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Impact of organic and inorganic source of silicon in imparting resistance against brown plant hopper *Nilaparvata lugens* (Stal.) in rice ecosystem

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Abstract
A field experiment was conducted during *Rabi* 2016 and 2017 in the Central Research Farm of Odisha University of Agriculture and Technology, Bhubaneswar, to evaluate the efficacy of different sources of organic (DAE and RHA)and inorganic form (Casio$_3$) of silicon at different doses were tested on rice *cv*., TN1 against brown plant hopper in rice. A population build up to the tune of 15.59, 16.42 and 15.65 hoppers /hill have been registered by highest dose of DAE, $CaSiO_3$ and RHA respectively at the peak activity of hopper as against 57.27 hoppers/hill in control, exhibiting their supremacy in arresting the pest. However, the performance was at par with that of medium doses indicating the importance of these silicate fertilizers at moderate doses and the application of this compound in the rice ecosystem can be an eco-holistic approach for effective integration into the pest management system.

Keywords: Silicon, rice, brown plant hopper, plant resistance

Introduction

Rice is known as Silicon (Si) accumulator [1-3] and the plant benefits from Si nutrition [4]. It is required for the development of strong leaves, stems and roots. The formation of a thick silicated epidermal cell layer reduces the susceptibility of rice plants to 'insects' *viz*., stem borers, plant hoppers and mite pests. 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 [5]. The current scenario of rice pests in the country causes severe yield reduction which includes brown plant hopper (BPH), *Nilaparvata lugens* (Stal.); white backed plant hopper (WBPH), *Sogatella furcifera* (Horvath); green leafhopper (GLH), *Nephotettix virescens* (Distant); stem borer, *Scirpophaga incertulas* (Walker); leaf folder, *Cnaphalocrocis medinalis* (Guenee) and gall midge, *Orseolia oryzae* (Wood-Mason) [6] An estimated 18-26% of annual crop production worldwide has been caused by insects. The losses have been heaviest in developing countries with a 13-16% loss in field condition [7]. The brown planthopper (BPH), *Nilaparvata lugens* (Stål) (Hemiptera: Delphacidae), is one of the migratory and most destructive pests of rice and a substantial threat to rice production [8]. The BPH is a monophagous herbivore, and is a typical vascular feeder. It sucks the phloem sap from leaf sheath of rice plants using its stylet, and causes direct damage to rice plants. BPH can also cause indirect damage to rice plants through the transmission of plant viruses. Extensive use of chemical insecticides has been the common practice for control of BPH, which has resulted in many problems, including toxicity to natural enemies [9], increased production cost, and possible long term agro-ecosystem and human health damage [10]. Breeding and utilization of resistant rice varieties is one of the most economical and effective strategies in controlling this insect pest. However, up to now only a few BPH-resistant rice varieties have been developed and cultivated in the rice cultivation area [11]. Thus, there is an urgent need to develop effective and ecologically sound alternative methods to improve the pest control. Silicon (Si) amendment may be one of such potential alternatives [12]. Hence the use of less toxic compounds of natural plant origin, host resistance, bioagent, adoption of cultural practices and inclusion of non rice crops in cropping system are given priority as important components for implementation of IPM programme.

Materials and Methods

Field experiment was carried out in the Central Agricultural Research Farm of Odisha University of Agriculture and Technology, Bhubaneswar which is situated at $20^0$15' N latitude and 85^0 22' E longitude with an elevation of 25.9 meters above the MSL. Most susceptible rice variety "TN1" in rabi 2016-2017 was taken in the present field investigation. "TN1", is a medium duration (140 – 150 days), semi dwarf variety with profuse tillering ability. The field experiments was conducted with 10 treatments comprising diatomaceous earth (DAE) at 0.15, 0.3, 0.45 t/ha, calcium silicate ($CaSiO_3$) at 2, 3, 4 t/ha and rice hull ash (RHA) at 2, 3, 4 t/ha along with an untreated control. DAE is an organic source of "Si" is a naturally occurring, soft, siliceous sedimentary rock extracted from sea diatoms of American coast containing 80% -90% silicon. $CaSiO_3$ is an inorganic source of silicon and commercially available for agricultural use and contain 45% Si whereas RHA is organic source, very cheap and available plentily in the locality containing 80-90% Si. All the sources of silicon are used at their high, medium, and low optimal dose recommended for soil amelioration to study their impact on brown plant hopper in rice. All the treatments were applied as basal dose to rice field during last puddling.

Statistical Analysis

The field experiment was laid out in Randomized Complete Block Design with three replications and each subplot measured (5m x 4m). Observations were recorded from 30DAT to 80 DAT randomly from ten plants from each plot treated with silicon amendments in variety TN1 during rabi season.

Results and Discussion

Brown pant hopper (BPH) is considered as one of the most serious insect pests of rice in Odisha during both *kharif* and *rabi* seasons. Insecticide application reduces the population of natural enemies along with their food supply, leaving the field open for pest build up by secondary and resurgent pests like the brown planthopper (BPH), *Nilaparvata lugens* (Stal) [13] and green leaf hopper (GLH) *Nephotettix* spp. [14]. Beside from causing pest out breaks, insecticide use is believed to have accelerated the adaptation of BPH to resistant varieties by favouring the survival and reproduction of virulent individuals [15]. So to overcome the situation host plant resistance has become a major component of integrated pest management. Induced resistance is the qualitative or quantitative enhancement of plants defense mechanism against pests in response to external physical or chemical stimuli. A richer knowledge of these phenomena will play a critical role in developing sustainable integrated pest management strategies.

During Rabi trial 2016, observations were taken from 30 DAT to 70 DAT of brown plant hopper infesting the rice crop in the field. At 30 DAT, number of insects per hill was found to be very low ranging from (1.30-2.67insects /hill) in all the treatments to (2.80 insects /hill in control). From 40 DAT- 50 DAT the population started increasing with (27.20 insects /hill) in RHA at 2.0 t/ha and (41.37 insects /hill) in control observed in 50DAT. At 60 DAT, there was a sudden increase in plant hopper population. Application of resurgence inducing chemical at lower dose of RHA at 2.0t/ha on 60 DAT, resulted in high pest load subsequently. As a result, at 60 DAT, response of DAE at 0.45t/ha (19.55 insects/hill) followed by $CaSiO_3$ at 4.0t/ha(21.58 insects/hill) and RHA at 4.0t/ha (21.08 insects/hill) caused significant variation in plant hopper population in different treatments. The lowest population of (19.55 insects/hill) was observed in T_3 which was at par with T_9 and T_6 treatments. But at 70 DAT, there was a decline in hopper population because of change in environmental conditions due to increase in temperature after 60 DAT. The hopper population in T_7 was the highest (16.12 insects /hill) which was significantly higher from rest of the treatments and was at par over control (23.02 insects /hill).

With respect to mean performance it could be observed that RHA at its highest dose supported (8.51 plant hopper/hill) which was less than the control (30.32 insects /hill). Among the treatments $CaSiO_3$ at 4.0t/ha harboured least hopper (8.61 insects /hill), followed by DAE at 0.45 t/ha (9.48 insects/hill) confirming the decline in level of field resistance to BPH at higher doses.

During rabi trial 2017, observations were taken from 30 DAT to 70 DAT of brown plant hopper infesting the rice crop in the field. At 30 DAT, number of brown plant hopper per hill was found to be very low ranging from (1.49-3.39 insects /hill in all the treatments to 3.96 insects /hill in control). From 40 DAT- 50 DAT the population of brown plant hopper started increasing with (29.64 insects /hill) in DAE at 0.15 t/ha and(36.14 insects /hill) in control in 50DAT. There was a sudden increase in plant hopper population in 60 DAT due to application of resurgence inducing chemical at lower dose of DAE (0.15 t/ha) on 60 DAT, resulted in high pest load subsequently. As a result, at 70 DAT, response of DAE at 0.45t/ha (11.63 insects/hill) followed by $CaSiO_3$ at 3.0t/ha (11.27 insects /hill) and RHA at 3.0t/ha (10.23 insects /hill) caused significant variation in brown plant hopper population in different treatments. The lowest population of (10.23 insects/hill) was observed in T_9 which was at par with T_6 and T_3 treatments. But at 70 DAT, there was a decline in hopper population because of change in environmental conditions. The hopper population in T_1 was the highest (6.51 insects /hill) which was significantly higher than the rest of the treatments but significantly lower than control (12.45 insects /hill). With respect to mean performance it could be observed that DAE at its lower dose supported (5.47 plant hopper/hill) which was less than the control (20.50 insects /hill). DAE at 0.45 t/ha showed less incidence of insects (5.47 /hill) which was lower than control (20.50 /hill) followed by $CaSiO_3$ at 4.0t/ha (6.15 /hill), and RHA at 4.0t /ha (6.06 /hill) confirming the decline in level of field resistance among different silicon treated plants.

Pooled data

The pooled data of two seasons trial with cv. TN1 presented in Table 3. showed that all the Si treatments showed low infestation of brown plant hopper over control. Supremacy of highest dose of DAE (0.45t/ha) with a record of (15.59 insects/hill) in 60DAT followed with high dose of $CaSiO_3$(4.0 t/ha) recorded (16.43 insects/hill) and highest dose of RHA (0.45 t/ha)recorded (15.66 insects/hill) over control (57.27 insects/hill). Similar trend was seen in 70 DAT with better results of DAE (0.45t/ha) recorded (5.20 insects/hill) followed with high dose of $CaSiO_3$(4.0 t/ha) recorded (4.13insects/hill) and highest dose of RHA (0.45 t/ha)recorded (4.88 insects/hill) over control (17.74 insects/hill).

Field experiments have been conducted with cultivar 'TN1' in rabi in 2016-2017. Rice cultivar 'TN1' is the most popular variety amongst the rice growers of the state and widely cultivated in rabi season. However, this cultivar is highly susceptible to major insect pests and diseases and hence, suitable for the entomological experiments. Brown plant hopper infestation was recorded at highest peak activity in both the season. In *rabi s*eason 2016 lowest incidence in DAE at 0.45t/ha (19.55insects/hill) was recorded in cv. TN1 followed with RHA at 4.0t/ha (21.08 insects/hill) and $CaSiO_3$ at 4.0t/ha (21.58 insects/hill) as against (70.73 insects/hill) control in table 1. In *rabi* season 2017 lowest incidence in DAE at high dose 0.45t/ha (11.63 insects/hill) was recorded in cv.TN1 followed by $CaSiO_3$ at high dose 4.0t/ha (11.27 insects/hill) and RHA at high dose 4.0t/ha (10.23 insects/hill) as against (43.81 insects/hill)in control in (table 2). Silicon amendments at various doses showed significant effects in arresting the brown plant hopper damage compared to that of control. However the efficacy differed from source to source and dose to dose. Over seasons DAE at 0.45 t/ha along with $CaSiO_3$ at 4.0 t/ha and RHA at 4.0 t/ha demonstrated their supremacy in restricting the brown plant hopper damage.

Host-plant resistance is the core of pest management system because it is specific to the target pest and has no adverse effect on the non-target organisms. Increased silica deposition, in the form of phytoliths in hairs, trichomes and spines, resulted from Si amendment [16], might have deterred BPH settlement on Si-amended plants. Similar role of high density and large volume of silica is reported in rice cultivars resistant to the small brown planthopper *Laodelphax striatellus* (Fallén) [17]. The increased time in non-probing and stylet pathway activities associated with Si addition may be a result of increased hardness and toughness of plant tissues (epidermis and mesophyll) because of silica deposition in plant tissues [18]. Enhanced plant defense associated with Si amendment has been previously reported in insect herbivores [19, 20, 21–23]. Silica content of fly ash has got translocated to the plant system which increases the layers of sclerenchymatous cells especially in culms and leaves which in turn induces resistance in the rice plant to the problems of BPH, GLH and other sucking insects [24].

In the present study, we observed that silicon application to rice plants through different sources reduced population growth and thus conferred resistance. (Table 1 and Table 2.) in restricting the brown plant hopper damage to rice plants. In the present study, plants receiving higher doses of DAE, $CaSiO_3$ and RHA showed low infestation and damage to the plant.

Conclusion

Results of this study clearly demonstrated a Si- mediated resistance to brown plant hopper. Soil amendments with DAE, $CaSiO_3$ and RHA at low, medium, and high doses reduced the pest damage which may be due to the direct effect of silicification of rice leaves and stem. Better performance of DAE, $CaSiO_3$ and RHA at high doses necessitates the reduced pest damage with particular reference to their economics. However, rice hull ash which is a renewable source of Si, abundantly available locally and a cheap source performed satisfactorily at 4.0 t/ha dose in inducing resistance against brown plant hopper hence should be recommended to rice farmers for field application as a component of integrated pest management in rice agro ecosystem.

Treatment details

Treatments no.	Test products	Source	Dose(t/ha)	Place of procurement
T_1	Diatomaceous earth	Organic	0.15	Low dose
T_2	Diatomaceous earth	Organic	0.30	Medium dose
T_3	Diatomaceous earth	Organic	0.45	High dose
T_4	Calcium silicate	Inorganic	2.0	Low dose
T_5	Calcium silicate	Inorganic	3.0	Medium dose
T_6	Calcium silicate	Inorganic	4.0	High dose
T_7	Rice hull ash	Organic	2.0	Low dose
T_8	Rice hull ash	Organic	3.0	Medium dose
T_9	Rice hull ash	Organic	4.0	High dose
T_{10}	Untreated check			

Table 1: Effect of silicon amendments on Brown plant hopper incidence in rice var. TN 1 during *rabi '* 2016

Tr. No.	Treatments	Dose (t/ha)	Brown plant hopper population (Nos./hill) in *rabi* 2016					
			30DAT	40DAT	50DAT	60DAT	70DAT	MEAN
T_1	DAE	0.15	2.12	7.47	22.22	47.38	15.04	2.12
T_2	DAE	0.30	2.20	2.24	17.38	25.71	8.19	2.20
T_3	DAE	0.45	1.71	2.75	14.70	19.55	8.69	1.71
T_4	$CaSiO_3$	2.0	1.30	6.64	18.56	39.57	13.70	1.30
T_5	$CaSiO_3$	3.0	2.04	2.86	11.19	26.28	8.74	2.04
T_6	$CaSiO_3$	4.0	1.90	2.43	11.52	21.58	5.62	1.90
T_7	RHA	2.0	2.67	8.06	27.20	53.55	16.12	2.67
T_8	RHA	3.0	1.87	3.12	16.96	30.02	10.87	1.87
T_9	RHA	4.0	2.04	2.62	10.03	21.08	6.79	2.04
T_{10}	Control		2.80	13.67	41.37	70.73	23.02	2.80
	SE(m) $\pm$		0.284	0.554	2.00	2.40	1.886	
	$C.D._{0.05}$		0.84	1.64	5.96	7.14	5.60	

DAT- Days after treatment

Table 2: Effect of silicon amendments on Brown plant hopper incidence in rice var. TN1 during *rabi* 2017

Tr. No.	Treatments	Dose (t/ha)	Brown plant hopper population (Nos./hill) in *rabi* 2017					
			30DAT	40DAT	50DAT	60DAT	70DAT	MEAN
T_1	DAE	0.15	2.06	4.21	29.64	28.35	6.51	14.15
T_2	DAE	0.30	1.49	2.32	11.73	15.24	2.35	6.63
T_3	DAE	0.45	2.56	2.68	8.76	11.63	1.71	5.47
T_4	$CaSiO_3$	2.0	3.39	4.14	21.96	25.73	4.58	11.96
T_5	$CaSiO_3$	3.0	3.15	3.02	15.10	16.60	2.36	8.05
T_6	$CaSiO_3$	4.0	2.22	2.65	11.99	11.27	2.63	6.15
T_7	RHA	2.0	2.71	4.04	27.29	28.08	5.11	13.45
T_8	RHA	3.0	2.87	3.32	14.94	19.91	2.75	8.76
T_9	RHA	4.0	3.01	3.23	10.85	10.23	2.96	6.06
T_{10}	Control		3.96	6.12	36.14	43.81	12.45	20.50
	SE(m) $\pm$		0.586	0.805	1.809	1.706	1.209	
	C.D.$_{0.05}$		1.74	2.39	5.37	5.07	3.59	

DAT- Days after treatment

Table 3: Brown plant hopper incidence pooled data over rabi ' 2016 and 2017 as influenced by different sources of silicon in rice var. TN1

Tr. No.	Treatment & dose (t/ha)	30DAT			40DAT			50DAT			60DAT			70DAT		
		2016	2017	Pooled (2016-2017)	2016	2017	Pooled (2016-2017)	2016	2017	Pooled (2016-2017)	2016	2017	Pooled (2016-2017)	2016	2017	Pooled (2016-2017)
T_1	DAE (0.15)	2.12	2.06	2.09	7.47	4.21	5.84	22.22	29.64	25.93	47.38	28.35	37.87	15.04	6.51	10.78
T_2	DAE (0.30)	2.2	1.49	1.85	2.24	2.32	2.28	17.38	11.73	14.56	25.71	15.24	20.48	8.19	2.35	5.27
T_3	DAE (0.45)	1.71	2.56	2.14	2.75	2.68	2.72	14.7	8.76	11.73	19.55	11.63	15.59	8.69	1.71	5.20
T_4	$CaSiO_3$ (2.0)	1.3	3.39	2.35	6.64	4.14	5.39	18.56	21.96	20.26	39.57	25.73	32.65	13.7	4.58	9.14
T_5	$CaSiO_3$ (3.0)	2.04	3.15	2.60	2.86	3.02	2.94	11.19	15.1	13.15	26.28	16.6	21.44	8.74	2.36	5.55
T_6	$CaSiO_3$ (4.0)	1.9	2.22	2.06	2.43	2.65	2.54	11.52	11.99	11.76	21.58	11.27	16.43	5.62	2.63	4.13
T_7	RHA (2.0)	2.67	2.71	2.69	8.06	4.04	6.05	27.2	27.29	27.25	53.55	28.08	40.82	16.12	5.11	10.62
T_8	RHA (3.0)	1.87	2.87	2.37	3.12	3.32	3.22	16.96	14.94	15.95	30.02	19.91	24.97	10.87	2.75	6.81
T_9	RHA (4.0)	2.04	3.01	2.53	2.62	3.23	2.93	10.03	10.85	10.44	21.08	10.23	15.66	6.79	2.96	4.88
T_{10}	Control	2.8	3.96	3.38	13.67	6.12	9.90	41.37	36.14	38.76	70.73	43.81	57.27	23.02	12.45	17.74
	SE(m) $\pm$	0.284	0.586	0.491	0.554	0.805	0.839	2.00	1.809	2.640	2.405	1.706	3.003	1.886	1.209	2.314
	C.D.$_{0.05}$	0.84	1.74	1.41	1.64	2.39	2.40	5.96	5.37	7.57	7.14	5.07	8.61	5.6	3.59	6.63

DAT- Days after treatment

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