Environment and Ecology 40 (2) : 389—394, April—June 2022
ISSN 0970-0420

Impact of Exogenous Application of Silicon through Diatomaceous Earth on Yellow Stem Borer, *Scirpophaga incertulas* (Walker), (Lepidoptera: Pyralidae) in Rice

S. Panda, L. K. Rath, S. K. Panda, I. O. P Mishra

Received 29 September 2021, Accepted 24 March 2022, Published on 21 April 2022

ABSTRACT

Silicon amendment through basal application of diatomaceous earth (DAE) at 50 to 500 kg/ha in rice field effectively induced varying levels of resistance against yellow stem borer. Best performance was observed in treatment receiving 300 kg/ha with 57 and 83% decline in borer damage at vegetative and heading stages respectively over control as against 48 and 71% decline by the standard check, calcium silicate at 2000 kg/ha. This enhanced resistance was attributed to greater silicon deposit (13%) in plant tissues compared to 4.3% in untreated check resulting in 80% extra yield over control.

Keywords Rice, Diatomaceous earth, Silicon, Yellow stem borer, *Scirpophaga incertulas.*

S. Panda*, L. K. Rath, S. K. Panda, I. O. P Mishra
Department of Entomology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar-751003, Odisha, India
email: surabhika12panda@gmail.com
*Corresponding author

INTRODUCTION

The Yellow Stem Borer (YSB), *Scirpophaga incertulas* (Walker) is one of the most destructive insect pest of rice, *Oryza sativa* L. and prevalent in all rice growing regions in Asia and South East Asia (Khan *et al.*1991). Being monophagous, it's pestiferous capacity pose a constant threat to the farmers in the post green revolution era (Bandong and Litsinger 2005). Freshly emerged larvae feed on leaf epidermal layer for a short period prior to crawling through the leaf sheath and boring into rice stalk as first instars. Plants damaged by *S. incertulas* show dead heart (DH) at vegetative stage and white ear head (WE) at the heading stage causing average global yield loss to the tune of 10 million tonnes per annum as against an estimated 40-60% loss in India (Jayaraj and Muthukrishna 2013). For controlling borer pests in rice farmers mostly rely on chemical insecticides, which are generally less efficacious because of narrow window phase resulting from larval boring into rice stalk at an early stage (Sheng *et al.* 2003). Moreover, chemical control is expensive, labor consuming and leads to environmental pollution including toxicity to the non-target species (Tanaka *et al.* 2000). Hence, there is a need to search for alternative ways for controlling this pest. To have a long term solution and wider applicability integrated pest management involving eco-friendly tactics such as host plant resistance and crop management should be developed (Hao *et al*. 2008). One of the crop management tactic for *S. incertulas*, which could benefit soil health and rice yield is through amendment of silicate fertilizers

(Alvarez and Datnoff 2001, Ma *et al.* 2001). Considering rice as a good silicon accumulator and role of silicon in creating plant physical barrier altering the herbivorus feeding behaviors (Lang *et al.* 2018) the current studies was undertaken with the hypothesis that Si amendment would amplify the defense response in rice plant to yellow stem borer attack.

MATERIALS AND METHODS

A replicated field trial was conducted in randomized block design during *kharif* '16 to test the efficacy of diatomaceous earth (DAE), a silicate fertilizer and optimize its dose for field use. DAE is an organic source of silicon, commercially marketed by Agripower Australia Pvt Ltd and contains sea diatoms having 63.7% SiO_2. Eight treatments comprising 50, 100, 200, 300, 400, 500 kg/ha doses of DAE along with the standard check, calcium silicate ($CaSiO_3$) at 2000 kg/ha were tested and performances compared with untreated check. The test products were soil incorporated as basal during final puddling one day before transplanting. Twenty five - day - old seedlings of var. TN1 were transplanted in 20 m^2 plots at the rate of two seedlings per hill at 20 x 15 cm spacing. All locally recommended agronomic practice except plant protection measure was followed for raising the crop. Observations on stem borer damage were recorded in both vegetative and reproductive stages from ten randomly selected hills leaving two border rows from all sides of the plot. Dead heart (DH) was recorded at 30 and 50 days after transplanting (DAT) by counting the total tillers to the infested ones. Similarly at 70 DAT white ear head damage was assessed by counting the total panicle bearing tillers to the infested ones. Spider population (numbers/hill) was recorded at 50, 60 and 70 DAT to ascertain effect of the test product on this most predominant natural enemy of insect pests. At pre-harvest plant samples were collected for Si estimation and thereafter, plants were harvested when 80 panicles got matured. Plot wise grain yield was recorded leaving two border rows from all sides to avoid border effect. Laboratory analysis of plant samples were carried out for silicon content following di-acid (nitric acid: sulfuric acid @ 4:1) digestion followed by silicon estimation in Perkin Elmer Avio™ 200 dual view instrument equipped

Table 1. Stem borer damage in rice as influenced by various doses of diatomaceous earth during *kharif* '2016. Figures inside the parentheses are the transformed values.

Treatments	Dose (kg/ha)	Stem borer damage in *kharif* rice: Vegetative stage (% DH) 30 DAT	50 DAT	Mean	% decrease over control	Heading stage (%WE) 70 DAT	% decrease over control	Si content (g/kg dry wt)	Grain yield (q/ha)	% increase over control
T_1: Diatomaceous earth	50	13.20 (3.69)	26.04 (5.15)	19.62	12.18	10.58 (3.32)	45.46	4.13 (2.15)	25.80	21.70
T_2: Diatomaceous earth	100	7.60 (2.83)	23.36 (4.88)	15.48	30.71	14.80 (3.90)	23.71	5.40 (2.42)	29.20	37.74
T_3: Diatomaceous earth	200	1.14 (1.25)	20.37 (4.56)	10.76	51.84	13.18 (3.68)	32.06	5.01 (2.34)	31.60	47.17
T_4: Diatomaceous earth	300	2.41 (1.67)	16.51 (4.11)	9.46	57.65	3.26 (1.91)	83.19	13.01 (3.66)	38.20	80.19
T_5: Diatomaceous earth	400	5.33 (2.39)	9.67 (3.18)	7.50	66.43	9.00 (3.07)	53.61	14.84 (3.91)	36.90	74.06
T_6: Diatomaceous earth	500	12.50 (3.59)	23.00 (4.84)	17.75	20.55	7.52 (2.82)	61.24	7.08 (2.83)	32.10	51.42
T_7: Calcium silicate	2000	9.58 (3.16)	13.41 (3.72)	11.50	48.52	5.10 (2.34)	73.71	9.12 (3.10)	30.80	45.28
T_8: Control	-	14.10 (3.81)	30.58 (5.57)	22.34	-	19.40 (4.46)	-	4.30 (2.20)	21.20	-
SE(m) ±		0.200	0.130			0.220		0.140	2.260	
CD(5%)		0.58	0.39			0.64		0.40	5.76	

with Syngistix™ software for ICP-OES (Inductively Coupled Plasma- Optical Emission Spectrometry) in the Central Laboratory of the University.

RESULTS AND DISCUSSION

The plant response to basal application of DAE at different doses in restricting the stem borer damage was evident from Table 1. In early tillering stage (30 DAT) borer damage varied significantly with a record of 1.14-13.3% DH compared to 14.10% in untreated check. Superiority of treatments with 200 and 300 kg/ha over other doses was observed with a record of 1.14 and 2.41% DH respectively followed by 100 and 400 kg doses with a corresponding damage of 5.33 and 7.60% DH at 30 DAT. Calcium silicate, on the other hand could restrict the borer damage to 9.58%, which was at par with that of 100 kg dose of DAE. Surprisingly the highest (500 kg) dose of DAE failed to restrict borer damage showing 12.5% DH at this early vegetative stage and remained on par with control.

At the active tillering stage (50 DAT), the YSB damage was lowest (9.67%) in 400 kg/ha treatment followed by 300 kg/ha (16.51%) as against 13.41% DH from standard check and 30.58% DH in control. All other test doses remained poor performer with 20.37-26.04% DH. Mean borer damage revealed better performance of DAE at 300 and 400 kg/ha doses with an average damage of 7.5-9.46% DH accounting to 58-67% decline over control followed by 52% decline in plots with 200 kg DAE/ha (Table 1). Effectiveness of silicon in restricting borer damage has earlier been reported by Fallah *et al*. (2011) who noticed 10-20% less stem borer infestation in silicate fertilizer treated plants, which was attributed to silica deposition in shoot, leaf and panicle. Han and Hou (2010) reported reduction in larval penetration into silica treated plants and greater exposure of these neonates to natural enemies due to increased exposure time. Antibiosis mechanism of resistance conferred by silicon against YSB has earlier been reported by Panda and Khush (1995).

At the heading stage distinctly lower borer damage of 3.26 and 5.1% WE in 300 kg/ha DAE and standard check against 19.4% WE in untreated check (Table 1) highlighted the practical utility of this medium dose of DAE. Higher doses (400 and 500 kg/ha) though proved efficacious with 7.5 -9.0% WE accounting for 53.61-61.24% decline in damage over control, remained inferior to 300 kg that resulted in 83.19% reduction in white ear damage. In rice damage in heading stage is more critical from yield point of view as reported by Krishnaiah and Verma (2012) attributing a yield loss of 27.6- 71.7% to WE damage as against 11.2-40.1% losses due to DH at the vegetative stage. Poor performance of DAE at higher doses in arresting borer damage both at vegetative and heading stage compared to 300 kg/ha dose may be attributed to breaking down of resistance to this pest at higher doses. This finding corroborates the recent findings of Mishra (2018) who opined that silicon supplements either through DAE, $CaSiO_3$ or rice hull ash at greater than optimal doses resulted in breaking down of resistance against YSB. Such finding has been substantiated by Kanew *et al.* (2006) who observed a maximal effect of enhanced resistance to stem borer (*Chilo suppressalis*) by addition of silicon at 20 g/kg. The increased damage on plants receiving higher doses of Si amendments indicates that the Si associated mechanical barrier mechanism was not effective or that Si addition did not improve such mechanism against yellow stem borers. Similar observations have been made earlier by Han *et al.* (2015) working with rice leaf folder.

Effect of DAE on silicon content in rice

Silicon content presented in Table 1 revealed a maximum accumulation of this beneficial nutrient in plant samples from plots receiving DAE at 300 and 400 kg/ha with a record of 13.01 and 14.84 g/kg dry weigh as against 4.3 g/kg in untreated check. Samples from highest dose (500 kg) recorded 7.08 g/kg, which was at par with that of standard check (9.12 g/kg). Lower doses on the other hand failed to increase the Si content of plants. Such higher Si accumulation at 300-400 kg/ha doses explain the reason for their effectiveness in arresting the borer damage and a corresponding increase in grain yield (36.9 – 38.2 q/ha) (Fig. 1). Marwath and Baloch (1985) observed a similar negative correlation between silica content in rice plants and YSB

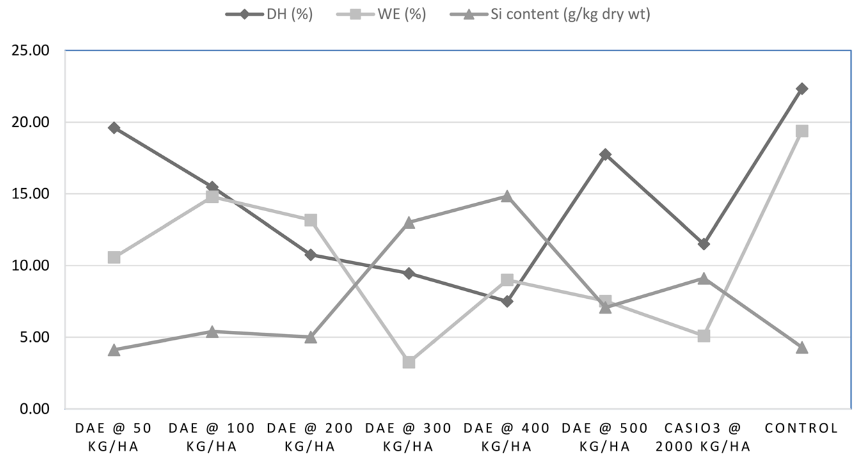

Fig.1. Relation of stem borer damage (DH and WE) with silicon content in plant samples as influenced by various doses of DAE.

damage. The reason was stated as wearing of larval mandibles while feeding on plants having more silicon, thus, creating impediment in penetration. Our finding on correlation of Si and yield have been substantiated with the findings of Ma and Yamaji (2006) who found that higher accumulation of silicon in rice benefitted the plants by promoting healthy growth, stable production and protection from important pests like stem borer.

Effect of DAE on spiders

Rice ecosystem is very rich in natural enemies of insect pests amongst which spiders are important ones. These are generalized feeder and abundantly available in rice ecosystem predating on large group

Table 2. Effect of different doses of diatomaceous earth on spider population in *kharif* rice. Figures inside the parentheses are the transformed values.

Treatments	Dose (kg/ha)	Population of spider (numbers/hill) 50 DAT	60 DAT	70 DAT	Mean	% decrease over
T_1: Diatomaceous earth	50	0.03	0.10	0.33	0.15	68.75
		(0.73)	(0.77)	(0.73)		
T_2: Diatomaceous earth	100	0.17	0.06	0.10	0.11	77.08
		(0.80)	(0.75)	(0.77)		
T_3: Diatomaceous earth	200	0.33	0.13	0.05	0.17	77.08
		(0.91)	(0.80)	(0.74)		
T_4: Diatomaceous earth	300	0.17	0.05	0.03	0.07	85.42
		(0.82)	(0.74)	(0.73)		
T_5: Diatomaceous earth	400	0.20	0.10	0.05	0.12	75.00
		(0.83)	(0.77)	(0.74)		
T_6: Diatomaceous earth	500	0.17	0.03	0.03	0.08	83.33
		(0.42)	(0.73)	(0.73)		
T_7: Calcium silicate	2000	0.10	0.07	0.07	0.08	83.33
		(0.77)	(0.75)	(0.75)		
T_8: Control		0.53	0.50	0.41	0.48	
		(1.01)	(1.00)	(0.95)		
SE(m)±		0.040	0.021	0.015		
CD(5%)		NS	NS	NS		

of insect pests. During the trial however, its population remained low with a maximum population record of 0.41-0.53 spiders /hill from control plots at different stages of the crop growth. Plots receiving different doses of DAE including standard check though showed numerically lower spider population but statistically remained on par with control (Table 2). Initially at the early vegetative stage its population was almost negligible and appeared in appreciable number only when insect pests population built up took place. At the maximum tillering stage (50 DAT) the population varied from 0.03 to 0.33/hill, which did not change appreciably at later stages and hence, difference between treatments remained non-significant. This signifies that none of the Si treatments had any adverse impact on this predatory arthropod and considered safe for use in rice.

Grain yield

Impact of Si amendment was clearly pronounced with distinct variation in grain yield in different treatments. Substantially higher yield was obtained from plots receiving DAE at 300-400 kg/ha with a record of 36.9-38.2 q/ha, which accounts to 74-80% gain over control. All other treatments, barring lowest dose, yielded 38-52% higher but remained on par with each other (29.2-32.1 q/ha) implying that DAE is also a soil ameliorating silicate fertilizer for increasing rice productivity. According to Takahashi and Miyake (1982) photo assimilation is enhanced with the supply of silicon and this promoted assimilation of carbon to the rice panicles, contributing towards greater yield.

CONCLUSION

The investigation demonstrated the effectiveness of DAE at various doses in inducing resistance to YSB in rice plants. Considering the overall performance of test doses at vegetative and reproductive stages, field application of DAE at 300 kg/ha was found more beneficial. It not only showed greater efficacy in restricting the borer damage due to greater silicon accumulation in plant tissue but also produced higher yield. The finding is of great practical utility from farmers point of view suggesting use of DAE at the rate of 300 kg/ha through basal soil application as a holistic approach in managing borer damage and yield enhancement in rice.

ACKNOWLEDGEMENT

Authors acknowledge the help rendered by Dr. S. Pattanaik, Former Professor and Head, Department of Soil Science and Agricultural Chemistry for providing the test materials and Dr. Sashi Kant Dash, Scientist I/C of Central Laboratory, OUAT for silicon estimation from plant samples.

REFERENCES

Alvarez J, Datnoff LE (2001) The economic potential of silicon for integrated management sustainable rice production. *Crop Prot* 20:43-48.

Bandong JP, Litsinger JA (2005) Rice crop stage susceptibility to the rice yellow stem borer *Scirpophaga incertulas* (Walker) (Lepidoptera : Pyralidae). *Int J Pest Manag* 51: 37–43.

Fallah A, Osko T, Khosravi V, Mohammadian M, Rosttami M (2011) Reduction of chemical pesticides by using silicate fertilizer in paddy fields. In: Proceedings of 5th International Conference on Silicon in Agriculture, Beijing, China. (13-18): 46.

Han YQ, Hou M (2010) Silicon mediated rice plant resistance to the rice stem borer *Chilo suppressalis*: Effects of silicon treatment, rice varietal resistance and larval stage. In: Proceedings of the 5th International Conference on Silicon in Agriculture, pp 62-63.

Han YQ, Lei W, Wen L, Hou M (2015) Silicon mediated resistance in asusceptible rice variety to the rice leaf folder, *Cnaphalocrocis medinalis* Gunee (Lepidoptera:Pyralidae). *PLoS ONE* 10(4): In press.

Hao LX, Han YQ, Hou ML, Liao XL (2008) Resistance of Japonica rice varieties in Liaohe Valley to *Chilo suppressalis and* its underlying mechanisms. *Acta Ecol Sin* 28:5987-5993.

Jayaraj J, Muthukrishnan N (2013) Controlling yellow stem borer in rice. The Hindu, Agriculture Research and Technology, 19th September, pp 22.

Kanew SR, Choi H, Kim JY, Vigneswaren S, Shim WG (2006) Removal of arsenic (III) from groundwater using low-cost industrial by-products – blast furnace. slag *Water Quality Res J* 41: 130-139.

Khan ZR, Litsinger JA, Barrion AT, Villanueva FFD, Fernandez NJ, Taylo LD (1991) World bibliography of rice stem borers. International Rice Research Institute, Manila. ISBN 971-22-0015-9, pp 415.

Krishnaiah K, Verma NRG (2012) Status paper on changing insect pest scenario in the rice ecosystem, a national perspective, Directorate of Rice Research, Rajendranagar, Hyderabad, pp 2-8.

Lang Y, Pei L, Fei L, Ali S, Sun X, Hou M (2018) Silicon amendment to rice plants contributes to reduce feeding in a phloem- sucking insect through modulation of callose deposition. *Ecol Evol* 8(1): 631–637.

Ma JF, Miyake Y, Takahashi E (2001) Silicon as a beneficial element for crop plants. In: Datnoff LE, Snyder GH, Kornodorfer GH (eds). Silicon in Agriculture Elsevier Amsterdam, The Netharlands, pp 17-30.

Ma JF, Yamaji N (2006) Silicon uptake accumulation in higher plants. *Trends Pl Sci* 11(8):392-397.

Marwath NK, Baloch UK (1985) Varietal resistance in rice to *Tryporyza* species of stem borers its association with plant moisture, total ashes silica contents. *Pak J Agric Res* 6: 278-281.

Mishra IOP (2018) Silicon-Induced Resistance to Stem borers and Leaf folder in rice (*Oryza sativa* L). PhD thesis. Submitted to Odisha University of Agriculture and Technology, Odisha, India.

Panda N, Khush G (1995) Host plant resistance to insects, CAB International, Wallingford, United Kingdom, pp 431.

Sheng CF, Wang HT, Sheng SY (2003) Pest status and loss assessmentof crop damage caused by the rice borers, *Chilo sup pressalis* and *Tryporyza incertulas*, in China. *Chin Bull Entomol* 40:289-294.

Takahashi E, Miyake Y (1982) The effect of silicon on the growth of cucumber plant. In: Proceedings of 9th International Plant Nutrition Collog, Warwick University, UK, pp 669.

Tanaka K, Endo S, Kazano H (2000) Toxicity of insecticides to predators of rice planthoppers: Spiders, the mirid bug dryinid wasp. *Appl Entomol Zool* 35:177-187.