarly, reduction in stem diameter could be attributable to more compactness of cells due to silicification and leaf sheath tissue toughness.

A high degree of positive correlation between Si uptake and grain yield as visualized in the present study also have been studied by many workers. Recently Kasturi Thilagum *et al*. [6]. from CRRI, Cuttack have observed that increase in rice yield occurred due to silicon induced enhanced efficiency of major essential elements like N, P and K.

Conclusion

From the entire field study and laboratory analysis, it can be inferred that the treatment T_2 (Orthosilicic acid @ 4ml/l as foliar spray four times) was the best treatment that enhanced the desirable yield attributing characters of rice plants and produced higher grain yield. Simultaneously, it caused significant reduction in yellow stem borer infestation in rice. Silicon played a major role in increasing the leaf sheath compactness and cell wall thickening which would have impaired larval penetration, thereby reducing stem borer infestation. Among all the sources of silicon, orthosilicic acid was adjudged as the effective product followed by calcium silicate, steel slag and fly ash.

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