Research Paper

Silicon Mediated Enhanced Resistance in Rice Plants Against Thrips; *Stenchaetothrips biformis* (Bagnall) (Thripidae: Thysanoptera)

G.D.S.N. Chandrasena[1]*, H.N.S. Fernando[2], W.M.J. Bandara[1], D.M.O.K. Dissanayake[1], U.C. Kahawaththa[1], P.M.H. Cooray[2], M. Pagirathi[3]

[1] *Rice Research and Development Institute, Batalagoda, Ibbagamuwa, Sri Lanka*
[2] *Regional Rice Research and DevelopmentCentre, Bombuwela, Sri Lanka*
[3] *Rice Research Station, Sammanthurai, Sri Lanka*

*Corresponding author: susanthinilminic@gmail.com

ARTICLE INFO

Article history:
Received: 15 May 2021
Revised version received: 06 October 2021
Accepted: 06 December 2021

Citation:
Chandrasena GDSN, Fernando HNS, Bandara WMJ, Dissanayake DMOK, Kahawaththa UC, Cooray PMH, Pagirathi M 2021. Silicon mediated induced resistance in rice plants against thrips; Stenchaetothrips biformis (Bagnall) (Thripidae: Thysanoptera). Tropical Agriculturist 169 (4): 16-24

Abstract

Silicon is considered as a beneficial element for plant growth mostly by inducing plant resistance to multiple stresses. As all the improved high yielding rice varieties in Sri Lanka are susceptible to rice thrips; *Stenchaetothrips biformis;* a major pest, farmers depend on synthetic insecticides to manage it. In view of this problem, three silicon-containing materials i.e. partially burnt paddy husk, powder form of amorphous silica and its granular form were evaluated against rice thrips to explore their thrips resistance enhancing effect. The experiments were conducted in randomized complete block design in Wet Zone (WZ), Dry Zone (DZ), and Intermediate Zone (IZ). The treatments were tested as soil amendments at different application rates. The degree of protection afforded by the treatments against the pest was assessed by their population density. The results revealed that, soil amendment of Si provides substantial protection from rice thrips. But the required application rate appeared to be varied according to the soil and environmental condition of the region. To get significantly better results, 16-26 kg of SiO_2 ha^{-1} need to be applied for the WZ and DZ, while 40- 52 kg of SiO_2 ha^{-1} is needed for the IZ. The resistance enhancing ability of silica-containing products is negatively correlated with their particle size i.e. smaller the particle size, the larger the effects.

Keywords: Amorphous silica, Enhanced resistance, Silicon, Thrip

Introduction

Rice thrips; *Stenchaetothrips biformis* is considered one of the major pests in rice cultivation in Sri Lanka (Kudagamage and Nugaliyadde, 1990; Nugaliyadde *et al*., 2000; Pushpakumari *et al*., 2010). Both adult and larvae suck the sap from tender leaves preferably in 2-4 week old plants. Dry weather conditions favor its development. Usually, thrips infestation is severe in late planted rice crops - hence short duration rice varieties are mostly affected. *Dahanala*, *Wanni-dahanala* and *Kalubala-wee* are three traditional rice varieties that possessed a high level of thrip resistance (Nugaliyadde and Heinrichs, 1984; Kudagamage and Nugaliyadde, 1990). Density of long curved trichome on the adaxial leaf surface was found as one of the characteristics related to the thrips resistance (Nugaliyadde and Heinrichs, 1984). The said donor varieties have been used by the Department of Agriculture (DOA) to develop thrips resistant rice variety. But little progress had been achieved as many complexities were encountered. (Pushpakumari *et al*., 2010). Therefore, farmers depend on synthetic insecticides for controlling the pest requiring sustainable thrips management methods. Under this context, enhanced resistance could be suggested as a good alternative.

Increasing evidences show that a high quantity of Silicon (Si) in plants confers resistance or tolerance to multiple stresses (Ma and Takahashi, 2002; Ma, 2004; Rodgers and Shaw, 2004; Laing *et al*., 2006; Reynolds *et al*., 2016; Yang *et al*., 2017; Han *et al*., 2018). These beneficial effects are mainly attributed to the high accumulation of Si on the tissues. Hence, the effects are clearly expressed in Si accumulating plants like rice (Ma, 2004). Mechanical defense derived from the deposition of amorphous silica on the plant tissues and function of Si as a signal to induce the production of phyto-alexins such as peroxidases are the two hypothesis proposed for the biotic stress tolerance property of Si (Cherif *et al*., 1994; Ma, 2004; Reynolds *et al*., 2016; Yang *et al*., 2017; Han *et al*., 2018). Si-enhanced biotic stress resistance have been documented on plant diseases, insect pests of diverse feeding guilds as well as to non-insect pests (Guntzer *et al*., 2012; Alhousari and Greger, 2018). Si-enhanced resistance under field conditions has been proven against rice stem borer (*Scirpophaga incertulas*), rice leaf folder (*Cnaphalocrocis medinalis*) and rice planthoppers (*Nilaparvata lugens* and *Sogatella furcifera*) (Han *et al*., 2018). Therefore, this study was conducted to explore the resistance enhancing effect of Si on rice thrips.

Materials and Methods

A series of field experiments were conducted to evaluate different Si-containing products at different application rates against rice thrips during four consecutive cropping seasons from 2018/19 *Maha* to 2020 *Yala*. The experiments were conducted at the Regional Rice Research and Development Centre (RRRDC), Bombuwela, Rice Research Station (RRS), Sammanthurai and Rice Research and Development Institute (RRDI), Batalagoda, representing the Wet, Dry and Intermediate Zones of Sri Lanka respectively. The trial at Bombuwela was conducted under rain-fed conditions while others were under irrigated conditions. The objectives of those studies were to evaluate the degree of protection afforded by Si amendments against rice thrips under field conditions as indicated by their population density and to find out the most effective rates for the promising amendments.

All the experiments were conducted in randomized complete block design replicated 3 or 4 times depending on the accessibility of land at each location. The plot size of the experiments at Batalagoda and Bombuwela was 4.5 m × 4.5 m while it was 6 m × 5 m at Sammanthurai. The plots were separated by bunds and movement of different treatments among plots was prevented by lining of vertical polythene barriers within each bund. The crop establishments were delayed by 10 -14 days than that of the adjacent crops to ensure high thrips infestation. The crops were established by sowing sprouted seeds at the rate of 100 kg $ha^{-1}$and maintained under pesticide free condition. Fertilizer applications were done according to the recommendation of DOA. Irrigation and draining of water were done separately to avoid the mixing of treatments.

Descriptions of the candidate treatments (resistant inducers)

1. Agrisilica granules (2-5 mm in diameter); Agrisilica (AgSi) contains amorphous silica which comes from the worlds' largest deposit of amorphous silica located in Queensland, Australia. It contains 26% of soluble silicon (SiO_2), 0.1% of extractable silicon [$Si(OH)_4$], 1.4% of calcium, 1.1% of Magnesium and 1.1% of iron (w/w) (Material Safety Data Sheet of AgSi). AgSi was incorporated with the soil one day before seed sowing.

2. Silo; Silo is powder form of natural amorphous silica and contains almost 100% of soluble silicon (w/w) as the active ingredient (Material Safety Data Sheet of Silo). It was incorporated with the soil just before seed sowing.

3. Partially burnt paddy husks (PBPH); Paddy husk contains 19.2 ± 1.52 percent (w/w) silicon [Si] (Thenabadu, 1979; Koyama *et al*., 2016). PBPH was incorporated with the soil one week before seed sowing.

Evaluation of AgSi and PBPH as resistance enhancers for rice thrips during 2018/19 *Maha*

Two separate field experiments were laid out at research fields of RRDI, Batalagoda and RRRDC, Bombuwela with 3 and 4 replicates respectively. The soil of the experimental site at Batalagoda was LHG with sandy loam texture while it was half bog soil with silty clay loam texture at Bombuwela. The varieties Bg 352 and Bg 300 were used at Batalagoda and Bombuwela respectively. Two application rates of AgSi (8 kg $ha^{-1}$and 12 kg ha^{-1}), PBPH at the rate of 500 kg ha^{-1} and seed treatment (20 g of Imidacloprid 70% WS per 100 kg seeds) were evaluated along with an untreated control.

Evaluation of Agrisilica and PBPH as resistance enhancers for rice thrips during 2019 *Yala*

The same treatments were tested at the same location at Batalagoda during 2019 *Yala* season to confirm the above results.

During the land preparation, straw was incorporated with the soil after first ploughing in order to improve the soil condition of the experimental site.

Evaluation of AgSi, PBPH and Silo as resistance enhancers for rice thrips during 2019/20 *Maha*

Two experiments were conducted at RRDI, Batalagoda and RRS, Sammanthurai with the same set of treatments using AgSi and Silo at higher application rates which could provide 16 kg of SiO_2 ha^{-1} (60 kg of AgSi and 16 kg of Silo) and 26 kg of SiO_2 ha^{-1} (100 kg of AgSi and 26 kg of Silo). The objective was to find out the most suitable SiO_2 application rates for IZ and DZ. PBPH was also tested at the rate of 625 kg ha^{-1}.

Pilot scale testing of AgSi, PBPH and Silo against rice thrips during 2020 *Yala* at farmers' fields, Dambulla

Results of the previous trials indicated that, requirement of Si amendment could be vary with the soil conditions. Hence, in this field trial, AgSi at 200 kg ha^{-1} (52 kg of SiO_2 ha^{-1}), Silo at 40 kg ha^{-1} (40 kg of SiO_2 ha^{-1}) and 52 kg ha^{-1} (52 kg of SiO_2 ha^{-1}) were tested along with PBPH at 625 kg ha^{-1} (122 kg of SiO_2 ha^{-1}) in a farmers' field at Dambulla. The objectives were to find out the most appropriate SiO_2 application rates for this region and to determine their performance under farmer's management condition in pilot scale level. The crop was established with variety Bg 358 on 12th June, 2020. The purpose of selecting a late planted field was to ensure high thrips infestation. Since the farmer was not willing to maintain an untreated plot, the treatment effects were compared with the farmers' practice; Seed treatment with Imidacloprid 70% WS (20g per 100 kg).The trial was conducted in RCBD design with four replicates.

In each experiment, number of thrips was counted in randomly taken 50 seedlings (main culm only) from each plot at three and four weeks after sowing and the data were statistically analyzed by using CATMOD procedure. The data on yield were recorded only from the farmers' field trial and subjected to ANOVA followed by mean separation through DMRT. Though it is important to measure the amount of Si in the test plant after treatment, it was not done as the facilities are unavailable in the research system of the DOA. Hence, severity of crop lodging was assessed by 1-9 scale (1- no lodging, 3 - most of the plants are slightly lodged, 5 - most of the plants are moderately lodged, 7 - most of the plants are nearly flat and 9 - all plants are nearly flat) assuming that, Si deposited on the plant tissues help reduce the tendency to lodging.

Results and Discussion

The results of the 2018/19 *Maha* trial at Bombuwela showed that there were significantly low thrips populations in each treated plot on each occasion when compared to the control plot (Table 1). Furthermore, the thrips population in each Si amended plot was statistically the same but higher than that of seed treatment. The pest population in the control treatment at Bombuwela has been drastically reduced from the first occasion to the second occasion. According to the meteorological data records at RRRDC, 87.2 mm rainfall

Table 1. Thrips population (no of adults and larvae/ 50 seedlings) in plots treated with different treatments and in untreated plots during 2018/19 *Maha* and 2019 *Yala*

Treatment	Number of thrips / 50 seedlings					
	Bombuwela 2018/19 *Maha* (average of 4)		Batalagoda 2018/19 *Maha* (average of 3)		Batalagoda 2019 *Yala* (average of 3)	
	3 WAS	4WAS	3 WAS	4 WAS	3 WAS	4 WAS
PBPH 500 kg ha^{-1}	44.00 ^{B}	03.75 ^{B}	960.00 ^{A}	309.00 ^{B}	26.00 ^{A}	74.66 ^{B}
PBPH 750 kg ha^{-1}	36.75 ^{B}	03.50 ^{B}	--	--	--	--
AgS 8 kg ha^{-1}	35.50 ^{B}	04.25 ^{B}	886.66 ^{A}	316.66 ^{B}	19.57 ^{B}	81.66 ^{B}
AgS 12 kg ha^{-1}	37.00 ^{B}	04.00 ^{B}	833.33 ^{A}	281.33 ^{B}	17.00 ^{B}	73.66 ^{B}
Imidacloprid 70%WS	00.50 ^{C}	00.25 ^{C}	61.66 ^{B}	31.33 ^{C}	2.33 ^{C}	07.00 ^{C}
Untreated control	114.50 ^{A}	19.75 ^{A}	910.00 ^{A}	424.66 ^{A}	27.33 ^{A}	103.66^{A}

Note:In each column, means followed by the same letter are statistically not significant at 5% probability level. WAS: Weeks after sowing.

has been occurred 3 days prior to the second thrips count. This might be the probable reason for the said results. The low or marginal effect of Si amendments at Batalagoda might be due to the sandy nature of the soils which hindered the effect of Si due to high leaching effect. This is supported by the statement of Ma and Takahashi (2002) that the beneficial effects of Si are expressed most clearly under high-density cultivation systems with heavy applications of nitrogen. Solubility of Si in the soil is affected by several dynamic processes occurring in the soil such as, the soil acidity (pH), presence of iron and phosphate ions (Rao and Susmitha, 2017). These factors could be the other causes for the above difference.

Incorporation of PBPH at 500 kg ha^{-1} also has performed equally to the AgSi treatments in preventing the thrips occurrence at both locations and both seasons. The above results indicate that, Si amendments contribute substantially to the reduction of population density of thrips in the susceptible rice variety requiring the appropriate application rates to maximize the effect.

The results of 2019/20 *Maha* trial at Sammanthurai showed that the degree of protection gained by the Si sources can be increased by increasing its application rates (Table 2).

Statistically the lowest pest population was observed in plots treated with Silo 26 (26 kg of SiO_2 ha^{-1}) and it was superior even to the AgSi 100 kg ha^{-1} which contained the same amount of SiO_2. This superiority might be due to the easy absorption of fine particles compared to the granular ones. Rao and Susmitha (2017) have mentioned that the solubility of Si in the soil is affected by the particle size of the Si fertilizer. Moreover, Ma (2004) has stated that, after the uptake, Si accumulates on the epidermis of various tissues mainly as a polymer of hydrated amorphous silica.

Table 2. Thrips populations (no of adults and larvae/ 50 seedlings) in plots treated with indicated Si sources and in untreated plots during 2019/20 *Maha*

Treatment	SiO_2 (kg ha^{-1})	Number of thrips /50 seedlings			
		Sammanthurai (average of 3)		Batalagoda (average of 4)	
		3WAS	4WAS	3WAS	4WAS
PBPH 625 kg ha^{-1}	120	18.33 B	21.00 B	607.75 B	85.00 AB
AgSi 60 kg ha^{-1}	16	14.67 B	15.00 B	595.25 B	79.50 B
AgSi 100 kg ha^{-1}	26	11.33 B	10.67 B	404.00 D	41.25 C
Silo 16 kg ha^{-1}	16	12.00 B	13.00 B	468.25 C	51.00 C
Silo 26 kg ha^{-1}	26	4.33 C	3.00 C	347.75 E	46.50 C
Untreated control		63.33 A	34.33 A	839.50 A	90.25 A

Note: In each column, means followed by the same letter are statistically not significant at 5% probability level. WAS: Weeks after sowing.

The smaller the particle size, higher the absorption and accumulation. Besides, the more Si accumulates in the shoots, the larger the effects. Incorporation of PBPH at 625 kg ha^{-1} has also performed equally to the both rates of AgSi and the lowest rate of Silo. Si supplementation caused no environmental contamination, is relatively cheap, and could easily be integrated with other pest management practices (Laing *et al*., 2006). Hence, PBPH provides a long-term and sustainable crop protection option against rice thrips at a low cost.

Summarized data revealed that, soil incorporation of silica amendments such as Agri-silica, Silo or PBPH; a natural silicon source enhances the resistance of rice plants against rice thrips. It is presumed that the response of rice plants for silicon application is depend on the soil condition of the location. That means, the application rate of Si amendment required for different zone or environment could not be the same.

The effect of higher application rates of SiO_2 on the pest occurrence under farmers' management condition at Dambulla is shown in the Table 3.

When compared with the seed treated plots, significantly low thrips populations were observed in plots treated with higher doses of Agrisilica and Silo that provided 40-52 kg of SiO_2 ha^{-1} (Table 3).

These results are in contrast with the data in Table 1 and 2 where the application rates of SiO_2 were far below 40 kg ha^{-1}. Hence, it can be reasoned that 40 kg of SiO_2 ha^{-1} is more effective in preventing thrips infestation than seed treatment. The trial planted extremely late in the season might be the other possible reason for that. In addition to low thrips population, low incidences of lodging were recorded with these Si treatments. It must be due to the increased rigidity of the culm through the deposition of amorphous silicon oxide (SiO_2) phytoliths on the plant tissues.

Since the silicon treatments were applied at the time of land preparation (before the crop infested with thrips), the low pest

Table 3. Thrips population, lodging severity and grain yield in plots treated with indicated Si sources and sown to Imidacloprid 70% WS treated seeds during 2020 *Yala* season in a farmers field, Dambulla

Treatment	SiO_2 (kg ha^{-1})	Number of thrips/ 50 seedlings		Lodging severity (1-9 scale)	Grain Yield (t ha^{-1})
		2WAS	3WAS		
PBPH 625 kg ha^{-1}	120	53.00 ^{B}	20.33 ^{B}	1.5	2.58 ^{AB}
AgS200 kg ha^{-1}	52	36 .00 ^{C}	14.66 ^{BC}	1.5	2.94 ^{AB}
Silo 40 kg ha^{-1}	40	35.00 ^{C}	13.00 ^{BC}	1.5	2.75 ^{AB}
Silo 52 kg ha^{-1}	52	30.66 ^{C}	9.00 ^{C}	1	3.10 ^{A}
Imidacloprid 70%WS		71.00 ^{A}	32.66 ^{A}	3	2.41 ^{B}
CV (%)					***12.94***

Note:In each column, means followed by the same letter are statistically not significant at 5% probability level. WAS: Weeks after sowing.

populations observed in silica treated plots were not due to the killing effect of Si but due to its indirect effect. It can be suspected that Si deposited in plants has act as physical barriers or reduced digestion efficiency to regulate the physiological development of the pest.

Furthermore, Silicon has been recognized as a beneficial element to alleviate chemical stresses such as salinity, Mn toxicity and Al toxicity (Ma, 2004) and also to increase rice grain yields (Ma and Takahashi, 2002; Tamai and Ma, 2008). Tamai and Ma (2008) have proved that, Si increases rice yield mainly by enhancing the fertility of spikelet. According to Han *et al*. (2018), grain yield of rice can be increased by application of 300 kg SiO_2 ha^{-1} through increased number of grains per panicle, grain filling percentage and 1000 grain weight. In the present study, significant effects on yield components were not observed with the tested SiO_2 application rates (Table 3). Therefore, further research is needed to determine the appropriate silicon application rates to get yield increments under the local conditions. It is also important to find the ways for reducing cost incurred in the Si application. One suggestion is to test the products under seedling broadcasting method (Parachute method) by mixing the Si sources with the soils before filling the parachute trays.

Conclusions

Soil amendment of Si-containing products like Agrisilica and Silo at the time of seed sowing contributes substantially to the reduction of population size of rice thrips; *Stenchaetthrips biformis* in both seasons and in all three climatic zones. However, the required application rate of the silica-containing product appeared to be varied according to the soil and the environmental condition of the region. The thrips resistance enhancing property of Si-containing products is negatively correlated with their particle size i.e. smaller the particle size, the greater the effects. Resistance against rice thrips can be significantly increased by using 16 - 26 kg of SiO_2 ha^{-1} (16 - 26 kg of Silo or 60 - 100 kg of Agrisilica) in the DZ while 40 - 52 kg of SiO_2 ha^{-1} (40 - 52 Kg of Silo or 150 - 200 kg of Agrisilica) is needed for the IZ. Thrips resistance can be induced significantly even with the application of 12 kg of Agrisilica or 3 kg of Silo ha^{-1} (3.1 kg of SiO_2 ha^{-1}) for WZ depending on the soil type. PBPH can also be applied to provide a comparable protection from the pest when it was applied at 625 kg ha^{-1} (125 kg of SiO_2). Based on the above findings, incorporation of Si amendments can be recommended as an eco-friendly key component of integrated management of rice thrips and for thrips management in organic rice farming as well.

Acknowledgements

Authors wish to acknowledge Mr. D.M.R. Dissanayake, 83-B, Pahalaarawala, Dambulla for the cooperation given to conduct the pilot scale trial in his paddy field.

References

Alhousari F, Greger M 2018. Silicon and Mechanisms of Plant Resistance to Insect Pests. Plants 7:33.

Cherif M, Asselin A, Belanger RR 1994. Defense Responses Induced by Soluble Silicon in Cucumber Roots Infected by *Pythium* spp. Phytopathology 84 (3):236 – 242.

Guntzer F, Keller C, Meunier JD 2012. Benefits of plant silicon for crops: a Review. Agronomy for Sustainable Development 32:201-213.

Han Y, Wen J, Peng Z, Zhang D, Hou M 2018. Effects of silicon amendment on the occurrence of rice insect pests and diseases in a field test. Journal of Integrative Agriculture 17(10): 2172–2181.

Koyama S, Katagiri T, Minamikawa K, Kato M, Hayashi H 2016. Effects of Rice Husk Charcoal Application on Rice Yield, Methane Emission, and Soil Carbon Sequestration in Andosol Paddy Soil. Japan Agricultural Research Quarterly 50(4): 319 - 327.

Kudagamage C, Nugaliyadde L 1990. Present status and future direction of insect pest management in rice. Proceedings of Rice Congress of the Department of Agriculture, Peradeniya, Sri Lanka. 39 -54.

Laing MD, Gatarayiha MC, Adandonon A 2006. Silicon use for pest control in agriculture: A Review. Proceedings of the South African Sugar Technologists' Association 80: 278–286.

Ma JF, Takahashi E 2002. Soil, Fertilizer and Plant Silicon Research in Japan, Elsevier Science, Amsterdam. Cross reference

Ma JF 2004. Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. Soil Science and Plant Nutrition 50(1): 11-18.

Nugaliyadde L, Heinrichs HA 1984. Resistance of Oryza spp. to thrips, *Stenchaetothrips biformis* (Bagnall) (Thysanoptera: Thripidae). Crop Protection 3(3): 305 -313.

Nugaliyadde L, Dissanayake DMN, Mithrasena J 2000. Advances of pest and disease management of rice in Sri Lanka: a review. Annals of the Sri Lanka Department of Agriculture 402-422.

Pushpakumari ASK, Nugaliyadde L, Liyanage K, Wickramasinghe S, Chandrasena GDSN 2010. A review of the rice pest management of Sri Lanka. Proceedings of Rice Congress of the Department of Agriculture, Peradeniya, Sri Lanka 113-136

Rao GB, Susmitha P, 2017. Silicon management in Rice. International Journal of Chemical Studies 5(6): 1359-1361.

Reynolds OL, Padula MP, Zeng R, Gurr, GM 2016. Silicon: Potential to Promote Direct and Indirect Effects on Plant Defense against Arthropod Pests in Agriculture. Frontiers in Plant Science 7: 744.

Rodgers-Gray BS, Shaw MW 2004. Effect of straw and silicon soil amendments on some foliar and stem based diseases in pot- grown winter wheat. Plant Pathology 53(6):733 – 740.

Tamai K, Ma JF 2008. Reexamination of silicon effects on rice growth and production under field conditions using a low silicon mutant. Plant and Soil 307(1-2): 21–27.

Thenabadu MW 1979. Silica content of rice husk as determined by soil properties and varietal differences. www.goviya.lk › Paddy › Paddy Research › Paddy_pdf (Accessed on 20 October 2020)

Yang L, Han Y, Li P, Wen L, Hou M 2017. Silicon amendment to rice plants impairs sucking behaviors and population growth in the phloem feeder *Nilaparvata lugens* (Hemiptera: Delphacidae). www.nature.com/scientificreports (Accessed on 20 October 2020)