

Impact of Silicon and Biofertilizer on Rice Yield and biotic stress Insect Pest Suppression

Vinita Kumari

Ph.D. Scholar

Department of Zoology

Malwanchal University Indore, (M.P.).

Dr. Ravi Shekhar

Supervisor

Department of Zoology

Malwanchal University Indore, (M.P.).

Abstract

India must increase its annual rice output by 3 million metric tons to guarantee its food and nutritional security. Efficient pest control may alleviate biotic stress, which is the only approach to enhance rice yield vertically. Biotic stresses may adversely affect agricultural productivity by causing physiological and biochemical harm to crops. The optimal method is to enhance resistance to stressors. Silicon alleviates some adverse effects when plants encounter biotic stressors such as drought, salinity, disease, and insect infestations. In minute grains, the accumulation of silicon inside cell walls and intercellular gaps contributes to disease resistance. Silicon positively influences plant development, growth, yield, and disease resistance in both trees and shrubs and dicots. The nutritional composition of sunflower is influenced by silicon treatment, which enhances the accumulation of macro and micronutrients. Consequently, in the 2023 and 2024 kharif seasons, researchers investigated the effects of several biofertilizers on rice, including both organic and inorganic silicon sources.

Keyword: *micro nutrients, pest, biotic stress, bio-fertilizers*

INTRODUCTION

Politicians and the general public must not ignore food security, one of the world's most basic needs. According to Vishnoi and Goel (2024), the adoption of inefficient farming practices has had a devastating effect on world food supply while also wreaking havoc on the ecosystem. [1]. The issue has also escalated since plant stress is becoming more common consequently of climate modification. Many believe that the lack of scientific research in farming is a big problem for global food security. About 30% of the world's farmable area is affected by droughts, which are an example of an abiotic pressure. Water stress is believed to be more detrimental to agriculture than salt stress, despite the fact that the two are similar (Zia et al., 2021). [2]. The rapid increase in heavy metal pollution in cultivated soil is a direct result of modern agricultural techniques. Because of its long half-life and toxic effects, this poses a significant risk to ecosystems (Etesami, 2018). The third. Nutritional imbalances may disrupt the normal physiological processes of plants when they are exposed to abiotic stress. Future agricultural output could be severely affected by an increase in environmental stresses caused by climate change. Environmental pressures are on the rise, and the amount of arable land available to feed a worldwide expanding population, decreasing (Etesami or Beattie, 2017; Shahzad et al., 2021). references [4,5,6].

A combination of silicon and beneficial soil bacteria may provide a lasting answer to the problem of plant stress brought on by biotic and abiotic variables, according to some earlier studies. Multitudes of silicon, the cosmos's second most abundant element, may be found in soils that include clay minerals. Plants take it up as silicic acid $[\text{Si}(\text{OH})_4]$ when the pH drops below 9 ($\text{pka} = 9.8$), and its concentration in soil solutions ranges from 0.1 to 1.4 mM

[7]. The tissues of every plant that lives in soil contain silicon. Because of synthetic fertilizers and repetitive harvesting, plants no longer have access to the same amount of silicon [8]. We often use silicon fertilizers to boost the yields of plants that acquire silicon, including sugarcane and rice, since we now know that agricultural productivity is limited by soils with low silicon levels [9].

Researchers and farmers should definitely pay greater attention to silicon. Whether silicon is deficient in agricultural soils, whether the plant in question can obtain silicon, and if silicon is better seen as a fertilizer, biostimulant, or plant protector are all points of contention [10]. Researchers and farmers are gradually coming to understand the many uses of silicon, and this underappreciated element may soon be recognized as a powerful tool for enhancing plant health and productivity. The development, yield, photosynthesis, nutrient availability balance, and ROS scavenging processes of plants have been highlighted in several studies as being positively impacted by silicon [11,12].

Many different crop types have incorporated silicon into their genetic makeup because of its positive effects on water, salt, and heavy metal stresses and because it provides disease and insect resistance [12–20]. Theoretically, Si strengthens stems via increasing lignin accumulation. For rice, strengthening the stems to avoid lodging has many benefits, including a decrease in reciprocal shadow, preservation of canopy photosynthesis, and an increase in yield [21, 22]. Ahmad and Haddad [23] discovered that the antioxidant system was enhanced when *Triticum aestivum* plants were treated. Research conducted by Song et al. [24] shown that plants exposed to high levels of zinc stress were able to recover their chloroplast order and chlorophyll content with addition of Si. Vila et al. [25] found that a silicon-nitrogen link increases the chlorophyll content of *Oryza sativa*.

Scientists have found a connection between Si and plants that are more resistant to pests and insects. The presence of amorphous Si deposits in plant tissues renders the plant more inflexible and abrasive, which insects perceive as unappetizing [26, 27]. Some species seem to be able to resist the drying and salty effects of dry habitats by upregulating their levels of proline and glycine betaine in response to Si [28, 29].

Researchers found that when borage plants were exposed to salt stress, their glycine betaine levels dropped, and when maize plants were treated to dehydration, their levels dropped even more [30,31]. The use of silicon fertilizer increases crop yields, and this agronomic practice is used in many regions. As a result, studies investigating the best methods for applying silicon fertilizer to different crops in agriculture and horticulture have recently surged. The results of many studies on the topic of silicon in plants and soils are presented on this page.

A lot of information is covered in this page, such as how plants use and absorb silicon, how much soil and plants need silicon, how to estimate how much soil and plants can ingest from silicon, and possible sources of silicon [32]. Monosilicic acid (H_4SiO_4) is the primary emphasis as we go over the chemical dynamics of the various soil-based silicon forms. Silicon is an appealing material for a variety of agricultural uses due to its unique properties. As shown in Figure 1, it has the potential to mitigate the impacts of several abiotic stressors more effectively than bulk material.

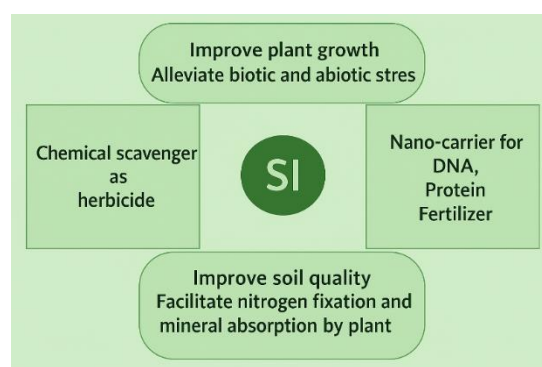


Figure 1: Silicon is shown schematically [33].**Objective of the study**

1. to study goal is to learn how various mixes of inorganic and organic silicon sources affect the rice plant's ability to ward against pests.
2. To study level of leaf folder infestation was reduced in the rice plants treated with various amounts of silicon, by way of associated to the control treatment.

MATERIALS AND METHODS

Medium-durability, sensitive 21-day-old, 15 x 20 cm²-spaced Basmati 11-21 rice seedlings were used in both study seasons. Following agronomic guidelines was typical for all cultural operations, including fertilizer rate, irrigation, and more. KSB and PSB bacteria, calcium silicate (CaSiO₃), and rice husk ash were used in this investigation. Table 1 lists each season's treatments and 10 test samples. The experimental design has one RBD and three replications. Each 4x5 m² subplot received one therapy from eleven possible combinations. Before planting, CaSiO₃, RHA, P. fluoroscens, and KSB were added to the soil to establish a foundation.

Five hills from each sub-plot were randomly selected at 30, 40, 50, 60, 70, and 80 days following transplanting to record *C. medinalis* leaf damage. The leaves and damaged ones were counted. We calculated the proportion of leaf damage caused by each treatment using this count. Each season's harvest was harvested at 80% maturity, leaving two rows of border crops on each subplot. Individual grain weights were measured on each subplot. To compare treatments, yields were converted to kg per acre.

To measure Si and other biochemical components, leaf samples were gathered from each treatment throughout the 2024 kharif season. After being wrapped in paper bags, the samples were dried in a 70°C oven for 72 hours. Drying the plant samples produced a fine powder. Powdered samples were packaged in polythene bags for lab biochemical analysis. ICP-OES measured sample silicon content. Bates et al., 1973 [34] described the proline measurement method. Bray and Thorpe [35] described the total phenol calculation method. Lowry and colleagues' method measured total protein concentration [36]. Calculating protein content involves multiplying weight by optical density and dilution factor. Analysis of variance on trial data was done using RBD after any required data adjustments [37] (Gomez and Gomez, 1984).

Data analysis

Table 1 : Rice during the 2023 rice leaf folders season of kharif was impacted by Si and biofertilizers.								
Treatment	days after transplantation						Mean	Per cent reduction over control
	30	40	50	60	70	80		
CaSiO ₃ (T1)	2.33 (1.68)	2.69 (1.77)	3.23 (1.91)	3.28 (1.94)	5.80 (2.46)	3.71 (2.04)	3.45	45.12

RHA(T2)	2.67 (1.78)	3.52 (2.00)	3.47 (1.99)	3.87 (2.08)	6.29 (2.60)	3.57 (2.01)	3.87	37.56
CaSiO ₃ + PF(T3)	2.00 (1.54)	2.67 (1.76)	2.93 (1.85)	2.42 (1.71)	5.28 (2.39)	3.21 (1.89)	3.88	50.98
CaSiO ₃ + KSB(T4)	1.53 (1.42)	2.66 (1.77)	2.88 (1.84)	2.02 (1.59)	4.93 (2.32)	3.14 (1.90)	2.05	54.66
CaSiO ₃ + PF + KSB(T5)	1.67 (1.46)	2.11 (1.60)	1.77 (1.49)	1.71 (1.48)	4.72 (2.29)	2.90 (1.84)	2.84	60.45
RHA + PF(T6)	2.27 (1.66)	3.09 (1.88)	3.07 (1.89)	3.01 (1.87)	6.07 (2.56)	3.95 (2.11)	3.88	42.90
RHA + KSB(T7)	2.64 (1.77)	3.27 (1.93)	3.26 (1.94)	3.41 (1.97)	6.35 (2.61)	3.98 (2.11)	4.66	39.07
RHA+ PF + KSB(T8)	1.70 (1.48)	2.50 (1.73)	2.93 (1.85)	2.17 (1.62)	3.13 (1.85)	2.68 (1.74)	3.53	59.81
PF(T9)	3.57 (2.01)	3.90 (2.09)	3.40 (1.96)	3.47 (1.97)	7.21 (2.77)	4.07 (2.14)	4.23	31.90
KSB(T10)	3.20 (1.92)	4.33 (2.19)	3.73 (2.05)	4.45 (2.21)	7.72 (2.86)	4.06 (2.13)	4.44	26.95
Pf+ KSB(T11)	2.73 (1.79)	4.06 (2.13)	3.53 (1.99)	3.65 (2.04)	7.97 (2.91)	4.10 (2.14)	4.55	30.78
Control(T12)	4.85 (2.31)	5.71 (2.49)	6.10 (2.57)	6.42 (2.63)	8.62 (3.02)	5.89 (2.53)	6.44	
<i>SE(m)</i> +	0.122	0.127	0.136	0.128	0.176	0.139		
<i>CD(P = 0.05)</i>	0.39	0.40	0.41	0.42	0.49	0.54		

Doze of CaSiO₃: 2 t/ha, Doze of RHA: 4 t/ha, Doze of PS: 10 kg/ha, Doze of KSB: 10 l/ha

Figures in parentheses are values

Treatment T4 had the least amount of leaf damage at 30 DAT during the 2023 kharif (1.53%), which was statistically similar to treatments T5, T8, T3, T6, and T1 (1.67 to 2.33%), according to Table 1. The control treatment had the most damage, at 4.85%. At 40 days after transplantation (DAT), T5 supported 2.11 percent leaf damage, compared to 2.50% for T8, 2.66% for T4, 2.67% for T3, 2.67% for T1, 2.69% for T6, and 3.27% for T7. In contrast, T12, the control treatment, had leaf damage of 5.71%. At 50 days after transplant (DAT), T5 had 1.77 percent leaf damage, which was statistically similar to T4 (2.88%), T8 (2.93%), and T3 (2.93%) treatments, in comparison to the control (6.10 percent). At 60 days after treatment (DAT), there was no significant difference between treatments T5, T4, T8, and T3 in terms of the 1.71 percent leaf damage induced by treatment T5. In contrast, a very high level of 6.42 percent leaf damage was seen with the control treatment, T12. At 70 days after transplantation (DAT), T8 induced

3.13 percent leaf damage, which was similar to T5 (4.72%) and T4 (4.93%); T5, on the other hand, was similar to T3, T1, T6, T2, T7, and T9 treatments (5.28 to 7.21%). T6, T2, T7, T9, T10, and T11 all showed statistically significant improvements over the control treatment, which showed 8.62% damage to the leaves. At 80 days after transplantation (DAT), T8 showed 2.68 percent leaf damage, which was similar to T5, T3, T4, T2, T1, T6, T7, and T10, which all registered 2.90%, 3.21%, 3.14%, 3.57%, and 3.71%, respectively. At 5.89 percent, the control treatment was statistically similar to T9 at 4.07% and T11 at 4.10% in terms of leaf damage.

Table 2: Effects of Si and biofertilizers on the frequency of rice leaf folders in the kharif season of 2024

Treatment	days after transplantation						Mean	Per cent reduction over control
	30	40	50	60	70	80		
CaSiO ₃ (T1)	0.71 (1.10)	4.39 (2.20)	9.80 (3.20)	10.09 (3.25)	8.27 (2.93)	3.84 (2.07)	7.11	47.88
RHA(T2)	0.87 (1.17)	6.24 (2.56)	10.28 (3.28)	10.13 (3.26)	9.09 (3.09)	4.12 (2.12)	6.23	42.54
CaSiO ₃ + PF(T3)	0.71 (1.09)	5.07 (2.36)	7.83 (2.87)	10.12 (3.25)	7.90 (2.89)	3.27 (1.92)	5.54	50.44
CaSiO ₃ + KSB(T4)	0.59 (1.04)	4.37 (2.19)	9.47 (3.14)	8.80 (3.05)	6.78 (2.69)	2.90 (1.84)	5.66	53.01
CaSiO ₃ + PF + KSB(T5)	0.56 (1.02)	4.37 (2.17)	7.13 (2.74)	8.96 (3.06)	5.99 (2.52)	2.43 (1.70)	6.76	58.23
RHA + PF(T6)	0.85 (1.14)	5.72 (2.45)	10.23 (3.27)	11.56 (3.43)	8.35 (2.97)	3.93 (2.10)	6.66	42.54
RHA + KSB(T7)	0.90 (1.18)	8.40 (2.97)	10.89 (3.37)	12.49 (3.60)	8.90 (3.06)	4.71 (2.28)	7.02	34.55
RHA+ PF + KSB(T8)	0.42 (0.96)	4.20 (2.13)	7.80 (2.86)	7.04 (2.74)	5.56 (2.43)	2.87 (1.83)	5.04	60.31
PF(T9)	1.12 (1.27)	8.32 (2.96)	10.98 (3.37)	13.10 (3.63)	9.58 (3.17)	4.97 (2.34)	8.76	32.43
KSB(T10)	2.43 (1.71)	9.60 (3.13)	11.84 (3.49)	13.36 (3.69)	9.52 (3.16)	6.26 (2.60)	8.21	25.99
Pf+ KSB(T11)	1.49 (1.40)	10.37 (3.27)	11.23 (3.42)	13.15 (3.69)	10.08 (3.24)	5.08 (2.36)	8.12	27.11

Control(T12)	3.01 (1.87)	12.28 (3.57)	14.96 (3.91)	16.06 (4.06)	14.10 (3.78)	10.47 (3.31)	12.43	
<i>SE(m)</i> +	0.089	0.176	0.175	0.235	0.167	0.115		
<i>CD(P = 0.05)</i>	0.27	0.53	0.55	0.70	0.50	0.38		

During the 2023 kharif season, the rates of leaf folders were found to be 60.45 percent, 59.81 percent, and 54.39 percent, respectively, when treated with T5T8 and T4. Based on the data from the 2024 kharif, the optimal treatment was T8 at 30 days after transplanting (0.42% damage to the leaves; see Table 2). This therapy was very similar to T5 (0.56%), T4 (0.59%), T3 (0.71%), T1 (0.71%), T6 (0.85%), T2 (0.87%), and T7 (0.90%). Statistically, the two treatments were statistically similar; both treatments demonstrated leaf damage, but the control treatment (T12) exhibited the highest percentage at 3.11%. At 40 days after treatment initiation, T8 was the most effective treatment because it supported the fewest leaves damaged (4.20%), which was less than T5 and T4 (4.37% each), T1 (4.39%), T6 (5.72%), and T2 (6.24%). The control treatment (T12) had the highest rate of leaf damage, at 12.28 percent, according to the statistical analysis. After 50 days, T5's leaf damage was 7.13 percent, which was on par with T8's 7.80 percent, T3's 7.83 percent, T4's 9.47 percent, and T1's 9.80 percent. There was no significant difference between the T12 control treatment (14.96% damage to leaves) and the T11 and T10 treatments (11.23% and 11.84% damage, respectively). At 60 days after treatment (DAT), T8 showed the greatest promise with 7.04% leaf damage; yet, it was on par with T4, T5, T1, T3, and T2 treatments. The percentage of damaged leaves varied from 11.56 (T6) to 16.06 (T12), with no discernible variation among the other treatments, including the comparison group. At 70 DAT, the data showed that all three therapies—T8, T5, and T4—were statistically equally helpful. In contrast, there was a statistically significant amount of leaf damage (14.10% in the control treatment, T12). There was an 80-day reduction in leaf folder infection regardless of therapy. Currently, the damage percentage was between 2.43% and 3.27%, and treatments T5, T8, T4, and T3 were all similarly affected. T12, the control treatment, severely damaged 10.47% of the leaves.

Table 3: Effects of applied silicon and biofertilizers on leaf folder damage incidence in rice crops grown in 2023 and 2024 (pooled)

Treatment	days after transplantation						Mean	Per cent reduction over control
	30	40	50	60	70	80		
CaSiO ₃ (T1)	1.52 (1.39)	3.54 (1.98)	6.52 (2.56)	6.69 (2.60)	7.03 (2.69)	3.77 (2.06)	5.45	45.65
RHA(T2)	1.77 (1.47)	4.88 (2.28)	6.87 (2.64)	7.00 (2.67)	7.69 (2.84)	3.84 (2.07)	6.04	54.54
CaSiO ₃ + PF(T3)	1.35 (1.31)	3.87 (2.06)	5.38 (2.36)	6.27 (2.48)	6.59 (2.64)	3.24 (1.90)	4.45	44.65
CaSiO ₃ + KSB(T4)	1.06 (1.23)	3.51 (1.98)	6.17 (2.49)	5.41 (2.32)	5.86 (2.50)	3.02 (1.87)	4.17	44.66

CaSiO ₃ + PF + KSB(T5)	1.11 (1.24)	3.24 (1.89)	4.45 (2.12)	5.34 (2.27)	5.36 (2.40)	2.67 (1.77)	3.70	59.07
RHA + PF(T6)	1.56 (1.40)	4.41 (2.17)	6.65 (2.58)	7.29 (2.65)	7.21 (2.76)	3.94 (2.10)	5.18	42.70
RHA + KSB(T7)	1.77 (1.47)	5.84 (2.45)	7.07 (2.66)	7.95 (2.78)	7.63 (2.84)	4.34 (2.20)	5.77	36.17
RHA+ PF + KSB(T8)	1.06 (1.22)	3.35 (1.93)	5.37 (2.36)	4.60 (2.18)	4.35 (2.14)	2.77 (1.79)	3.58	65.55
PF(T9)	2.34 (1.64)	6.11 (2.53)	7.19 (2.66)	8.28 (2.80)	8.40 (2.97)	4.52 (2.24)	6.14	32.08
KSB(T10)	2.82 (1.82)	6.96 (2.66)	7.79 (2.77)	8.91 (2.95)	8.62 (3.01)	5.16 (2.37)	6.71	30.66
Pf+ KSB(T11)	2.11 (1.60)	7.21 (2.70)	7.38 (2.70)	8.40 (2.86)	9.03 (3.07)	4.59 (2.25)	6.45	45.05
Control(T12)	3.93 (2.09)	8.99 (3.03)	10.53 (3.24)	11.24 (3.34)	11.36 (3.40)	8.18 (2.92)	9.04	
SE(m) +	0.096	0.121	0.113	0.131	0.134	0.135		
CD(P = 0.05)	0.25	0.37	0.35	0.39	0.37	0.42		

Table 4 displays the figures for grain production in kharif, 2023, and 2024, with a mean for 2023, based on the application of Si and biofertilizer. In 2023 kharif, the highest grain yield (4640.67 kg/ha) was achieved by the T5 treatment, which was statistically similar to the T6 (3778 kg/ha), T7 (3880 kg/ha), T3 (3968.67 kg/ha), T1 (4183.67 kg/ha), T8 (4241.33 kg/ha), and T4 (4371.33 kg/ha) treatments. This information is shown in Table 4. Concurrently, the control treatment achieved the lowest grain yield of 2875 kg/ha. Compared to the T10 and T9 treatments, as well as T2, T11, and T6, this yield was almost the same (3080.67 kg/ha and 3778 kg/ha, respectively). Treatments T5, T4, and T8 all led to yield increases of 61.41%, 52.05%, and 47.52%, respectively, compared to the control. Treatment T5 was on par with treatments T3, 4, and 8, with a maximum grain yield of 4311 kg/ha in the 2024 kharif, compared to 3680 kg/ha, 3835 kg/ha, and 4105.33 kg/ha, respectively. At 2389 kg/ha, the control treatment had the lowest grain production. Treatments T5, T8, and T4 all resulted in yield increases of 80.45% compared to the control, 71.84%, and 60.53%, respectively.

The greatest grain yield (4475 kg/ha) was achieved by treatment T5, which was similar to T4 (4103.17 kg/ha) and T8 (4173.33 kg/ha), as calculated for the kharifs of 2023 and 2024 by pooling the results. According to the combined results, the T5 treatment resulted in a 70.5% increase in yield, the T8 treatment a 58.56% increase, and the T4 treatment a 559.0% increase.

Researchers in Karnataka discovered that the optimal rate of calcium silicate application for rice was 4 t/ha [40]. They emphasised that silicon consumption increased grain output due to its anti-illness effects and increased rates of photosynthesis, plant uprightness, efficient utilisation of solar radiation, and other nutrient intakes. Mishra and

his Odisha colleague found that after applying 2 t/ha of CaSiO₃ to rice, grain output rose to 33.64 q/ha, compared to 24.24 t/ha in the control group that was not treated [41].

Hence, our finding that silicon absorption boosted grain yield is well supported by the work of the aforementioned authors. Another synergistic explanation for higher grain production was a reduction in biotic stress, which was brought about by greater silica absorption.

Table 4: Biochemical characteristics of rice affected by silicon and biofertilizer use(Grain yield (kg/ha))

Treatment	Kharif, 2023	% increase over control	Kharif, 2024	% increase over control	Pooled (kharif, 2023 or 2024)	% increase over control
CaSiO ₃ (T1)	4183.67	45.52	2916.67	22.09	3550.17	33.88
RHA(T2)	3510.00	22.09	3962.33	24.00	3236.17	22.95
CaSiO ₃ + PF(T3)	3968.67	38.04	3680.00	54.04	3824.33	45.30
CaSiO ₃ + KSB(T4)	4371.33	52.05	3835.00	60.53	4103.17	55.90
CaSiO ₃ + PF + KSB(T5)	4640.67	61.41	4311.00	80.45	4475.83	70.05
RHA + PF(T6)	3778.00	31.41	3075.00	28.71	3426.50	30.19
RHA + KSB(T7)	3880.00	34.96	2839.67	18.86	3359.83	27.65
RHA+ PF + KSB(T8)	4241.33	47.52	4105.33	71.84	4173.33	58.56
PF(T9)	3275.33	13.92	2700.00	13.02	2987.67	13.51
KSB(T10)	3080.67	07.15	2630.33	10.10	2855.50	08.49
Pf+ KSB(T11)	3667.00	27.55	2750.00	15.11	3208.50	21.90
Control(T12)	2875.00	-	2389.54	-	2632.00	-
SE(m) +	294.987		256.345		189.254	
CD(P = 0.05)	798.63		815.76		693.43	

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Hence, our finding that silicon absorption boosted grain yield is well supported by the work of the aforementioned authors. Another synergistic explanation for higher grain production was a reduction in biotic stress, which was brought about by greater silica absorption.

Table 5: Biochemical characteristics of rice affected by silicon and biofertilizer use

Treatments	Silicon (%)	Increase over control (%)	Proline ($\mu\text{g/g}$)	Reduction over control (%)	phenol (mg/g)	Increase over control (%)	Total Protein (mg/)	Decrease over control (%)
CaSiO_3 (T1)	5.19	47.86	8.20	21.38	0.29	46.67	6.80	32.00
RHA(T2)	4.83	37.60	8.60	17.55	0.28	41.67	7.95	20.50
CaSiO_3 + PF(T3)	5.25	49.57	7.17	31.26	0.31	55.00	6.74	32.60
CaSiO_3 + KSB(T4)	6.96	98.29	6.93	33.56	0.32	60.00	6.53	34.70
CaSiO_3 + PF + KSB(T5)	7.71	119.65	6.77	35.09	0.34	70.00	6.50	35.00

RHA + PF(T6)	6.42	82.90	8.00	23.30	0.31	55.00	8.30	17.00
RHA + KSB(T7)	6.11	74.07	7.83	24.93	0.30	50.00	7.33	26.70
RHA+ PF + KSB(T8)	6.63	88.88	6.83	34.52	0.33	65.00	6.67	33.30
PF(T9)	4.04	15.09	8.33	20.13	0.26	30.00	8.40	16.00
KSB(T10)	4.15	18.23	8.50	18.50	0.22	10.00	8.23	17.70
Pf+ KSB(T11)	4.10	16.80	8.67	16.87	0.24	20.00	8.10	19.00
Control(T12)	3.51	-	10.43		0.20		10.00	
SE(m) +	0.345		0.123		0.132		0.212	
CD(P = 0.05)	0.86		0.44		0.65		0.36	

Analysis of the Si content of leaf samples collected at 60 DAT is shown in Table 5. Results showed that, statistically speaking, treatments T4 (6.96%) and T5 (7.71%) had the highest silicon concentrations. Next best in terms of silicon concentration was treatment T8, which had 6.63%. Despite being the control treatment with the lowest Si content, it was just as effective as T9, T11, and T10. Therefore, it was shown that when biofertilizers were used, the rice plants had more availability to Si from inorganic sources compared to organic ones. The data in the table demonstrate that, relative to the other treatments, the control treatment had a considerably higher proline level (10.43 µg/g) than the other eleven treatments that were considered. The least accumulation (6.77 µg/g) was seen in the T5 treatment (CaSiO₃ + PF + KSB), which was similar to T8 (6.83 µg/g) and T3 (6.93 µg/g). All three of these treatments were effective in reducing the insect infestation because they increased the concentration of silica and lowered the quantity of proline. According to Table 5, the highest total phenol content was found in the T5 (CaSiO₃ + PF + KSB) treatment (0.34 mg g⁻¹ fresh wt. basis), which was similar to the phenol content in the T8, T4, T6, T3, T7, and T1 treatments (0.33 to 0.29 mg/g fresh wt.). Furthermore, compared to the control treatment plants, all plants treated with silicon had a higher phenol content. T5 therapy resulted in a 70% increase in phenol content, T8 treatment in a 65% increase, and T4 treatment in a 60% increase, relative to the control value.

There was a statistically significant difference between the treatments, with the control group having the highest concentration of total soluble protein (10.00 mg/g). No significant variation was seen between the T5, T4, T8, T3, and T1 treatments (6.50 to 6.80 mg g⁻¹). Of the five treatments, T5 produced the lowest amount of soluble protein. Treatments with a greater silicon content also had lower quantities of soluble protein, as seen in Table 5. The protein concentration decreased by 35.00 percent, 34.70%, and 33.30% in the T5, T4, and T8 treatments, respectively.

In comparison to the control group, which experienced more biotic stress due to insect infestation, almost all of the experimental groups' proline concentrations were lower. Nonetheless, stress was reduced in every other treatment due to silicon absorption by the rice. Treatments T5, T8, and T4 achieved the lowest proline concentrations. The low proline content was believed to be a defensive characteristic of the plant produced by silicon, since proline works as an antioxidant. Panda looked into a related discovery and found that stem borer-infested plants accumulated less proline as a consequence of increased silicon collection [42].

Table 5 shows that there was a high concentration of phenol in rice leaf samples treated with various concentrations of silicon, particularly in the T5, T8, and T4 treatments. Plants increase their production of salicylic acid and phenol in response to increased silicon absorption. While phenols do not influence resistance in and of themselves, the oxidation of phenols produces quinone. The inability of rice leaf insects to digest and absorb proteins is a direct result of quinones, which are toxic, antifeedant, and conjugate with proteins.

Among the several treatments that were done, the ones with the greatest amounts of phenol were T5 (CaSiO₃ + PF + KSB) and T4 (CaSiO₃ + KSB). An increase in phenolic content may have caused the reduction in infestation level, given the minimal biotic stress in these treatments.

Researchers found that by coating rice with silica gel, phenolic compounds were increased, which boosted the plant's defences against biotic stress [43]. According to Rani and Jyothsna [44], there was a notable rise in the phenol content of rice that had been infested with brown plant hopper, yellow stem borer, and leaf folder. We also discovered a strong and positive association between the silicon and phenolic levels in rice plants that were treated with silicon (Table 5). The results we obtained agree with the reports made by those journalists.

All treatments, with the exception of control, exhibited reduced total soluble protein levels, as shown in Table 5. The protein levels in treatments T5, T4, and T8 were, for example, as low as 35%. Although reduced protein levels do not prevent phagocytosis, they do allow for an increase in phagodeterrent concentrations. Addition of protein stimulates phagocytosis. Therefore, it was believed that low protein levels were a defensive mechanism, and silicon absorption reduced the protein percentage.

Researchers discovered that palisade grass with CaSiO₃ applied to it had lower crude protein levels and less accumulation of that protein [45]. Research found that when silicon was given to rice plants infected with leaf folders, the amounts of soluble protein were low [46]. Thus, it was clear that silicon might have had a role in the reduction in leaf protein content, which could have led to feeding stress in the test insect.

Discussion

The study looked at the potential synergistic effects of silicon and certain biofertilizers on the ability of rice plants to withstand insect pests, a major threat in paddy fields. This pest often attacks rice plants, leading to significant decreases in harvest yields. The backbone of conventional pest control is the use of chemical pesticides, which are harmful to both humans and the environment. Thus, it is essential for integrated pest management to research environmentally favourable and biologically friendly methods.

More and more people are starting to notice that silicon (Si) may be used to make plant structural defences stronger. The addition of silicon to rice leaves enhanced the levels of phenolic chemicals, according to this study. Phenolic chemicals, which are secondary metabolites, are shown to increase plant resistance by strengthening cell walls, producing lignin, and starting processes associated with insect deterrence. This biochemical enhancement not only stops pests from eating on the rice plants, but it also makes them less tasty and harder for insects to digest, which is an anti-nutritional component.

In addition, silicon was associated with a reduction in soluble protein content in rice tissues. Insects can't mature or grow without soluble proteins. When this protein is scarce, the insect's ability to absorb nutrients is impaired, leading to delayed maturation and decreased chances of survival. This finding agrees with other studies that suggest silicon could alter the nutrient content of host plants to deter herbivorous insects.

The increased silicon deposition in rice leaves was further confirmed by the increased formation of silica cells. The presence of these silica cells makes the leaf tissues more resistant to herbivory because they function as physical

barriers. Insect pests can't feed efficiently on harder tissues, and the abrasive roughness caused by silica deposits makes things worse.

Soil health and plant nutrient absorption were both improved by bio-fertilizers, which amplified the benefits of silicon. These beneficial bacteria may cause plants to build a systemic resistance, which would make them more resistant to pests. The complementary nature of silicon and biofertilizers demonstrates a long-term solution to pest management by reducing the need for chemical pesticides without compromising crop quality or output.

Conclusion

Findings suggest that a combination of silicon and biofertilizers might be an effective strategy to reduce damage caused by insect pests. Silicon not only strengthens the biochemical and physical defences of rice plants, but it also stops pests from eating and developing on the plants. Biofertilizers boost nutrition absorption and encourage induced resistance mechanisms simultaneously. By using this combined strategy, chemical pesticides may be replaced with something less harmful to the environment, which would be great for sustainable agricultural practices.

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