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ROLE OF SILICON IN ENRICHMENT OF MAJOR PLANT NUTRIENTS AND PLANT DEFENSE AGAINST YELLOW STEM BORER, *SCIRPOPHAGA INCERTULAS* (WALKER) IN RICE

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Abstract: Silicon (Si) amendment through soil basal application of diatomaceous earth (DAE) at 400 kg/ha and rice husk ash (RHA) at 2000 kg/ha enhanced the plant defense response for resistance against *Scirpophaga incertulas* registering 51-57% decline in plant damage over control, which is chiefly attributed to higher Si deposits (9.6 and 6.5%, respectively) compared to that of control (4.9%). Silicon supplements at higher doses supported better plant health through increased uptake of major nutrients. A distinctly higher accumulation of Nitrogen (0.84 and 0.92%), Phosphorus (0.16 and 0.19%), and Potassium (2.17 and 2.02%) were registered with above treatments as against (0.58, 0.15 and 1.8%, respectively) in untreated check. Feeding stimuli received from stem borer larvae further augmented the uptake of nitrogen from 0.73 to 0.87% and phosphorous from 0.15 to 0.19% but declined in potassium uptake from 2.01 to 1.85%. The utility of exogenous application of silicon in rice was felt necessary for better plant health management indirectly contributing to induced host plant resistance against *S. incertulas.*

Index Terms **- Rice, *Scirpophaga incertulas*, major plant nutrient, biotic stress**

I. INTRODUCTION

Food and nutritional security is the most important sustainable developmental goal identified by the United Nations for removing hunger from the world, besides addressing the health issues of the increasing human population. Rice plays a vital role in meeting the food requirements of over half of the world's population especially in Asian and African countries. India is the second largest producer of rice next to China in the world (FAOSTAT, 2016), but with a low productivity of 3.6 t/ha as against 6.9 t/ha in China. The reasons for low yield are many, including poor nutrient management and severe biotic stress (Lobella *et al*., 2011; DACFW, 2017). Rice is inflicted by a diverse group of insect pests, amongst which the yellow stem borer (YSB) is the most important one and dominates in East and South-East Asia (Khan *et al*., 1991). The larvae contribute to yield loss by boring into the stem, resulting in dead heart at vegetative stage and white ear at heading stage resulting in a range of 10 to 90% yield loss (Muralidharan and Pasalu, 2006). Since chemical control of this insect is difficult because of a narrow window phase of larval exposure prior to entry into the stem, inducing resistance in rice plants with certain biotic and abiotic elicitors to tackle such stress is being widely experimented. Silicon (Si) is one such elicitor, which has been reported to impart resistance in rice crops against various stress (Ma and Yamaji, 2006; Alhousari and Greger, 2018).

Silicon (Si) as a beneficial element, plays a vital role in plant system and promotes plant growth and yield especially under stress situation. This element is capable of mitigating both biotic and abiotic stress in plants leading to higher productivity (Ma *et al*., 2001). Even as a fertilizer it has been used since 1955 in Japan with a record of remarkable increased rice production (Takahashi *et al*., 1990). Rice accumulates Si in the shoots many times higher than N, P, and K (Ma and Takahashi, 2002; Nhan *et al*., 2012). Silicon has been reported to enhance nutrition accretion by enhancing root activity (Chen *et al*., 2011) increasing water uptake (Sonobe *et al*., 2010) and improving roots hydraulic conductance (Hattori *et al*., 2008). As such, mineral nutrition also protects plants by enhancing the resistance power against biotic stress (Marschner, 1995; Waraich *et al*., 2011). It is further documented that Si is the only quasi-essential element having no detrimental effect even if it excessively accumulated in the plant tissue. Therefore, the use of Si in agriculture has become a new trend for sustaining the crop production (Etesami and Byoung, 2018). Evidences on Si fertilization affecting the uptake of nutrients exist (Greger *et al*., 2018; Shen *et al.,* 2009; Korndorfer *et al.,* 2001) , which are supposed to alter the plant defense system indirectly. Hence, this study was carried out to understand the impact of exogenous application of Si in altering the plant defense mechanism against yellow stem borer (YSB) through changes in uptake of major plant nutrients under biotic stress.

II. RESEARCH METHODOLOGY

Pot culture experiment was undertaken in *kharif* 2021 at Navsari Agricultural University, Navsari in Complete Randomized Design with 11 treatment combinations comprising two organic sources of Si *viz*., diatomaceous earth (DAE) at 100, 200, 300, 400, 500 kg/ha; and rice husk ash (RHA) at 1000, 1500, 2000, 2500, 3000 kg/ha along with an untreated check. The treatments were tested with and without YSB infestation to ascertain the impact of Si on uptake of macro nutrients and their role in defending YSB damage in rice. Earthen pots of 12” diameter filled with 10 kg of paddy soil were imposed with treatments through basal soil incorporation of Si products before planting. Single ten day old petri-plate germinated seedlings of susceptible rice variety TN1 were transplanted in each pot and immediately covered by transparent Mylar cage to protect it from outside pest attack. A separate set of treatments was maintained for imposing biotic stress in which five freshly hatched YSB larvae, obtained through laboratory rearing, were released at 20 days after transplanting (DAT). Stem borer damage was assessed at 7, 14 and 21 days after infestation (DAI). Plant samples were collected after crop maturity for nutritional uptake studies. Samples were oven dried at 70 ^{0}C for 72 hours, ground to fine powder and used for laboratory estimation of plant nutrients.

Major nutrients such as Nitrogen (N), Phosphorus (P), Potassium (K) were estimated following standard procedures in the analytical chemistry laboratory, whereas Si was estimated using ICP-OES (Inductively Coupled Plasma- Optical Emission Spectroscopy) in the Central Laboratory of Odisha University of Agriculture and Technology, Bhubaneswar. For obtaining the plant sample extract the following procedure was followed - One gram of plant sample was subjected to tri-acid digestion by mixing 5 ml Nitric acid in a conical flask, keeping it for overnight and then putting on hot plates for heating at 100 ^{0}C till acid gets completely evaporated. After cooling, 10ml of nitric acid:perchloric acid (3:2) was added and then heated till the sample gets charred. The content was then cooled, dissolved with five ml of hydrochloric acid and then filtered into a 100ml volumetric flask using Whatman No. 42 filter paper. The volume of the filtrate was then made up with double distilled water. This sample extract was diluted 10 times and used in ICP-OES for estimation of Si content. Data on per cent borer damage were square root transformed prior to subjecting to ANOVA test following the procedure laid out by Gomez and Gomez (1994) for test of significance. Nutrient uptake data were analyzed using SPSS (Version 23.0) for calculating standard error mean for comparing healthy and infested sample means.

III. RESULTS AND DISCUSSION

3.1 Effect of silicon on stem borer damage

Data presented in Table 3.1 revealed the silicon mediated response of cultivars to YSB damage at the vegetative stage of the crop. Application of silicate fertilizers significantly reduced the borer damage at all the test doses with a record of 13.33 to 33.03% DH, the minimum being in plants receiving RHA at 2000 kg/ha followed by DAE at 400 kg/ha registering about 15.63% damage compared to 41.11% DH in control. At their highest doses, neither DAE nor RHA gave encouraging results, which needs further investigation. On the other hand, the susceptible variety receiving the lowest dose of DAE was the least effective treatment with minimal effect on borer damage resulting in 33.03% DH. Observation taken two weeks after infestation revealed almost the similar trend but with a greater level of damage. However, DAE at 400 kg/ha proved most efficacious with 20.37% DH, followed by same product at 300 kg and RHA at 2000 kg/ha resulting in about 24% DH as against 43.91% DH in control. At 21 DAI the supremacy of DAE at 400 kg/ha dose in arresting the borer damage was confirmed with a record of 22.64% DH as against 50.67% in control. Irrespective of date of observations the mean borer damage was the lowest in plant receiving DAE at 400 kg/ha with a mean incidence of 19.55% DH followed by RHA 2000 kg/ha with a record of 22.15% DH contributing to about 57 and 51% reduction in borer damage over control, respectively thus exhibiting the superiority of these two treatments in containing the YSB damage.

3.2 Silicon and plant nutrients

Plant defense mechanism against stress is a complex phenomenon. Silicon confers resistance to host plants against biotic stress in various ways including altering the nutritional uptake by plants and acceleration of the release of plant organic volatiles to attract natural enemies (Alhousari and Greger, 2018; Islam *et al*., 2019). The earth consist of several elements which play an immense role in enhancing the quality, quantity and protection of several plants. A number of studies showed that Si has the ability to protect plants not only from biotic and abiotic stresses, but it also plays a role in enhancing the availability and regulating the nutrient balance in plants during the stress and non-stress periods (Marschner, 1995; Waraich *et al*., 2011). Silicon enhances nutrient accretions by augmenting root activity (Chen *et al*., 2011), increasing water uptake (Sonobe *et al*., 2010) and improving root hydraulic conductance (Hattori *et al*., 2008).

3.3 Silicon content in plant samples

In the current studies exogenous application of DAE and RHA at all doses resulted in significant increase in Si accumulation with a record of 5.1 to 9.6% as against 4.93% in control, which has contributed towards enhanced plant defense against the YSB in rice. Such high Si deposits in various plant tissues provides resistance against chewing insects as has been reported by Savant *et al*. (1997); and Massey *et al*. (2006). Feeding stimuli received from YSB larvae has also led to increased accumulation (average 7.15%) of this beneficial element compared to the healthy one (5.96%), presumably to prevent further damage by the borer (Table 3.2).

3.4 Effect of silicon amendment on uptake of major plant nutrients

3.4.1 Nitrogen (N)

Addition of Si has resulted in significant increase in N concentration with a record of 0.71 to 0.95% concentration in different treatments as compared to 0.58% in control (Table 3.2). The highest accumulation of N was observed with plants receiving higher doses of RHA irrespective of biotic stress. A synergistic relation of Si application to plant and nitrogen uptake has earlier been observed with a report of positive interaction of both elements by Mali and Aery (2008) and Kasturi Thilagum *et al*. (2014). Si is observed to have the potential to improve the optimal nitrogen rate and photosynthesis in rice resulting in enhanced productivity (Pati *et al*., 2016). Compared to control (Si non-amended crop) the increase in N content was observed in all the treatments either

Table 3.1: Stem borer damage in susceptible TN1 rice variety as influenced by sources and doses of silicon under pot culture during *kharif* '21

Tr. No	Sources	Dose (kg/ha)	Stem borer damage at vegetative stage (% Dead heart)				
			7 DAI	14 DAI	21 DAI	Mean	Reduction over control (%)
T1	DAE	100	33.03 (5.73)	37.05 (6.09)	41.77 (6.46)	37.28	17.65
T2	DAE	200	30.03 (5.44)	33.26 (5.75)	36.57 (6.05)	33.29	26.47
T3	DAE	300	22.53 (4.73)	23.81 (4.88)	26.29 (5.13)	24.21	46.52
T4	DAE	400	15.63 (3.93)	20.37 (4.51)	22.64 (4.75)	19.55	56.82
T5	DAE	500	27.27 (5.22)	25.46 (5.04)	25.91 (5.09)	26.21	42.10
T6	RHA	1000	24.00 (4.89)	36.24 (6.02)	43.83 (6.62)	34.69	23.37
T7	RHA	1500	18.18 (4.25)	29.64 (5.44)	38.37 (6.19)	28.73	36.53
T8	RHA	2000	13.33 (3.61)	24.64 (4.96)	28.48 (5.33)	22.15	51.07
T9	RHA	2500	16.67 (4.08)	25.03 (5.00)	26.12 (5.11)	22.61	50.05
T10	RHA	3000	30.00 (5.47)	31.43 (5.60)	33.33 (5.77)	31.58	30.22
T11	Control	0	41.11 (6.41)	43.99 (6.63)	50.70 (7.12)	45.27	-
	Mean	-	24.71 (4.89)	30.08 (5.45)	34.00 (5.78)		
	SE(m)±		0.071	0.050	0.038		
	$CD_{0.05}$		0.20	0.16	0.11		

Figures inside the parentheses are the square root values of (x+0.5)
DAE- Diatomaceous earth, RHA- Rice Husk Ash, DAI – days after infestation

Table 3.2: Effect of organic sources of silicon on nutrient uptake by rice plants grown under pot culture with and without *S. incertulas* infestation

Tr. No.	Source	Dose	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Silicon (%)		
		(kg/ha)	H	I	Mean	H	I	Mean	H	I	Mean	H	I	Mean
T1	DAE	100	0.64	0.78	0.71	0.14	0.16	0.15	2.06	1.33	1.70	4.30	5.95	5.13
T2	DAE	200	0.70	0.90	0.80	0.14	0.20	0.17	2.18	1.69	1.94	4.95	6.58	5.76
T3	DAE	300	0.73	0.86	0.79	0.16	0.20	0.18	2.27	1.87	2.07	7.70	9.10	8.40
T4	DAE	400	0.81	0.87	0.84	0.16	0.17	0.16	2.35	1.99	2.17	9.25	9.90	9.58
T5	DAE	500	0.78	0.90	0.84	0.17	0.15	0.16	2.26	1.86	2.06	6.05	7.75	6.90
T6	RHA	1000	0.71	0.80	0.75	0.12	0.20	0.16	1.28	1.67	1.48	4.75	5.95	5.35
T7	RHA	1500	0.67	0.81	0.74	0.13	0.22	0.17	1.51	1.75	1.63	5.20	6.38	5.79
T8	RHA	2000	0.81	1.04	0.92	0.16	0.21	0.19	2.08	2.04	2.06	6.05	6.90	6.48
T9	RHA	2500	0.86	1.04	0.95	0.18	0.24	0.21	2.05	2.17	2.11	6.55	7.03	6.79
T10	RHA	3000	0.76	0.98	0.87	0.16	0.19	0.17	2.29	2.19	2.24	6.70	7.40	7.05
T11	Control	0	0.50	0.65	0.58	0.14	0.15	0.15	1.82	1.80	1.81	4.10	5.75	4.93
		Mean	0.73	0.87		0.15	0.19		2.01	1.85		5.96	7.15	
		SE (±)	0.03	0.04		0.01	0.01		0.10	0.07		0.47	0.41	

DAE: Diatomaceous earth, RHA: Rice Husk Ash, H: Healthy plant, I: Borer Infested plant

with or without YSB damage. However, the incremental effect was more pronounced under the biotic stress (0.87%) compared to the healthy (0.73%), probably to compensate the loss caused by YSB damage. Our finding is in the line of earlier report suggesting that Si fertilization is known to improve N use efficiency and agronomic parameters of crops (yield and nutritional value) as observed in the long-term experiments in rice (Cuong *et al.*, 2017).

3.4.2 Phosphorus (P)

Increased P uptake (0.16 to 0.21%) was noted in Si amended plants compared to the unamended plants (0.15%) irrespective of biotic stress (Table 3.2). The level of enhancement was however, more in YSB damaged plants (0.15 to 0.24%) as against (0.12 to 0.18%) in healthy ones. Insect feeding showed a marginal increase in P uptake in plants with or without Si addition. The role of Si in P uptake by plants was one of the first effects of former element ever studied. Si fertilization increasing the yield of barley grown in P deficient soil has earlier been reported (Fisher, 1929) suggesting that Si made the soil phosphorus more available to plants. This finding was endorsed by Eneji *et al*. (2008) establishing a positive correlation between these two elements. Earlier studies had shown that the effect of Si under phosphorus deficiency could be due to an inplanta mechanism, implying an improved utilization of phosphorus, probably through an increase in phosphorylation (Cheong and Chan, 1973). In contrast, when phosphorous was supplied in excess, Si limited P uptake and the appearance of chlorosis, probably by reducing the transpiration rate (Ma *et al.*, 2001).

3.4.3 Potassium (K)

Exogenous application of silicate fertilizers resulted in enhanced K uptake (1.9-2.2%) in most of the treatments except in treatments with lower doses of DAE and RHA compared to that of control (1.8%). According to Singh *et al*. (2005) application of Si increases K uptake in rice. The positive response of higher doses of silicon application towards K uptake was earlier reported by Pati *et al*. (2016). However, unlike N and P, the uptake of potassium was hindered by feeding stimuli from YSB in most of the treatments, in which case Si played a vital role in enhancing its concentration. On an average the K uptake was 1.85% on plants with biotic stress as against 2.01% in healthy plants. The present finding is in complete agreement with the earlier report of Sangakkara *et al*. (2001); Umar (2002); Kaya *et al.* (2006) suggesting under stress, decreased concentration of K in plants is observed, which increases its level with the addition of Si in plant.

IV. CONCLUSION

Availability of quality food for the increasing global population is a big challenge. Exogenous application of Si has appeared to provide a better health to the crop against various biotic stress by improving the mineral status and contributing to increased productivity. This study demonstrated the role of organic sources of silicon in increased uptake of N, P, K and enhanced plant defense response for resisting the *S. incertulas* damage in rice. Feeding stimuli exerted from YSB larvae augmented uptake of nitrogen and phosphorous, which is considered to be favouring the plant health that can better defend the borer pest. Since rice is a good Si accumulator and gets benefited from positive impact of this beneficial element, the recycling of Si by plants is strongly recommended.

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