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Soil application of potassium silicate reduces insect pest damage and impact of next generation seed germination in TN-1 rice variety

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Abstract
Potassium silicate has been shown to improve plant tolerance against biotic and abiotic stresses and also benefit for plant growth. The mother plant transfers a large amount of the nutrients it has accumulated during its vegetative life to the F_1 generation through its seeds. This study examines the effects of soil application of PS of different guilds in susceptible variety and impact on F_1 generation seed parameters. The percent reduction of DH damage in different doses of PS at graded doses; it was in the range 16-65% compared to the control. Similarly, the percent reduction of honeydew excretion, oviposition, and NS of the BPH in different doses of PS was in the range of 80-92%, 2-37%, and 12-49%, respectively, compared to the control. The application of PS increased the silica content of the treated plants than in the untreated control. Moreover, the F_1 generation seeds from K_2SiO_3 treated plants showed significant improvements for all seed quality traits. Improvements in GP (25%), ShL (25%), RL (13%), SL (16%), SVI (36%), SVII (37%), SOG (20%), and SC (176%) were observed. These results open up new avenues for future studies on improved performance of next generation seeds through silica amendment.

Keywords: Potassium silicate, F_1 generation, seed quality, YSB

Introduction
Rice (*Oryza sativa* L.) is a key staple food around the world, particularly in Asia and the global annual output is estimated to be approximately 505 million tonnes (Statista, 2021) [61]. Rice is a main source of carbohydrates, but also supply proteins, fibers, vitamins, and minerals. Globally, India has the highest acreage under rice (45 million hectares) but ranks second in terms of production (122 million tonnes milled rice) after China (148 million tonnes milled rice) (Statista, 2021) [61]. Though rice demand is expected to double by 2050 (FAO, 2020) [23]. The production is confronted with numerous issues, including climate change, labour shortages, water scarcity, and crop area loss due to rising urbanization and industrialization (Hellin *et al*., 2020) [29]. The present scenario calls for the productivity enhancement of rice through sustainable and eco-friendly approaches.
Rice is attacked by more than 100 species of insects, of which about 20 are major pests (Pathak & Saxena, 1980) [47]. Among the various insect pest inflicting yield losses, the yellow stem borer, *Scirpophaga incertulas* (Walker) is one of the major pests in all rice-growing regions of India. Larval feeding and subsequent internodal penetration during vegetative and reproductive stage cause severing of the growing apical plant part and finally results in the characteristic symptom of dead heart and white ear head at the vegetative and reproductive growth stage of rice plant, respectively. YSB cause yield losses ranging from 3-95 per cent (Prasad *et al*., 2007) [50]. The brown planthopper is Asia's most damaging pest, causing significant economic losses in tropical, subtropical, and temperate rice-growing areas every year (Jena & Kim, 2010) [33]. BPH (both nymphs and adults) sucks the phloem sap from leaves, stems, and especially the leaf sheath, causing yellowing, browning, drying, and wilting of the paddy crop, termed "hopper burn," which leads up to 70–100% yield loss (Jena *et al*., 2018) [34]. Besides direct damage, BPH also acts as a vector of grassy stunt and ragged stunt viral diseases in paddy crop (Li *et al*. 2014) [69]. Insecticides are widely used to manage rice yellow stem borer and BPH. However, the continuous use of a wide range of insecticides has caused many adverse effects. Hence, there is a need to find a suitable alternative to the chemical method of insect control. Insect pest damage may also be reduced through careful management of nutrient requirements of the crop or amendments with mineral nutrients, such as silicon (Si), that reduce crop susceptibility to pests (Meyer & Keeping, 2005) [43].

One of the such widely explored mineral nutrients under various stress and normal conditions is Silicon (Si), the second most abundant element in the earth's crust. Silicon has been regarded as a beneficial element and reported to assist plant in combating several biotic and abiotic stresses (Bakhat *et al*., 2018; Etesami & Jeong, 2018) [13, 22]. Positive impact of Si on plant development has been demonstrated in laboratory and field experiments over the years, and found to promote seed germination (Biju *et al*., 2017) [15], salinity stress (Rady *et al*., 2019) [51-53], alkalinity stress (Abdel Latef & Tran, 2016) [1] and UV-B stress (Tripathi *et al*., 2017) [63] etc. More significantly, Si is an environmental friendly element, which means that there is no detrimental residue in food or the environment after being used in crops (Sarma *et al*., 2019) [56]. Si has been used for soil fertilization and foliar spray (Meena *et al*., 2014; Othmani *et al*., 2020) [42, 44] and found to enhance the some or all of the yield attributes in various crops like maize (White *et al*., 2017; Hanafy *et al*., 2008) [64, 26], soybean (Kalandyk *et al*., 2014) [37], sugar beet (Artysak *et al*., 2017) [9] and potato (Kadalli *et al*., 2017; Crusciol *et al*., 2009) [36, 20]. Si treatment has also been reported to improve the seed vigour in many cereals *viz*., maize (Yankun *et al*, 2021) [70], cucumber (Soumya *et al*., 2020) [60], rice, wheat, pea and mustard (Chaurasiya *et al*., 2021) [19]. Seed quality and performance are critical in achieving better productivity in any crop. Seed performance is a multi-faceted feature that includes seed germination, seedling emergence and growth (Finch-Savage & Bassel, 2016) [24] and seed vigour a crucial indicator of seed quality determining uniform emergence potential and establishment of plants (Finch Savage & Bassel 2016) [24].

Although, the effect of Si application on seed traits have been the subject of research in recent years but transgenerational effect of Si on paddy seeds could not be traced out in spite thorough review of available literatures. The present study investigated in detail the effect of soil application of potassium silicate on F1 generation rice seed of susceptible rice variety, as well as treatment with potassium silicate of different guilds, i.e., YSB (biting and chewing) and BPH (sucking) in the same doses.

Material and Methods

Test material and silica source

TN-1 rice variety were collected from ICAR-NRRI, rice gene bank, Cuttack, Odisha and sown in plastic tray (42 x 28 x 8 cm, LWH) at Crop Protection Division net house. Transplanted 25-30 days old seedlings into pots containing well-puddle soil fertilized with NPK @ 100-60-40 kg/ha and maintained @ 2 seedlings/pot and kept free of insects and pathogens infestation.

Potassium silicate containing 54% SiO_2 supplied by Noble Alchem Limited, Indore, India was employed as a silica source to experiment the effect of potassium silicate soil application on insect infestation and transgenerational effect of Si amendment on rice seeds.

Insect Culture

Yellow stem borer: Adult female moths of YSB were available for a particular period in a crop season were collected from the fields during morning hours and released into the cages maintained with susceptible rice variety to allow the moths to lay eggs, which were then collected and allowed for hatching under suitable condition for continuous supply of first instar larvae for release on the test plants (Annamalai *et al*., 2022) [7].

Brown planthopper (BPH)

Twenty adult males and females were released for 24 hours onto 40-day-old susceptible insect-pest and disease free potted rice plants for oviposition to obtain the same age group of BPH. After the oviposition exposure period, plants were placed to the rearing cages, and the emerging insects were used for the experiment (Anant *et al*., 2021) [6].

Effect of potassium silicate application on Yellow stem borer

Dead heart infestation caused by the rice yellow stem borer, experiment was carried out according to the methodology adopted by Jeer *et al*., (2016) [71]. 30 days old seedlings were planted in mud pots at two seedlings per pot in TN-1 variety. Thirty five days after transplanting potassium silicate was applied on the soil. Seven days after application, the plants were infested with newly emerged YSB @ 25 larvae per pot plant by releasing the larvae near the leaf auricles of rice plants. All plants were evaluated on 7th days of YSB larva release for dead heart of the rice plants is observed.

Effect of potassium silicate application on brown planthopper

Honeydew excretion test

The sucking time of BPH was found out by calculating the amount of honeydew excretion by newly emerged females using a graphical technique (Jena *et al*., 2015) [35]. In short, a filter paper was taken with a small hole in the middle of it, and a longitudinal cut was made from the margin to the hole. These circular filter papers was dipped in a 0.5% bromocresol green solution prepared in ethanol (80%) and kept under shade for one hour to allow the papers to dry. The cardboard sheets were cut with a wide opening in the middle and pushed through the tip of the seedling to its base. A machined circle of filter paper is set on a cardboard sheet, and an altered plastic glass with an opening in the base is embedded through the highest point of the sheet into the filter paper. Three newly emerged female BPH brachypterous were restrained for three hours before being released into each pot and cared for at the seedling base for 24 hours. (Begum and Wilkins, 1998) [14]. A cotton plug was fixed at the mouth of the glass to keep insects from getting away. The honey dew beads excreted by the female were saved on filter paper and caused shedding to change from yellow-orange to blue. The area of blue spots brought about by the arrival of honey dew on the filter paper was estimated graphically. The amounts of honeydew excreted by the insects of TN-1 rice variety were estimated based on the average area (mm^2) of excreted honeydew.

Ovipositional response (Total fecundity)

Ovipositional response was carried out according to the methodology adopted by Reddy *et al*. (2005) [52]. After 25 DAT, the TN-1 rice plants was washed and cleaned by removing dried and excess leaves to make them suitable for oviposition. The rice plants were well covered with mylar cages. Three adult gravid female insects were released with the help of aspirator in the mylar cage and open end of the tubes was covered with muslin cloth and tied with rubber band. The plants were observed for nymphal hatching and the hatched nymphs recovered and transferred from the rice plant.

After all the eggs were hatched or when all the BPH nymphs emerge from (after 15-20 days of adults release) plants were cut at the base and examined under stereo binocular microscope.

Nymphal survival

TN-1 rice variety @ two seedlings per pot was transplanted into well puddled soil in a pot and maintained three replications for each treatment. After 30 days of transplanting, plants were covered with mylar cages and released twenty number of 2nd instar BPH nymphs on rice plants by gently tapping. The plants were observed daily, counted the number of live and dead nymphs and calculated the nymphal survival per cent (Heinrichs *et al*., 1985) [72].

Transgenerational effect of potassium silicate supplementation

25 days old seedlings of TN-1 rice variety was transplanted into 7-kg pots containing well-puddled soil fertilized as per recommended dosages and kept free of insects and pathogens. Thirty-five DAT, a soil application of potassium silicate 200 mg K_2SiO_3/kg soil with one set of untreated control were maintained and replicated thrice. At physiological maturity stage, the panicles were harvested, threshed, dried the seeds to moisture content below 14% and stored in craft bags. The germination tests were conducted within six month after the harvesting of TN-1 rice seeds.

Germination test

Germination percent and Speed of Germination

The germination percentage (GP) for TN-1 rice variety was tested following standard procedure. In brief, fifty healthy and fully filled rice seeds were surface sterilized with 2% sodium hypochlorite followed by washing with sterilized water several times, and finally shade dried on tissue paper. Then 50 seeds soil applied potassium silicate treatment along with untreated control were equally distributed on double-layered filter paper in sterilized Petridishes (14.5 cm dia.) and moistened the filter paper with distilled water. Each treatment was replicated four times. Monitored and counted the seed germination daily till 10 days where the seed germination was marked by the emergence of a 2 mm radicle length (Sardoei & Mohammadi, 2014) [55]. After 10 days, the number of germinated seeds was recorded, and the germination percentage (GP) was calculated using the following formula (Abdul-baki & andarson, 1970) [3].

$$GP = (\text{Total no. of germinated seeds} / \text{Total no. of initial seeds}) \times 100$$

Based on the daily germination count calculated the speed of Germination (SOG) as described by the Association of Official Seed Analyst (AOSA, 1983) [8],

$$SOG = \text{No. of germinated seed} + \ldots + \text{No. of germinated seed} / \text{Day of first count} + \ldots + \text{Day of final count}$$

Seedling parameters

After ten days, five seedlings were randomly selected from each replication and maximum shoot length (cm), root length (cm), weight (both fresh and dry weight in g) for each seedlings was determined using a ruler (Abdul-baki & Andarson, 1970) [3] and electronic weighing balance respectively (Yan, 2018) [65]. After taking fresh weight, the seedlings were oven dried at 80°C for 24 hours and dry weights were measured.

Seed vigor index

Seed vigor index (SVI) was calculated following standard procedure of Abdul-Baki & Anderson, 1973 [2]. These are derived from germination percent and seedling growth parameters i.e. seedling length and dry weight as per the following formulae:

1. Seed vigour Index-I = Germination percent (%) × Average seedling length (cm)
2. Seed vigour Index-II = Germination percent (%) × Average seedling dry weight (mg or g)

Silica content in rice husk

After harvesting, F1 generation seed samples was dried in a hot air oven at 70°C and processed with a palm husker to remove the husk. The silica content of rice seed husk was determined following molybdenum yellow spectrophotometric method (Elliot & Snyder, 1991) [21]. In brief, 100 mg of seed husk from TN-1 rice variety was taken in a 50 mL polypropylene tube and warmed in a hot air oven at 60°°C. Added to the tubes 3mL of 50 percent NaOH solution, homogenized and then autoclaved at 121 °C for 20 minutes. Filtered the content through Whatman No. 1 filter paper and transferred the extractant to fresh 50 mL polypropylene tube. The volume was made up with double distilled water and 1.0 mL aliquot was taken and transferred to another 50 mL polypropylene tube. Added 30 mL acetic acid (20%) and 10 mL ammonium molybdate solution (54 gL^{-1}, pH7.0) and mixed the solution properly. After 5 min, 5 mL tartaric acid (20%) and 1 mL reducing agent (solution A- 2 g Na_2SO_3, 0.4 g 1-amino-2-napthaline-4-sulphanilic acid; Solution B- 25 g $NaHSO_3$ in 200 mL distilled water) was added. Then again the volume was made up to 50 mL and after 30 min the absorbance was measured at 650 nm in UV Spectrophotometer (Bhattacharyya *et al*., 2020) [15]. Standard curve was arrived following standard procedure using Certipur^R Si standard purchased from Sigma-Aldrich. Calculated the SiO_2 content of rice seed husk and expressed in per cent.

Statistical analysis

Data on the YSB infestation and BPH nymphal survival were arcsine $\sqrt{X/100}$ transformed and other data of BPH were $\sqrt{X+0.5}$ transformed to meet normality assumptions of residual and the homogeneity of variance. Tukey HSD test was used to separate the differences between treatments. Data then were subjected to analysis of variance (ANOVA) by SAS and graphical representation in sigmaplot v 12.0.

Transgenerational rice seed quality experiments were conducted using a randomized complete block design with a factorial arrangement of treatment and four replications. Paired t-test of the all data to analyse the significant differences between treatment and control.

Result

Effect of potassium silicate application on Yellow stem borer

Dead heart damage caused by yellow stem borer was significantly different in TN-1 rice variety in soil applications of potassium silicate (p<.0001). The dead heart damage percent was 85.00% in the untreated control whereas in different doses of potassium silicate application was in the range of 71.46-29.09% (table 1). Thus, the result reveals that in susceptible rice variety, potassium silicate applications significantly reduce dead heart damage caused by YSB compared to the untreated control. Considering the per cent dead heart damage in PS treatment compared to untreated control, maximum dead heart reduction was observed in (65.78%) for the highest concentration of PS. But all other doses of soil application of PS also had shown a commendable quantum of dead heart damage reduction (Fig.1).

Effect of potassium silicate application on brown planthopper

Honeydew excretion test

Susceptible rice variety treated with soil application of potassium silicate performed significantly ($p<0.001$) better regarding the honeydew excretion of brown planthopper compared to control. The honeydew excretion in TN-1 rice variety was 626.67 mm^2 in the untreated control (table 1). Among the treatment, minimum honeydew excretion (45mm^2) was observed in soil application of PS at 500 mg/ kg dose whereas maximum honeydew excretion (121.33 mm^2) was observed in soil application of PS at 25 mg/kg dose. But all other doses of soil application of PS also had shown a commendable quantum of honeydew excretion reduction (fig 2).

Ovipositional response (Total fecundity)

TN-1 rice variety treated with soil application of potassium silicate performed significantly ($p<0.001$) better regarding the total egg of BPH compared to without application of potassium silicate. The total egg of BPH in rice plant was 159.33 in the untreated control whereas in different doses of potassium silicate exogenous amendment as soil application at graded doses (25-500 mg PS / kg of soil) it was in the range of 99.33-159.33 (Table 1). Thus, the data disclosed that in rice plant, total egg laid by BPH was significantly less on plants applied with potassium silicate as soil application caused compared to the untreated control plants. Considering the reduction of total egg of BPH in potassium silicate treated plant compared to control, maximum reduction was 37.63% for the highest concentration of PS (Fig 3).

Nymphal survival

BPH nymphal survival in the TN-1 variety treated with soil application of potassium silicate performed significantly different ($p<.0001$) than not treated with potassium silicate application. In the variety, the BPH nymphal survival was 98.33% in the untreated control, whereas it ranged from 50-86.67% when a potassium silicate exogenous amendment was applied as a soil application at graded levels (25-500 mg PS / kg of soil) (Table 1). Thus, the result reveals that in tested variety, soil application of potassium silicate produced significant reduction in BPH nymphal survival compared to the untreated control. All doses of soil application of PS had shown a commendable quantum of BPH nymphal survival reduction (table 1). Pertaining to maximum percent reduction of BPH nymphal survival 49% was observed in response of potassium silicate soil application at different doses in rice plant compared to the control with the highest increase observed for the highest dose (fig 4).

Effect of potassium silicate on germination parameter

The effect of potassium silicate soil application on the seed quality traits such as germination per cent (GP) and speed of germination (SOG) was presented in table 2. The soil application of potassium silicate treatment promotes the germination of rice seeds, resulting in GP values higher than those in the untreated control.

In the soil application of potassium silicate shown significantly increased germination percentage compared to control ($t<0.05$) in TN-1 variety. The result showed that rice seeds from plants applied with potassium silicate in soil had higher GP was observed in treated plant (96.00%) as compared to untreated control (81.50%). Considering the GP percent increase in potassium silicate treated plant compared to control was observed in 25.49%.

The SOG in rice seeds significantly ($P<0.05$) increased with potassium silicate soil treatment compared with the untreated control (Table 2). The SOG values were significantly more for seeds from the plants amended with potassium silicate in soil. Rice seeds from the plants applied with potassium silicate in soil the seeds from the untreated plants had lower mean SOG (15.06) than treated plant (18.21). Considering the SOG percent increase in potassium silicate treated plant compared to control was observed in 20.92%.

Effect of potassium silicate on seedling parameters

The effect of potassium silicate soil application on the seed quality traits such as shoot length (ShL), root length (RL) and seedling length (SL) was depicted in table 2. Significant differences ($t<0.05$) in tested variety were observed for ShL, RL and SL seed quality traits. The soil application of potassium silicate treatment promotes rice seedling growth, resulting in higher ShL values than the untreated control. In TN-1 rice variety, soil application of potassium silicate significantly increased shoot length compared to control ($t<0.05$). It was observed that rice seeds from plants amended with potassium silicate in soil had higher ShL 6.79 cm compared to untreated control having only 5.09 cm. Considering the shoot length percent increase in potassium silicate treated plant compared to control was observed in 25.49%.

The root length in rice seedling significantly ($P<0.05$) increased with potassium silicate soil treatment compared with the untreated control (Table 2). The RL values for seeds from plants amended with potassium silicate in soil were significantly higher. Rice seeds from the plants applied with potassium silicate the seeds from the untreated plants in soil had lower RL (5.51cm) than treated plant (5.77cm). Considering the root length percent increase in potassium silicate treated plant compared to control was observed in 13.14%.

Similarly, the SL values for seeds from the plants of soil amended potassium silicate were significantly higher. Where higher SL (12.56 cm) was observed in treatment than in the untreated plants (10.80 cm) (table 2). The percent increase in potassium silicate treated plant compared to control was observed in 16.25%.

Effect of potassium silicate on seed vigor index

The effect of soil applied potassium silicate on Seed vigor (SV-I and SV-II) was presented in table 2. The soil application of potassium silicate treatment enhanced rice seedling growth, resulting in higher SV-I values in treatment than in untreated control. In the soil application of potassium silicate shown significantly increased SV-I compared to untreated control ($p<0.05$) in TN-1 plant. The result shown that rice seeds from plants supplied with potassium silicate in soil had higher SV-I was 1204.63 compared to untreated control having 880.54. The percent increase in potassium silicate treated plant compared to control was observed in 35.90%.

The seed vigor-II in rice seedling significantly ($p<0.05$) increased with potassium silicate soil treatment compared with the untreated control (Table 2). The SV-II values were significantly more for seeds from the plants amended with potassium silicate in soil. Where higher mean SV-II (0.76) was observed than seeds from the untreated plants (0.56). The percent increase in potassium silicate treated plant compared to control was observed in 37.02%.

Effect of potassium silicate on rice husk silica content

The effect of potassium silicate soil application on rice husk silica content (SC) was presented in table 2. The soil treatment of potassium silicate induced more silica accumulation in transgenerational rice seed, resulting in increased values higher than those in the untreated control. In the soil application of potassium silicate shown significantly increased SC compared to control ($p<0.05$) in TN-1 plant. The result reveals that rice seeds from plants amended with potassium silicate in soil had higher husk SC was 7.29% compared to untreated control having only 2.64%. The percent increase in potassium silicate treated plant compared to control was observed in 176%.

Discussion

To ensure long-term rice production, eco-friendly pest control methods must be developed. One such potential alternative could be the Si amendment (Savant *et al*., 1997) [57]. Increasing evidence suggests that high silicon content in plants confers tolerance to various biotic and abiotic stresses (Ma 2004). The soil application of potassium silicate promoted germination parameter, seed vigor and silica content in transgeneration rice husk.

Soil application of potassium silicate adversely affected the different guilds, i.e., YSB (biting and chewing) and BPH (sucking) in rice plant. In our study was found that application of PS shown minimum percent reduction of dead heart damage caused by YSB in rice plant. In rice plants treated with potassium silicate, the incidence of yellow stem borer was significantly lower than in untreated controls (without potassium silicate application). The damage of yellow stem borer incidence was significantly gradually less in the application of potassium silicate. This is in agreement with finding of Swedhapriya & Chandramani (2015) [18] found that a basal application of 200 kg calcium silicate per ha combined with a foliar spray of 0.25 percent sodium meta silicate (SMS) significantly reduced the incidence of rice stem borer. This is again in endorsement with the finding of Jeer *et al*., (2017) [31] who stated that the higher soil application of DE had a predominantly negative impact on stem borer activity, significantly reducing the percentage of white ear damage. Si content resulted in a lower stem borer incidence. The Si deposited in stem tissues might be acting as a physical barrier and hindering the feeding activity of stem borer larvae due to the wearing of the mandibles and preventing further feeding, as in the case of yellow stem borer larvae in rice. Similarly, Jeer *et al*., (2020) [32] reported that soil application of DE @ 300 kg ha1 significantly reduced stem borer incidence with the lowest percent white ear damage. Patel *et al*., (2021) [46] also concluded that the effect of different doses of both soil and foliar application of silicon as compared to control on the incidence of yellow stem borer in rice. Soil application of calcium silicate @ 1500 and 2000 kg/ha significantly reduced dead heart incidence due to rice yellow stem borer. Likewise, Hosseini *et al*., (2011) [30] showed that there was a decrease in white ear head damage with an increase in silica application rate in rice. The present findings are in close conformity with reports Panda *et al*., (2022) [45] who reported that exogenous silica application of diatomaceous earth enhancing plant resistance to rice stem borer. A maximum of 69.8 and 67.2% decline in borer damage were recorded at vegetative stage.

The results revealed that the incidence of brown plant hopper was significantly less in plants treated with soil application of potassium silicate as compared to untreated control. This is in line with the finding of Goussain (2005) [25] who reported that the accumulation of silica in the intercellular spaces and cell wall matrix, as well as silica deposits in the cell wall, could easily increase the rigidity of cell walls and potentially impede the penetration of the stylet and the feeding of phloem-feeding species by forming a mechanical barrier. Furthermore, increased plant silica concentrations may cause biochemical changes within the plant, causing the stylet to be quickly withdrawn from the plant tissue by lowering the quality of phloem sap, affecting sap feeder development. Similarly, He *et al*., (2015) [27] who observed that rice line treated with a high concentration of silicon solution from the 24 h time point. Furthermore, BPH insects on both rice lines treated with high silicon concentrations were significantly less fertile and excreted less honeydew compared to control. Yang *et al*., (2017) [66] also studied that the soil application of silica significantly decreased brown planthopper population growth rates while increased population doubling time. BPH female feeding on and preference for plants with the high Si addition rate were also reduced. Our present study confirmed the results of Yang *et al*., (2018) [67] that Si-amended rice plants reduced honeydew excretion and therefore feeding of brown planthopper. Furthermore, we were able to demonstrate that callose deposition responded positively to BPH infestation in both with Si and without Si plants, as indicated by more callosic sieve plates in the BPH-infested than in the uninfested plants. More interestingly, with Si plants harbored more callosic sieve plates than without Si plants at 24 hpi, which corresponds to the significantly reduced feeding by BPH on with Si than on without Si plants at 24 hpi.

The seed germination percentage and seed vigor index are important indicators for determining the performance of plant seed germination (Zhang *et al*., 2012) [69]. A plant's seed is a unique stage in its life. It is the fundamental basis for the next generation and the survival of the species. To ensure the success of the new generation, the mother plant transfers a large portion of the nutrients accumulated during its vegetative life to the next generation through its seeds (Mari *et al*., 2020) [41]. The findings of this study show that potassium silicate application of soil significantly promotes the GP, ShL, SL, RL, SOG, SV-I and SV-II of transgenerational rice crop seeds. Knowledge of the positive association of a desired trait required for selection with other non-targeted traits helps in concurrent improvement of the traits.

In this study, the rice seeds obtained from the plants applied exogenously with potassium silicate as soil amendment had higher GP than the rice seeds obtained from the untreated control in test variety. Through no reports could be traced on the transgeneration effect of potassium silicate application on F1 progeny rice seeds the result of treatment immediate effect was discussed under the portion. Annamalai *et al*., (2022) [7] reported that after application of potassium silicate, the rice varieties TN-1 and AD09219 had the highest germination percent of 86.7 and 100%, respectively compared to untreated control. Likewise Lu *et al*., (2015) [38] also reported an increased germination percentage of tomato seeds (70.3%) after application of nano silica suspension. Similarly, after treating maize seeds with silicon, seed germination were increased by 2-11 percent (Yuvakumar *et al*., 2011). The treatment with SNPs increased the germination percentage of rice seed to 98.75 percent compared to control (88.50%), indicating a 10.38 percent increase over the control (Patil NB, 2018) [48]. Thus all the previous results in rice and other different crops are in conformity with our results of increased germination of seeds due to potassium silicate application.

Speed of germination is an important parameter expresses the rate of germination in terms of the total number of seeds that germinate in a time interval. Higher values indicate greater and faster germination. Our data is in confirm it with the findings of Patil *et al*., (2018) [48] who reported that the rice seed treatment with SNPs enhanced the SOG by 26.86 percent as compared to control. Similarly, Alsaeedi *et al*., (2019) [5] found that the increased speed of germination of cucumber seeds (70.3%) after application of SNPs. Thus, all the previous findings in rice and other crops are in consistent with our present findings of increased speed of germination of seed due to application of potassium silicate.

Our finding are in confirm it with the findings of previous work by Patil *et al*., (2018) [48] who reported that the rice seed treatment with a concentration of 125 ppm of silica nanoparticles showed 18.30%, 30.64%, and 21.88% increases in root length, shoot length and seedling length, respectively, as compared to control. This finding are consistent with the results Sabaghnia & Janmohammadi (2014) [54] found that the application of silicon di oxide has a positive effect on the shoot, root and seedling length of the lentil seeds. Similarly, Lu *et al*., (2015) [38] reported that nanosilica powder significantly improved the shoot length of tomatoes. The addition of 5gL-1 nanosilica powder increased average shoot length by 55% over untreated control seeds.

Seed vigor is an important characteristics of seed germination determines and specifies weather seedling was able to keep growing and perform better well after germination. Our results are supported by other results reported by Patil *et al*., (2018) [48] found that the rice seed had higher SV I and SV II recorded in 125ppm of nano silica, which were 29.96 and 15.49% over the control, respectively. Similarly, Azimi *et al*., (2014) [11] who said that applying nano silica by 40 mg L^{-1} increased SVI of wheatgrass seeds by 120% against control seeds.

The result of the current study showed significant increase in rice husk silica content due to potassium silicate application in test variety. Our result is supported by other result reported by Pilon *et al*., 2013 application of Si resulted in higher Si accumulation in the whole plant. Foliar application of Si resulted in the greatest Si concentration in leaves, and soil application increased Si concentration in leaves, stems, and roots. Similarly, Artyszak *et al*., (2021) [10] who said that the application of silicon caused a significant increased as compared to the control. About 70% of the silicon taken up by sugar beet is stored in roots and 30% in leaves. Similarly, Aziz *et al*., (2020) [12] reported that potassium silicate @ 200 mg kg^{-1} of soil gave higher values in almost all physiological and yield parameters in rice.

Table 1: Effect of soil application of potassium silicate on dead hearts due to Yellow stem borer and Brown planthopper incidence in TN-1 rice variety

Treatment (mg/kg soil)	Dead heart (%)	Honey dew excretion (mm^2)	Fecundity		Nymphal survival (%)
			Hatched egg (no.)	Total egg (no.)	
25	71.46^B (60.13)	121.33^B (10.99)	148.00^A (12.14)	159.33^A (12.60)	86.67^B (68.66)
50	60.74^C (53.41)	101.67^C (10.07)	112.33^B (10.57)	128.00^B (11.29)	73.33^B (58.93)
100	53.03^D (46.74)	87.00^D (9.35)	104.33^B (10.19)	125.33^B (11.17)	71.67^B (57.86)
200	40.56^E (39.56)	59.33^E (7.73)	90.33^C (9.53)	110.67^C (10.50)	51.67^C (45.96)
500	29.09^F (32.63)	45.00^F (6.74)	74.67^D (8.67)	99.33^D (9.94)	50.00^C (45.00)
Control	85.00A (67.34)	626.67^A(25.02)	151.00^A (12.27)	159.33^A (12.60)	98.33^A (85.69)
General mean	49.97	11.65	10.56	11.35	60.35
p-value	<.0001	<.0001	<.0001	<.0001	<.0001
CV (%)	4.07	1.50	1.45	1.56	6.49
CD	2.980	0.316	0.279	0.238	7.122
SE (m)	1.20	0.10	0.08	0.07	1.75

Figures in parentheses are arc sin transformed values,
In columns, mean followed by the same letter do not differ significantly from each other by tukeys HSD ($p<0.05$)

Table 2: Effect of soil application of potassium silicate on seed germination traits

TN-1				
Parameters	**Control**	**Treatment**	**% increase (%)**	**Student T-Test**
Germination %	81.50±4.12	96.00±3.65	25.49	0.003^{**}
SOG	15.06±0.29	18.21±0.87	20.92	0.002^{**}
Shoot length (cm)	5.09±0.09	6.79±0.49	33.30	0.003^{**}
Root length (cm)	5.51±0.33	5.77±0.41	13.14	0.008^{**}
Seedling length (cm)	10.80±0.19	12.56±0.50	16.25	0.010^{*}
SV-I	880.54±55.26	1204.63±48.64	35.90	0.004^{**}
SV-II	0.56±0.06	0.76±0.04	37.02	0.004^{**}
Silica content (%)	2.64±0.03	7.29±0.07	176.07	0.006^{**}

Significance obtained from paired t-test (*) at 0.05, (**) at 0.01 and (***) at 0.001

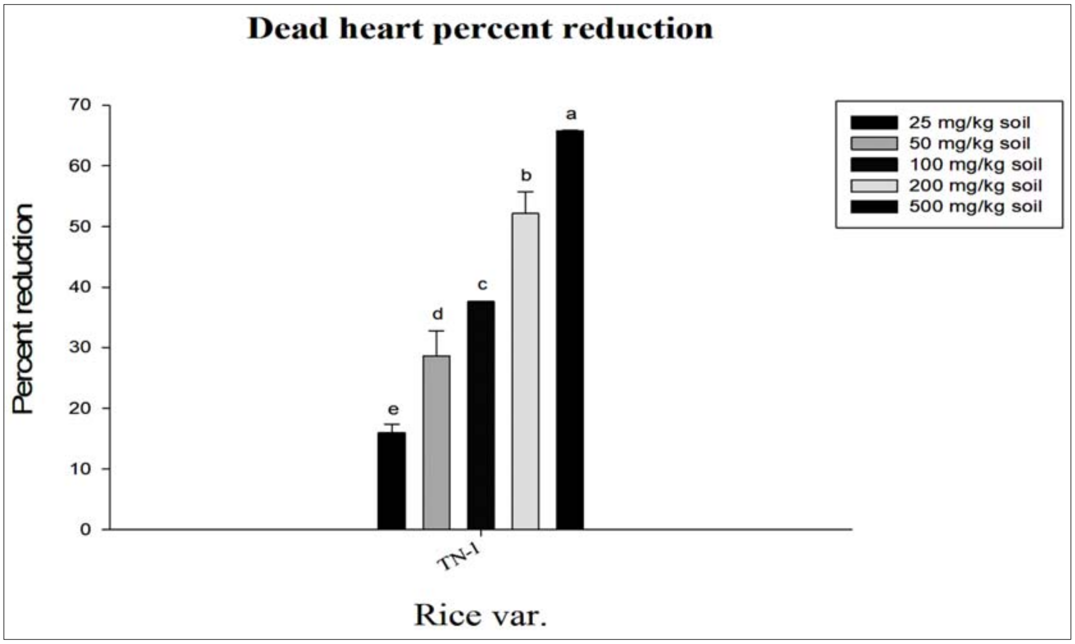

Fig 1: Percent reduction due to caused by YSB in soil application in TN-1 rice variety compared to untreated control

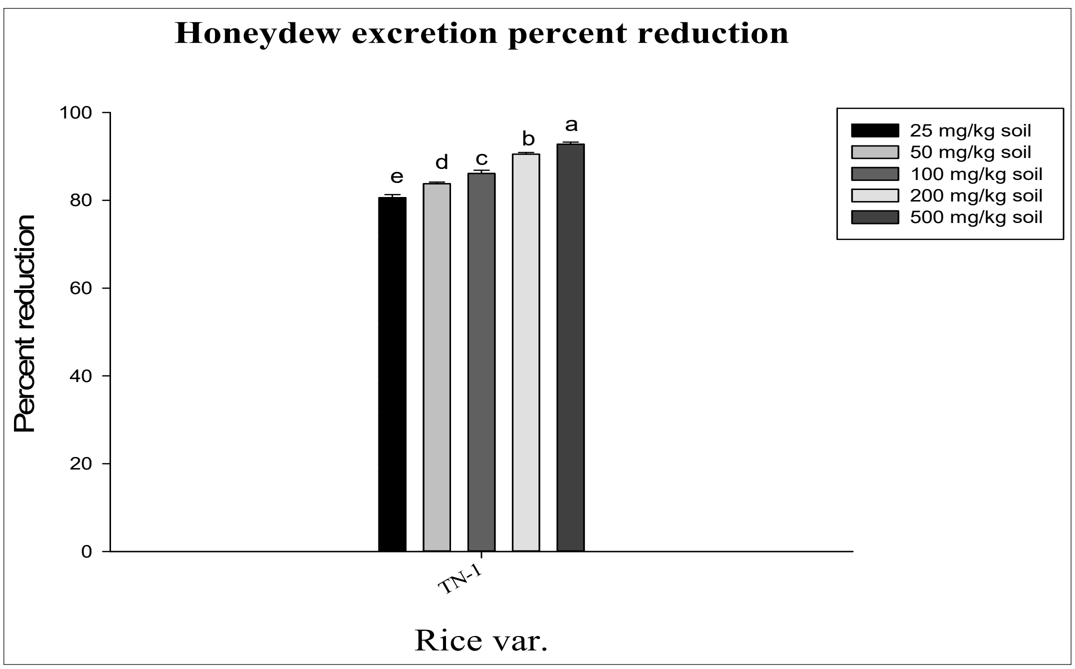

Fig 2: Percent reduction in brown planthopper honeydew excretion in TN-1 rice variety treated with different doses of potassium silicate in soil applications compared to the untreated control

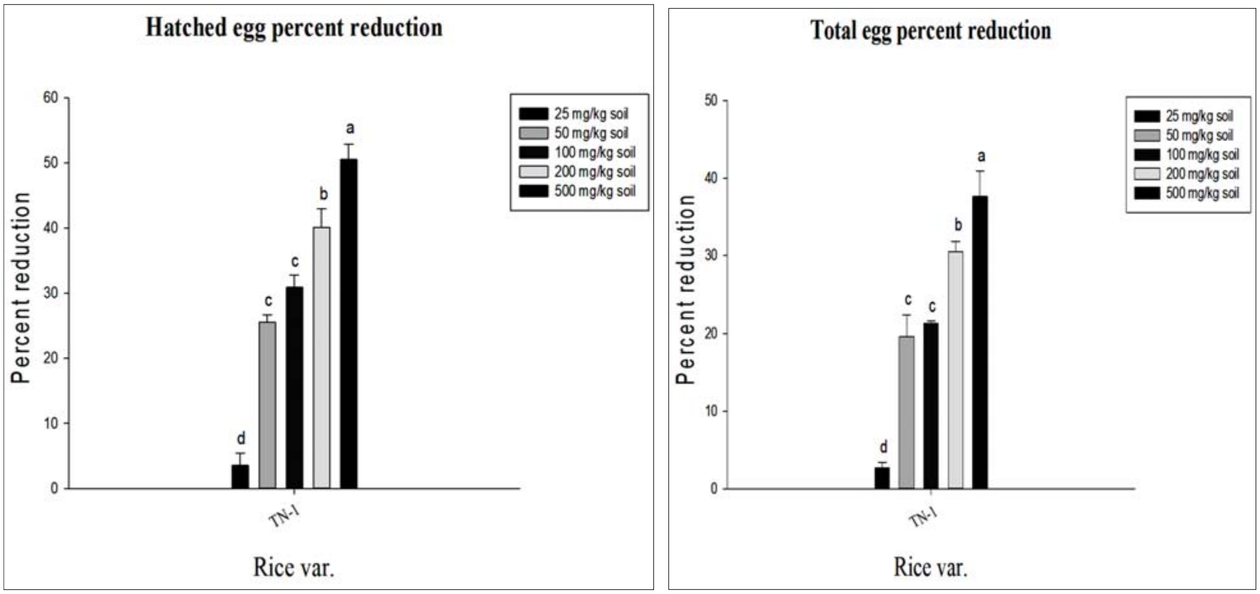

Fig 3: Percent reduction in brown planthopper oviposition in TN-1 rice variety treated with different doses of potassium silicate in soil applications compared to the untreated control

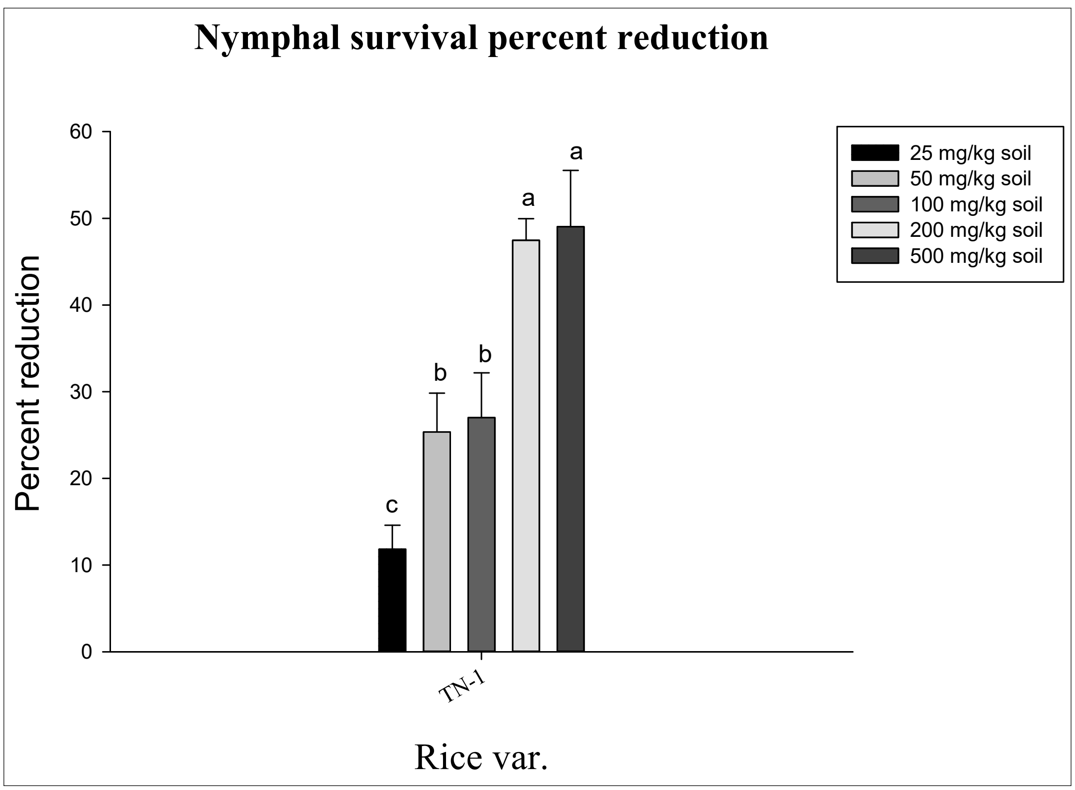

Fig 4: Percent reduction in brown planthopper nymphal survival in TN-1 rice variety treated with different doses of potassium silicate in soil applications compared to the untreated control

Conclusion

This is the first study exploring the effect of application of same doses of potassium silicate and observing its efficacy in managing insect of different guilds i.e., biting and chewing (YSB) and sucking insect (BPH). It was found that the same doses can able to manage the damage caused by insect of different guilds (biting and chewing and sucking insect) and observed that damage caused by YSB and BPH is much lesser compared to untreated control.

This is also the first study exploring soil application of potassium silicate on mother plant and its trans-generation effect on progeny seed performance of test variety. It was found that soil application on mother plant showed positive trans-generation effect by improving different seed parameters like germination percent, speed of germination, shoot length, root length, seedling length, seed vigor I and seed vigor II in the progeny seed of tested rice variety.

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