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**Rakesh Sil Sarma**
Department of Plant Physiology, Banaras Hindu University, Varanasi, Uttar Pradesh, India.

**Deepti Shankhdhar**
Department of Plant Physiology, GBPUAT, Pantnagar, Uttarakhand, India.

**Shailesh Chandra Shankhdhar**
Department of Plant Physiology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand India.

**Correspondence**
**Rakesh Sil Sarma**
Department of Plant Physiology, Banaras Hindu University, Varanasi, Uttar Pradesh, India

# Beneficial effects of silicon fertilizers on disease and Insect-Pest management in rice genotypes (*Oryza sativa.* L)

**Rakesh Sil Sarma, Deepti Shankhdhar and Shailesh Chandra Shankhdhar**

**Abstract**
A field experiment was conducted in kharif season of 2015 to investigate the influence of silicon fertilizers on different rice genotypes namely PA-6129, PA-6201, PA-6444, PHB-71, US-312, and BPT-5204. Soil application of silicon solubilizer was given at the time of maximum tillering, panicle initiation and 50% flowering stage. Various parameter like leaves dry matter content, leaves Silicon content, Pest infestation (Yellow stem borer- dead heart and white ear head), Disease infestation (Rice blast, False smut) was observed. After silicon fertilizers treatment leaf weight significantly increased of all varieties at three perspective growth stages (Maximum tillering, Panicle initiation, Flowering). BPT-5204 showed very good responses in increasing leaf weight compared to other varieties. Silicon content in leaves (at 50% Flowering stages) increases as compared to control in all perspective varieties under silicon solublizers treatment, and BPT-5204 showed maximum accumulation of silicon in leaves. Stem borer infestation (Dead heart and white ear head) was significantly reduced after application of silicon fertilizers in all rice genotypes. In case of stem borer infestation also BPT-5204 showed maximum reduction in larva was found as compared to other genotypes. Rice blast disease was significantly reduced in all rice genotypes as compared to control after silicon solublizers treatment in soil. Similar results was found in false smut disease also, soil application of silicon fertilizers reduced infestation of false smut and severe false smut in all rice genotypes as compared to control.

**Keywords:** Silicon fertilizers, disease, *Oryza sativa.* L

## Introduction
Silicon (Si) is the second most abundant element in the earth's crust, and comprises up to 70% of soil mass**.** Si was initially not recognized as an essential element for higher plants, although it was known to be beneficial for plant growth and production. Si is absorbed by plant roots in its neutral form ($H_4SiO_4$) through a passive process regulated by transpiration stream, which occurs via the xylem, along with water (mass flow) or by an active process, through transporters located in the plasma membrane of root cells plasma membranes (Rodrigues *et al.*, 2011) [15]. Its accumulation among plant species differs greatly, due to differences in root Si uptake capacity (Takahashi *et al.*, 1990) [17]. Generally, Si uptake takes place through plant roots as monosilicic acid [$Si(OH)_4$], an uncharged molecule (Ma and Yamaji, 2006) [11], and passes through the plasma membrane via two Si transporters, Lsi1 and Lsi2, which function as influx transporters and efflux transporters, respectively (Ma *et al.*, 2008) [12]. Generally, food security and health concerns are two critical issues, for human life. Due to the population growth, especially in developing countries, and the spread of communicable and noncommunicable diseases in human population, having a flexible agricultural system is more necessary than ever. Agricultural systems are reliable ways to increase food for the humans by using natural resources. To increase the food qualities and quantities, plants should utilize different strategies to overcome the adverse environmental effects. By utilizing genes strategies, plants can increase their resistance against negative environmental impacts. Along with that, scientists made an effort to increase plants tolerance against pathogens.

Reportedly, Si is able to decrease the susceptibility of rice crops against sheath blight diseases (Zhang *et al.*, 2006 and Cai *et al.*, 2008) [7, 9]. Plant opal or glass and hard coating of $SiO_2$ polymerisation in the plant cuticle layer is the possible mechanism for reducing disease susceptibility by Si (Rudrigues *et al.*, 2003) [4]. It has been speculated that Si is able to decrease the effect of sheath blight by enhancing the defence mechanisms of the crops against pathogens, increase the amounts of phenolics components, and increase the activities of defence related enzymes like, peroxidase, chitinases, polyphenoloxidase, $\beta$-1, 3-glucanases, and phenylalanine ammonia lyase etc (Rudrigues *et al.*, 2003) [4]. Silicon fertilizers can reduce the intensity of blast disease in the leaf and the panicle during different growth stages.

Reduction of the leaf lesions of rice after 96 hrs of inoculation with *M. grisea* between Si-treated and untreated plants has been examined (Rudrigues *et al*., 2004) [3]. Silicon has been applied to prevent the occurrence of powdery mildew disease, one of the plant diseases created by *Sphaerotheca fuliginea*. Silicon has been reported to be an effective suppressor of powdery mildew (*Blumeria graminis*) (Fautex *et al*., 2006). In addition to blast and powdery mildew, the occurrence of brown spot, stem rot, sheath brown rot on rice, fusarium wilt and corynespora leaf spot on cucumber decreased by increasing the Si supply. In turf grass, several diseases were also suppressed by silicon fertilizers application (Datnoff *et al*. 2002) [1]. Increasing the Si content in cucumber shoots leads to a decrease in powdery mildew incidence. Silicon-enhanced resistance is associated with the density of silicified long and short epidermal cells, the thick layer of silica under the cuticle, the double cuticular layer, the thickened Si-cellulose membrane, formation of papilla, and complexes formed with organic compounds in epidermal cell walls that strengthen plants mechanically. The physical barriers inhibit pathogen penetration and make plant cells less susceptible to enzymatic degradation caused by fungal pathogen invasion (Van *et al*., 2015) [18]. Several studies have reported the role of Si in disease resistance by activating defence-related enzyme activities such as chitinase, peroxidases, polyphenoloxidases, beta-1, 3-glucanase, phenylalanine ammonia-lyase, uperoxide dismutase, ascorbate peroxidase, glutathione reductase, catalase, lipoxygenase, and glucanase. PAL, involved in the synthesis of plant secondary antimicrobial substances, is essential for plant disease resistance responses (Waewthongrak *et al*., 2015) [20].

## Material and Methods

The field experiment was carried out at Norman E. Borolaug Crop Research Centre & Department of Plant Physiology, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand) during kharif season of 2015 for the purpose of studying the influence of soil application of silicon fertilizers on growth, development, physiological attributes and pest, disease resistance in different genotypes of rice (*Oryza sativa* L.). Different rice genotypes namely PA-6129, PA-6201, PA-6444, PHB-71, US-312, and BPT-5204 were obtained from the Indian institute of Rice Research, Rajendranagar, Hyderabad. The field experiment was carried out in three separate independent split plot design with three replications with 10 gm solid silicon crystal dissolved in 2 litre water and make to 10 litre. Sprayed it at different growing stages mainly in, at maximum tillering, Panicle initiation, 50% flowering.

### Leaf weight

The dry matter of the rice leaves is its solid contents i.e. all its constituents except water. Total leaves dry matter was recorded at three growth phases including maximum tillering, 50% flowering and maturity. TDM can be calculated by placing the plant sample in oven at $65^0$C for three days.

### Estimation of silicon content

Silicon content of rice leaves was estimated by the methods described by Wei-min *et al*. (2005) [21]. Sodium silicate solution was used as standard. Take 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 ml silicon standard solution to a 50 ml volumetric flask respectively. Add 30 ml acetic acid (20%) and 10 ml ammonium molybdate solution. Kept for 5 min and then add 5 ml 20% tartaric acid and 1ml reducing solution. Adjust to 50 ml, with 20% acetic acid. Stored in a tightly stopered plastic bottle in the dark. 30 minutes later, measure the absorbance at 650nm. Each sample was grind and sifted through a 60-mesh sieve. Collected leaves powder (100mg) for silicon estimation. Transfer 1ml sample solution to a 50ml volumetric flask. Add 30 ml 20% acetic acid and 10 ml ammonium molybdate solution, shake up to mix thoroughly. Keep for 5 min after that immediately add 5 ml 20% tartaric acid and 1ml reducing solution. Adjust to 50 ml with 20% acetic acid. After 30 minutes later, measure the absorbance at 650 nm.

### Disease and Pest Infestation

### Pest infestation (yellow stem borer)

The scoring system was adopted from method given by Ning *et al*., (2014).

### Dead heart and white ear head infestation

Out of total plants in a plot, the plants which were infested by yellow stem borer were counted. Then the percentage of infested plants was calculated by dividing dead heart infested plants to total number of plants. Evaluation of white year head infestation was done at flowering stage. The percentage of white ear head infestation was calculated by the same method as used for the dead heart infestation and scoring was done by following table:

**Scale of dead heart/white ear head percent infestation**

| Dead heart percent infestation (%) | Scale |
|---|---|
| No damage | 0 |
| 1 to 10(%) | 1 |
| 11 to 20(%) | 3 |
| 21 to 30(%) | 5 |
| 31 to 60(%) | 7 |
| 61 and above | 9 |

### Disease infestation (Rice false smart)

Disease infestation evaluation was done at flowering, at the time of false smut ball formation. Incidence of false smut was calculated by counting percent false smut ball bearing tillers in one meter square area. Scoring was done by the methods as same as dead heart and white ear head.

### Rice blast disease

Disease infestation was done at flowering stage. Incidence of rice blast was calculated by counting percent of blast in leaves/one square meter

**The rating score related to the rice blast**

| S. No | Score | Rate |
|---|---|---|
| 1 | Up to 20% | + |
| 2 | Up to 40% | ++ |
| 3 | Up to 60% | +++ |
| 4 | Up to 80% | ++++ |
| 5 | Up to 100% | +++++ |

## Result and Discussion

**Leaf weight (g $m^{-3}$):** The effect of silicon fertilizers in leaf weight was observed in maximum tillering, panicle initiation, and 50% flowering stages in all the rice genotypes. The overall mean of all rice genotypes and treatment showed the enhanced (3.05 g/$m^2$) when compared with control (2.43 g/$m^2$) in maximum tillering stages. Statistically showed that interaction between treatment and genotypes was found significant with respect to all the treatments, in maximum tillering stages. In panicle initiation, The overall mean of all rice genotypes showed the enhanced (7.87 $g/m^2$) when compared with control (7.25 $g/m^2$). Statistically showed that interaction between treatment and genotypes was found significant with respect to all the treatments and all the genotypes at panicle initiation stage. Among all the rice genotypes and silicon treatment the leaf weight of BPT-5204, significantly affected from all other genotypes at panicle initiation stage. At 50% Flowering stages The overall mean of all rice genotypes showed the enhanced (8.68 $g/m^2$) when compared with control (8.03 $g/m^2$), Statistically showed that interaction between treatment and genotypes was found significant with respect to all the treatments and all the genotypes. In similar studies it was observed that in water stress condition silixol application can increased 25% leaf dry weight of rice where compared without silixol fertilization (Ma *et al.*, 2004) [10]. In another study application of silicon (500kg/ha) in rice showed enhance leaves dry weight by 15.29% compared with control (Fallah *et al.*, 2013) [6].

**Table 1:** Effect of silicon application on leaf dry matter (LDM) at maximum tillering, panicle initiation and at 50% flowering in different rice genotypes

| Name of the rice genotypes | Leaf weight ($g\ m^{-2}$) at tillering | | | | Leaf weight ($g\ m^{-2}$) at panicle initiation | | | | Leaf weight ($g\ m^{-2}$) at 50% flowering | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Silicon solubilizer treatment | Mean | % increase | Control | Silicon Solubilizer treatment | Mean | % increase | Control | Silicon Solubilizer treatment | Mean | % increase |
| PA-6129 | 1.89±0.10 | 2.44±0.14 | 2.16 | 28.87 | 6.82±0.02 | 6.89±0.05 | 6.86 | 00.98 | 6.10±0.10 | 6.73±0.01 | 6.41 | 10.33 |
| PA-6201 | 1.35±0.08 | 1.75±0.18 | 1.55 | 28.99 | 7.97±0.43 | 8.04±0.11 | 8.00 | 00.84 | 9.20±0.05 | 10.27±0.04 | 9.73 | 11.67 |
| PA-6444 | 3.30±0.15 | 3.45±0.13 | 3.38 | 04.43 | 7.30±0.15 | 8.46±0.03 | 7.88 | 15.98 | 8.03±0.13 | 8.44±0.02 | 8.23 | 05.06 |
| PHB-71 | 3.33±0.08 | 3.56±0.12 | 3.44 | 06.80 | 6.70±0.05 | 7.36±0.14 | 7.03 | 09.85 | 7.56±0.17 | 8.57±0.04 | 8.07 | 13.30 |
| US-312 | 3.63±0.14 | 3.88±0.02 | 3.76 | 06.97 | 6.73±0.21 | 7.98±0.04 | 7.35 | 18.56 | 8.00±0.05 | 8.61±0.32 | 8.30 | 07.62 |
| BPT-5204 | 2.43±0.13 | 3.21±0.28 | 2.82 | 32.05 | 8.00±0.15 | 8.52±0.05 | 8.25 | 06.50 | 9.30±0.10 | 9.48±0.52 | 9.39 | 02.01 |
| Mean | 2.65 | 3.05 | | | 7.25 | 7.87 | | | 8.03 | 8.68 | | |
| | Genotype (G) | | Treatment (T) | TxV | Genotype (G) | | Treatment (T) | TxV | Genotype (G) | | Treatment (T) | TxV |
| S.Em. ± | 0.06 | | 0.10 | 0.15 | 0.06 | | 0.11 | 0.16 | 0.07 | | 0.12 | 0.17 |
| CD at 5% | 0.18 | | 0.31 | 0.44 | 0.20 | | 0.35 | 0.49 | 0.20 | | 0.36 | 0.51 |

**Silicon Content**

The silicon content in leaves was found significantly more in 50% flowering as compared to controls in rice genotypes. It was observed that four varieties mainly PA-6201, PA-6444, US-312, and BPT-5204 having higher accumulation of silicon in leaves, as compare to other varieties like PA-6129, and PHB-71. This is due to Silicon which can act as a physical barrier in the leaf epidermal cells, and results a mechanism of defence, reduces lodging, increase photosynthesis capacity, reduce transpiration losses (Ma *et al.*, 2003). Monocots such as rice, wheat, maize and barley are categorized as Si accumulators due their very high silica contents (10–15%) (Epstein *et al.*, 1999). In rice it was found that crop accumulate silica behave the range 0.1–15% of their dry weight. The degree of accumulation depends on uptake and transport mechanisms in plant leaves (Ma *et al.*, 2013). The uptake and distribution of silicic acid by plants is increased many folds by the presence of different type of influx and efflux transporters in leaves (Ma and Yamaji, 2011) [13].

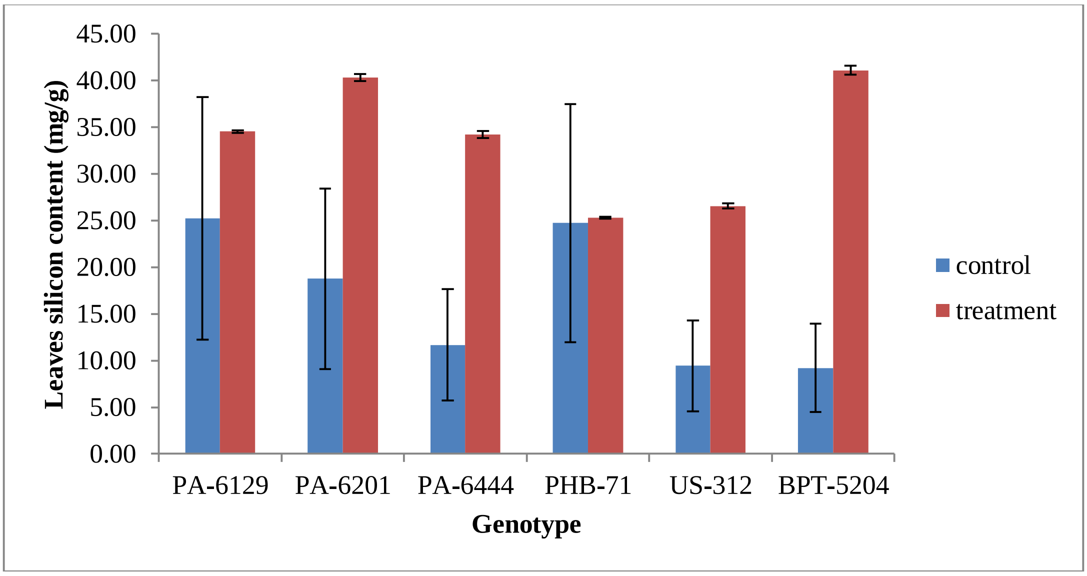


**Fig 1:** Silicon content (mg/g) in leaves of rice Genotypes at flowering stages.

**Pest infestation, yellow stem borer (dead heart and white ear head)**

The larvae of the stem borers is known as caterpillar which bore into central shoot and tillers of paddy, cause the drying of the central shoot known as Dead heart**.** Yellow stem borer infestation (%) evaluation was done in two different stages, at the time of tillering and 50% flowering. Dead heart symptoms infestation was significantly influenced by the silicon solubilizers in soil. However silicon fertilizers showed maximum decreased (75.00%) in PA-6201 and minimum (20.00%) in PHB-71 where compared to control. As compared to control (10.08 in scale 3) the overall mean of all genotypes showed decreased dead heart infestation (6.61 in scale 1) under silicon fertilizers treatment. The interaction between treatment and genotypes was found statistically significant in respect to almost all the genotypes. During flowering stage in paddy caterpillar of stem borer severely attack the panicle/grains, it become chaffy and white is known as white ear head. Soil application of silicon solubilizer can significantly decreased the white ear head infestation in rice crop at 50% flowering stage. However silicon solubilizer showed maximum decreased (56.36%) in PHB-71 and minimum (15.78%) in US-312 where compared to control. As compared to control (10.14 in scale 3) the overall mean of all genotypes showed decreased white ear head infestation (6.83 in scale 1) under silicon solubilizer treatment. The interaction between treatment and genotypes was found statistically significant in respect to almost all the genotypes. It might be due to silicon accumulation in beneath cuticle epidermal cells of leaves and stems in plants, which act as mechanical barrier for insect infestation in crop. It was also observed that application of silxol complex sources like pyridine N-oxide (PNO) and 4-morpholino pyridine N-oxide (MNO) can significantly reduced stem borer infestation (Ranganathan *et al.*, 2006) [14]. Similarly silicon solubilizer treatment can reduced stem borer infestation from control (54.4%) to treatment (8.4%) in rice crops (Guntzer *et al.*, 2012) [8].

**Table 2:** Effect of silicon application on stem borer infestation (%) in different rice genotypes.

| Name of the rice genotypes | Dead heart/ plot (%) | | | | White ear head/ plot (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Control | Silicon solubilizer treatment | Mean | % increase | Control | Silicon solubilizer treatment | Mean | % increase |
| PA-6129 | 13.33±0.33 | 8.66±0.16 | 11.00 | -61.11 | 12.00±1.52 | 8.66±0.88 | 10.33 | -27.77 |
| PA-6201 | 9.33±0.33 | 7.33±0.00 | 8.33 | -75.00 | 10.33±1.07 | 8.00±0.57 | 9.16 | -22.58 |
| PA-6444 | 7.53±0.44 | 5.33±0.00 | 6.43 | -50.00 | 8.20±0.52 | 6.33±0.88 | 7.26 | -22.76 |
| PHB-71 | 8.50±0.28 | 3.33±0.30 | 5.91 | -20.00 | 9.16±0.53 | 4.00±0.57 | 6.58 | -56.36 |
| US-312 | 9.50±0.29 | 8.33±0.16 | 8.91 | -70.83 | 9.50±0.50 | 8.00±0.58 | 8.75 | -15.78 |
| BPT-5204 | 12.33±0.00 | 6.66±0.00 | 9.50 | -60.00 | 11.66±1.50 | 6.00±0.57 | 8.83 | -48.57 |
| Mean | 10.08 | 6.61 | | | 10.14 | 6.83 | | |
| | Genotype (G) | | Treatment (T) | TxV | Genotype (G) | | Treatment (T) | TxV |
| S.Em. ± | 0.10 | | 0.18 | 0.26 | 0.28 | | 0.49 | 0.69 |
| CD at 5% | 0.31 | | 0.54 | 0.76 | 0.83 | | 1.44 | 2.04 |

**Disease infestation (rice blast, false smut)**

Rice blast disease infestation was recorded in maximum tillering and 50% flowering stages**.** As compared to control (16.34 in score +) the overall mean of all genotypes showed decreased blast disease infestation (11.27 in score +) under silicon solubilizer treatment. PA-6201 (6.46%in score +) showed highest reduction of blast infestation under silicon solubilizer treatment. The interaction between treatment and genotypes was found statistically significant in respect to almost all the genotypes. Soil application of silicon solubilizer significantly reduced the severity of rice blast disease, with respect to control. In silicon treatment the Rice blast infestation was significantly decreased from 18.57 to 41.68% as compared to control. It might be due to silicon application in rice plants induces cell wall fortification by deposition of silicon in epidermis of leaves which may act as a mechanism of resistance to blast disease. It was observed that Si-induced resistance to powdery mildew in wheat and blast in rice is attributed to enhanced production of antifungal compounds called phytoalexins (Rodrigues *et al.*, 2013) [16]. Similarly, In case of rice plant Calcium silicate application at 1000kg/ha reduced neck blast by 30.5% and brown spot by 15% over the control (Datnoff *et al*., 2003) [2].

The false smut disease infestation was recorded in 50% flowering stage. Like rice blast disease, PA-6201 (9.75%) showed maximum reduction of false smut under silicon solubilizer treatment. As compared to control (20.09) the overall mean of all genotypes showed decreased false smut infestation (11.89) under silicon solubilizer treatment. Severity of false smut disease (%) was also calculated by percent formation of black smut balls per plant. PA-6201 (8.34%) showed maximum reduction of severe false smut under silicon treatment compare to control. As compared to control (13.98) the overall mean of all genotypes showed decreased severe false smut infestation (10.30) under silicon solubilizer treatment. It might be due to when pathogenic fungi attacks on plants, silicon triggers a rapid and extensive deployment of natural defenses of the plant by increasing the protein activity. Similarly it was recorded that silicon application in soil like histidine, glutamic acid can increased resistance to false smut and blast disease (Voleti *et al.*, 2008) [19]. It was also reported that silicon protects rice plants from stalk rot, blast, false smut, fusarium wilt, and leaf spot diseases (Ma and Yamaji, 2011) [13]. In rice application of 1.5mM silicon had significantly lower the disease severity as compared with control (without silicon) (Zhang *et al.*, 2013) [22].

**Table 3:** Effect of silicon solubilizer treatment on rice blast and false smart infestation in different rice genotypes.

| Name of the rice genotypes | Rice blast/plot (%) | | | | False smut/plot (%) | | | | Severe condition false smut/plot (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Silicon solubilizer treatment | Mean | % increase | Control | Silicon solubilizer treatment | Mean | % increase | Control | Silicon Solubilizer treatment | Mean | % increase |
| PA-6129 | 16.27±0.64 | 11.66±0.33 | 13.97 | -22.22 | 20.66±2.50 | 13.84±1.69 | 17.25 | -33.01 | 14.53±0.65 | 11.33±1.45 | 12.93 | -22.03 |
| PA-6201 | 10.54±0.29 | 6.46±0.29 | 8.50 | -35.36 | 17.32±1.26 | 9.75±0.66 | 13.54 | -43.73 | 10.67±1.22 | 8.34±0.88 | 9.50 | -21.89 |
| PA-6444 | 17.53±0.28 | 13.09±0.58 | 15.31 | -22.96 | 18.52±1.50 | 12.72±1.44 | 15.62 | -31.32 | 12.69±2.00 | 10.35±0.86 | 11.52 | -18.43 |
| PHB-71 | 18.53±0.27 | 10.49±0.28 | 14.31 | -41.68 | 22.73±2.50 | 13.53±0.79 | 18.13 | -40.46 | 17.68±1.50 | 10.49±0.75 | 14.08 | -40.68 |
| US-312 | 14.73±0.37 | 11.40±0.30 | 13.06 | -18.57 | 22.00±3.00 | 11.75±1.18 | 16.87 | -46.56 | 16.29±1.12 | 12.00±1.52 | 14.14 | -26.33 |
| BPT-5204 | 20.45±0.29 | 14.55±0.29 | 17.50 | -30.69 | 19.33±2.51 | 9.79± 0.53 | 14.56 | -49.36 | 12.00±1.15 | 9.33±0.88 | 10.66 | -22.22 |
| Mean | 16.34 | 11.27 | | | 20.09 | 11.89 | | | 13.98 | 10.30 | | |
| | Genotype (G) | | Treatment (T) | TxV | Genotype (G) | | Treatment (T) | TxV | Genotype (G) | | Treatment (T) | TxV |
| S.Em. ± | 0.11 | | 0.20 | 0.29 | 0.54 | | 0.94 | 1.33 | 0.41 | | 0.72 | 1.02 |
| CD at 5% | 0.35 | | 0.60 | 0.86 | 1.60 | | 2.77 | 3.90 | 1.22 | | 2.12 | 3.00 |

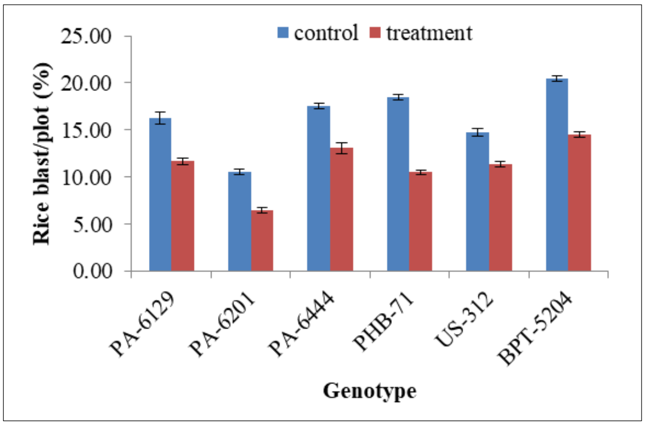


**Fig:** Silicon significantly reduced rice blast infestation in different genotypes.

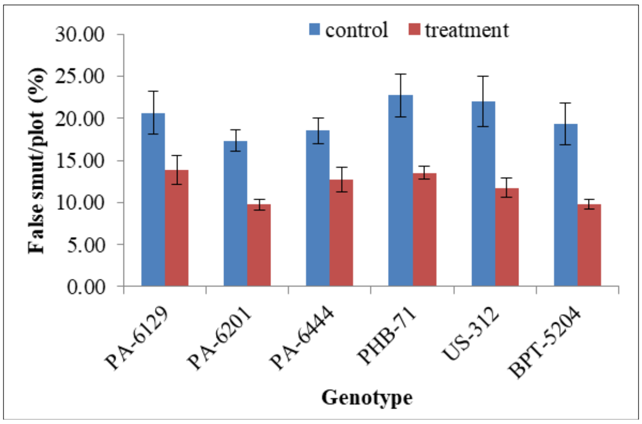


**Fig:** Silicon reduced false smut infestation in Rice genotypes.

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