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OPTIMIZING NUTRIENT STRATEGIES FOR RICE BLAST DISEASE CONTROL AND PADDY YIELD ENHANCEMENT

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ABSTRACT

Rice blast disease, caused by *Pyricularia oryzae*, is one of the most destructive and devastating fungal diseases affecting rice crops. Traditionally, the disease is managed through host resistance and the application of fungicides; however, the latter approach is environmentally toxic and not always feasible. The objective of the present study was to evaluate the effectiveness of various nutrients, both individually and in combination, for disease control. Greenhouse experiments were conducted over two consecutive years, 2019 and 2020, to assess three nutrients and their combinations against rice blast disease. The nutrient combinations of potash (20g/L) and silicon (1g/L) resulted in disease incidence reductions of 79.38% and 78.76%, respectively, compared to the application of Nativo, which achieved slightly higher reductions of 82.38% and 80.76%. Among the zinc treatments and its combinations, zinc (2g/L) and silicon (1g/L) showed disease reductions of 72.39% and 73.4% in 2021 and 202, respectively. In 2019, the combination treatment of potash (20g/L) and silicon (1g/L) yielded the highest plant height (120.03 cm), number of tillers (23.01), panicle length (28.93 cm), and number of grains per panicle (128.19). In 2020, the same treatment resulted in the highest plant height (122.61 cm), number of tillers (17.23), panicle length (28.31 cm), and number of grains per panicle (122.61). The overall results of this study suggest that the application of alternative disease management strategies not only reduces the use of chemicals but also lowers the risk of residual effects on paddy grains, thereby enhancing the export potential of paddy.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the main food crops, providing 23% of the daily energy intake for six billion people (Pandey, 2010). It is an essential staple crop in Asia, offering 20% of the world's nutritional value, surpassing corn and wheat (Muthayya et al., 2014). Among the twenty-four species of rice, *Oryza sativa* L. and *Oryza glaberrima* L. are the most widely cultivated worldwide. Developing countries highly depend on rice due to its adaptability to various climates and its high nutritional value (Aureus, 2011). With the increasing global population, the demand for rice production continues to rise (Gumma et al., 2011). Basmati varieties, such as Super Basmati, Basmati-2000, Shaheen Basmati, PS-2, Bas-385, Basmati-515, Kissan Basmati, Punjab Basmati, and Chenab Basmati, are renowned for their taste and aroma. Punjab accounts for 68% of Pakistan's total rice production, followed by Sindh at 23%, Baluchistan at 6%, and Khyber Pakhtunkhwa at 3%

(Akhtar et al., 2016; Bashir et al., 2007).

Rice blast disease, also known as "rice fever" in China (Wang, 2009), is caused by the pathogen *Pyricularia oryzae*. It is a significant threat to global food security, responsible for approximately 30% yield reduction. *Pyricularia oryzae* is the asexual stage, while *Magnaporthe oryzae* is the sexual stage, with the fungus predominantly existing in its asexual form (Wang, 2009). Symptoms appear as white to gray/brown spots on leaves, leading to necrosis, rupture, and darkening of the panicles. The pathogen can infect all above-ground parts of the plant (Couch and Kohn, 2002), with the neck and individual panicles being particularly vulnerable, resulting in color changes from brown to black and significant yield reductions. Neck blast infection is the most devastating, causing severe per-acre yield loss compared to leaf and node blast infections (Ribot et al., 2008).

Rice blast disease is exacerbated by continuous rains and average temperatures of 18-25°C during the panicle initiation stage, followed by hot, sunny, and humid conditions (Kohli et al., 2011). In South and Southeast Asia, the disease causes annual losses of about US$55 billion. Yield losses range from 41% to 72% in the Philippines and Nigeria (Sukanya et al., 2011), with a reported 50% reduction in Pakistan (Ashfaq et al., 2017). Different combinations of botanicals and microorganisms have been shown to reduce disease incidence and severity (Bag et al., 2010). The application of PGPR (Plant Growth-Promoting Rhizobacteria) is an effective strategy for disease management (Shah, 2009). Silicon sources, such as calcium metasilicate and slag, have also been effective against rice blast disease and have positively impacted yield (Correa-Victoria et al., 2001).

Plant disease management through plant extracts is environmentally safe (Iftikhar et al., 2010). Various combinations of botanicals and microorganisms reduce disease incidence and severity (Bag et al., 2010). Salicylic acid (SA) plays a crucial role in plant growth and enhances resistance (Hayat et al., 2007). Silicon is a beneficial element and nutrient for plants, helping them resist biotic and abiotic stresses (Massey and Hartley, 2006). Managing diseases with nutrients is safer and more economical compared to chemicals, which can pollute the environment and leave residual effects on paddy grains, reducing export and foreign exchange earnings (Phong et al., 2009). Therefore, replacing chemicals with nutrients, plant activators, and alternative strategies for plant disease control is necessary.

Managing diseases with nutrients not only reduces disease incidence but also positively impacts yield. Nutrient management for rice blast disease enhances agronomic traits such as the number of tillers per plant, 1000-grain weight, number of grains per panicle, and overall paddy yield. The objective of this study was to evaluate the impact of nutrients on rice blast disease and yield-associated traits. We hypothesized that nutrients, either individually or in combination, would minimize disease incidence and improve yield traits. The results are discussed in the context of using nutrients as alternatives to hazardous fungicides to enhance rice production.

MATERIALS AND METHODS

Sowing of Rice Nursery

The experiment was conducted in the greenhouse of the University of Agriculture Faisalabad, Pakistan (31.4278° N, 73.0758° E), over two cropping years from 2019 to 2020. The rice variety PS-2 was sown in plastic trays and, after twenty-five days of germination, transplanted into pots containing clay loam soil. The greenhouse was located in the Department of Plant Pathology at UAF. Recommended cultural practices were followed throughout the experiment.

A total of thirty-seven treatments were applied, each with three replications, using a randomized complete block design. Urea and DAP fertilizers were applied to the pots to promote optimal paddy growth. Manual weed removal was carried out, and granular insecticides were applied to combat stem borer pests.

Collection of Disease Samples

Two disease samples from each treatment were collected based on typical symptoms at the tillering and panicle initiation stages. Leaf samples (4-5 leaves) were placed in separate labeled brown envelopes and transported to the laboratory for pathogen isolation. Infected leaf samples were kept in an icebox to maintain viability during transportation to the laboratory for further processing.

Isolation of *Pyricularia oryzae*

Infected leaves were first washed with tap water and cut into 2 mm pieces, each containing both infected and healthy tissue. These pieces were surface sterilized with 0.1% sodium hypochlorite solution for two minutes and then rinsed with water. The sterilized pieces were placed on Petri plates containing 20 ml of potato dextrose agar (PDA) medium and incubated at 28±1°C. The plates were regularly observed and examined for any fungal growth or contamination over a period of 14 days.

After 4-5 days, slides were prepared from pure fungal colonies and mycelia, and the shape of the spores was observed under a microscope (Labomed, USA).

Preparation of Inoculum and Inoculation

A mycelial disc from a 10-14 days old fungal culture was placed on Petri plates containing potato dextrose agar (PDA) medium. After 14 days, the inoculum was harvested from the cultured plates, blended in 200 ml of water, and filtered through a muslin cloth. The inoculum's concentration was determined using a hemocytometer, and the spore suspension was adjusted to a concentration of 1 × 10^5 spores per ml with 1% Tween-20.

Plants were inoculated 45 days after transplanting. They were covered with polyethylene bags and incubated at 26°C for 48 hours. After two days, the bags were removed, and the plants were sprinkled with water to maintain humidity. Typical blast symptoms, including minute water-soaked brown specks that enlarge and become elliptical, diamond-shaped, or eye-shaped with grayish centers, were monitored. Infected leaves were collected for further inoculum preparation. The pathogen inoculum was prepared by scraping mycelia from the Petri plate surface with a brush. All plants were then sprayed with the spore suspension (1×10^5 conidia/ml).

Application of Different Nutrients with Combinations

Three nutrients, namely Sodium Silicate (Silicon), Potassium Chloride (Potash), and Zinc Sulfate (Zinc), were evaluated both individually and in combination at three different concentrations against rice blast disease (Table 2). The treatments included silicon concentrations of 1, 2, and 3 g/L, potash concentrations of 20, 30, and 40 g/L, and zinc concentrations of 2, 4, and 6 g/L, along with all possible combinations of these nutrients.

The treatments were applied to pots arranged in a randomized complete block design with three replications, following inoculation. The atomizer was rinsed with 95% ethanol and then sprayed with distilled water, according to the procedure outlined by Hans et al. (2003). Each treatment was applied in two sprays, one 15 days after inoculation (DAI) and the other 30 DAI, along with control treatments.

Disease incidence and severity percentages were recorded 60 and 90 days after transplanting, using the standard disease rating scale developed by the International Rice Research Institute (SES, IRRI, 2002) (Table 2). Agronomic and yield-related characteristics, including plant height (cm), number of tillers, panicle length (cm), number of grains per panicle, thousand-grain weight (g), and plant yield, were recorded 100 days after transplanting.

Disease severity was determined by using following formula;

$$\text{Disease severity \%} = \frac{\text{Number of diseased leaves}}{\text{Total number of leaves inspected}} \times 100$$

Table 1. Disease rating scale for Rice blast disease severity.

Rating Scale	% area infected of rice plant	Plant reaction
0	Lesions 0%	Highly Resistant
1	Lesions 0-1%	Resistant
3	Lesions1-5%	Moderately Resistant
5	Lesions6-25%	Moderately Susceptible
7	Lesions26-50%	Susceptible
9	Lesions51-100%	Highly Susceptible

Following formula was used for percentage increase yield (PIY);

$$\text{PIY} = \frac{\text{treated plant yield kg/acre} - \text{control plant yield kg/acre}}{\text{Control plant yield kg/acre}} \times 100$$

Following formula was used for the calculation of increase 1000 grain weight percentage;

$$\frac{\text{1000 grain weight (g) of treated plants} - \text{1000grain weight (g) of control plants}}{1000 - \text{grain weight (g) of control plant}} \times 100$$

Statistical Analysis

A Completely Randomized Design (CRD) was used for the greenhouse experiments, and data were analyzed using the computer software Statistix 8.1. Treatment means were compared using the Least Significant Difference (LSD) test, as described by Steel et al. (1997).

RESULTS

Isolation and Description of *Pyricularia oryzae*

The blast-infected leaf samples were placed on PDA plates and characterized based on symptoms, colony morphology, and spore characteristics (Figure 1). The infected leaf samples exhibited typical rice blast disease symptoms, including diamond-shaped lesions with a grayish center and brown margins (Figure 1a). On PDA, the infected leaf samples developed grey to white hyaline mycelium emerging from the leaf margins (Figure 1b). The colony morphology on PDA plates was smooth with a fluffy surface, and some colonies had aerial mycelium. Colony color varied from dark grey to light grey, with some colonies showing translucent grey or brown hues. All plates displayed fungal growth with a circular form and entire margins.

The pathogen's spores were pear-shaped with a narrowed apex, broad base, and were hyaline in color (Figure 1c). Both conidia with and without conidiophores were observed. The sample isolate was preliminarily identified based on spore morphology (Figure 1d). The observed spore characteristics matched those described in previous studies of *Pyricularia oryzae* (Hussin et al., 2020; TeBeest et al., 2007).

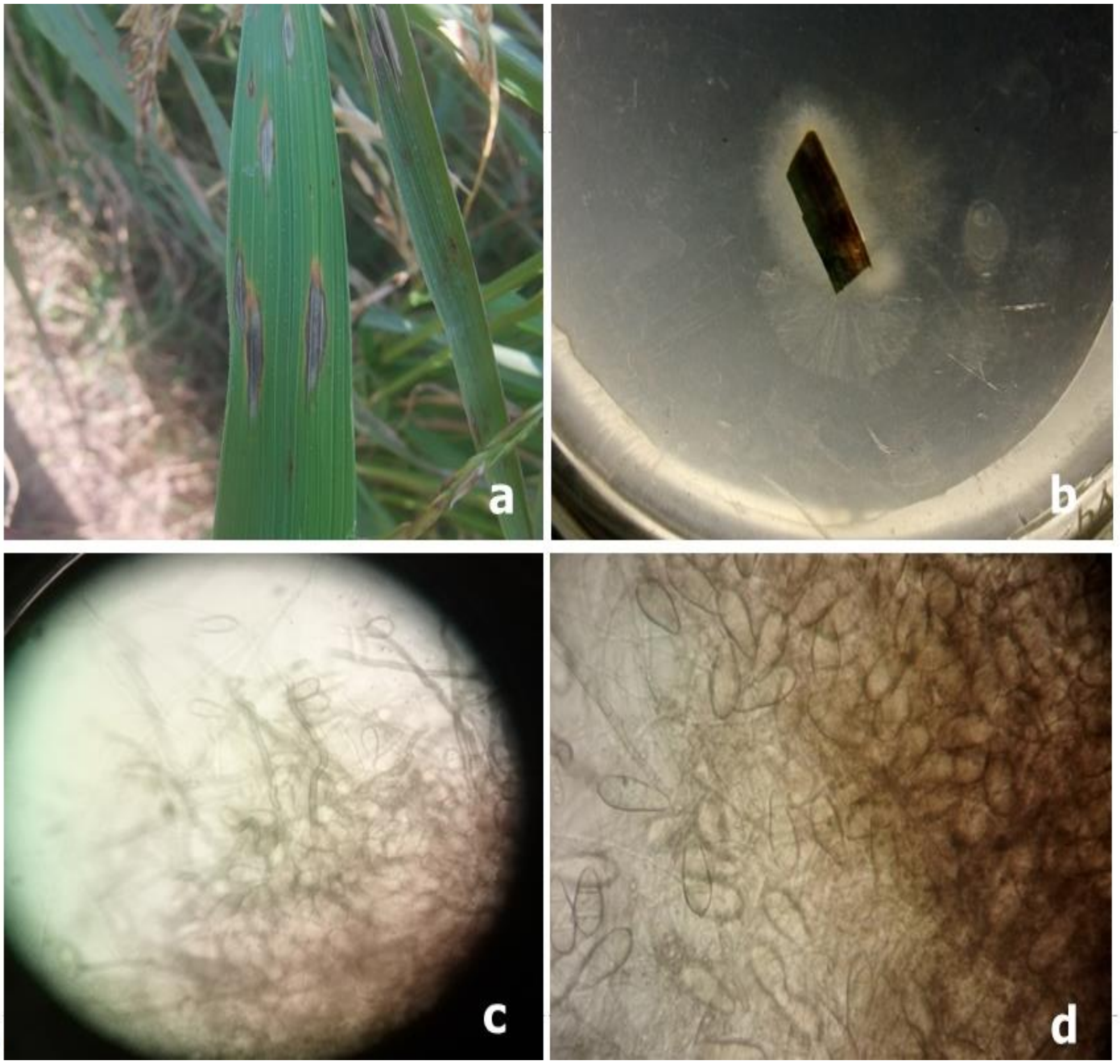

Figure 1. Symptoms, colony, and spore morphology of *Pyricularia oryzae*. (a) Rice leaf exhibiting diamond-shaped lesions with gray-white centers and brown to red-brown margins. (b) Five-day-old culture of *P. oryzae* on potato dextrose agar. (c) Slide of conidia and conidiophores of *P. oryzae* under a 20x microscope, prepared from a seven-day-old culture. (d) Conidia of *P. oryzae* showing three septa under a 40x lens of a compound microscope.

Effect of Different Nutrients on Rice Blast Disease Incidence

The experiment was conducted over two consecutive years, 2019 to 2020, in a greenhouse to evaluate the efficacy of three nutrients—Potash, Silicon, and Zinc—at three different concentrations, along with their various combinations, against rice blast disease. The results indicated a significant difference between treatments in terms of disease impact (Table 2). All treatments significantly reduced disease incidence compared to the control. In 2019, the Nativo treatment achieved the highest reduction in rice blast disease incidence at 82.38%. This was followed by the combination of potash at 20 g/L and silicon at 1 g/L, which reduced disease incidence by 79.38%, and silicon alone at 1 g/L, which achieved a 78.63% reduction. The combination of potash at 20 g/L and silicon at 1 g/L was the most effective in reducing the incidence of rice blast disease.

Table 2. Efficacy of three nutrients and its different combination against the incidence of rice blast disease.

Treatment	Name of Treatment	% Reduction of disease		Treatment	Name of Treatment	% Reduction of disease	
		2019	2020			2019	2020
T1	K 20g	75.68bc	74.50b	T 20	K30g+Zn 4g	67.37jk	69.24gh
T2	K 30g	72.64cd	70.99de	T 21	K30g+Zn 6g	69.53ef	71.09de
T3	K 40g	69.36fg	68.71ij	T 22	K40g+Si1g	68.14ij	67.59op
T 4	Si 1g	78.63ab	77.69ab	T 23	K40g+Si 2g	68.17i	68.99hi
T 5	Si 2g	72.28de	72.12cd	T 24	K40g+Si 3g	68.97gh	70.70de
T 6	Si 3g	73.56bc	71.47cd	T 25	K40g+Zn2g	70.12ef	71.07de
T 7	Zn 2g	69.53efg	68.07mn	T 26	K40g+Zn 4g	66.74k	68.27lm
T 8	Zn 4g	68.50hij	69.08hi	T 27	K40g+Zn 6g	69.62e	69.15hi
T 9	Zn 6g	66.18lm	66.77p	T 28	Si1g+Zn2g	72.39de	73.4bc
T 10	K 20g+Si 1g	79.38b	78.76b	T 29	Si1g+Zn 4g	72.31d	69.9fg
T 11	K 20g+Si 2g	76.06b	70.93de	T 30	Si1g+Zn 6g	70.76de	69.6gh
T 12	K 20g+Si 3g	70.63e	69.94fg	T 31	Si2g+Zn 2g	70.10ef	68.60jk
T 13	K20g+Zn 2g	70.23ef	72.56bc	T 32	Si2g+Zn4g	68.32ij	67.77no
T 14	K20g+Zn 4g	66.69kl	68.30lm	T 33	Si2g+Zn6g	71.45d	70.47d
T 15	K20g+Zn 6g	69.45fg	70.60de	T 34	Si3g+Zn 2g	69.66ef	68.43kl
T 16	K30g+Si 1g	68.86gh	70.08ef	T 35	Si 3g+Zn 4g	70.19e	70.78de
T 17	K30g+Si 2g	68.92g	71.95cd	T 36	Si 3g+Zn 6g	71.82d	72.32bc
T 18	K30g+Si 3g	67.86ij	69.41gh	T 37	Nativo	82.38a	80.76a
T 19	K30g+Zn2g	68.74gh	70.66de	SEM	1.5643	2.2470	
				LSD0.05	3.1183	2.2470	

Means followed by same letter are not significantly different ($p < 0.05$).

In 2020, the results indicated that the Nativo treatment achieved the greatest reduction in rice blast disease, with an 80.76% reduction compared to all other treatments. The second most effective treatment was silicon at 1 g/L, which reduced disease incidence by 80.69%. The third best treatment was potash at 20 g/L, which resulted in a 74.50% reduction in disease incidence, compared to 62.84% in the control.

Overall, the combination of potash at 20 g/L and silicon at 1 g/L showed the most significant reduction in rice blast disease incidence across all treatments. The results from both years demonstrated that the combination of potash at 20 g/L and silicon at 1 g/L was the most effective treatment for reducing rice blast disease and increasing paddy yield.

Effect of Nutrients on Agronomic Traits of Rice

The results demonstrated variable effects of nutrients and their combinations on rice agronomic traits (Table 3). The combination of potash at 20 g/L and silicon at 1 g/L resulted in the highest plant height of 120.03 cm, compared to 116 cm with the chemical treatment. This combination also recorded the maximum number of tillers, with 23.08 compared to only 12.02 in the control. The highest panicle length of 28.93 cm was observed with potash at 20 g/L and silicon at 1 g/L, compared to 26.10 cm in the control.

Table 3. Effect of nutrients and their combination on rice agronomic traits.

Treatment	Name of treatment	Plant height (cm)		No. of tillers/plant		Panicle length(cm)		No. of grains/panicle	
		2019	2020	2019	2020	2019	2020	2019	2020
T1	K 20g	118.55d	118.18c	17.40de	17.58bc	28.03bc	27.63cd	115.73cd	116.31cd
T2	K 30g	118.52de	118.14cd	16.06ef	18.06bc	27.82bc	27.98abc	117.15c	117.82bc
T3	K 40g	118.94cd	118.09cde	17.42de	17.13bc	27.93bc	27.87ab	116.28cd	115.96cd
T 4	Si 1g	119.32bc	119.14ab	21.78ab	20.69a	28.43ab	28.29a	122.87b	120.86ab
T 5	Si 2g	118.77cd	117.98cd	17.40de	18.50b	27.86bc	28.18ab	118.50c	117.51bc
T 6	Si 3g	117.75gh	118.39bc	16.50ef	17.52bc	27.92bc	28.06ab	116.34cd	115.74cd
T 7	Zn 2g	117.96fg	117.89cd	15.93e	18.04b	27.61cd	27.63 de	115.59cd	115c
T 8	Zn 4g	118.06fg	117.96cd	14.51hi	17.89bc	27.95bc	28.05ab	115.09de	114.67cd
T 9	Zn 6g	117.67ij	117.97cd	16.13ef	17.50bcd	27.89bc	27.91ab	115.15de	115.05cd
T 10	K 20g+Si 1g	120.75a	119.83a	23.08a	21.24a	28.93a	28.31a	128.19a	122.61a
T 11	K 20g+Si 2g	119.52bc	118c	19.26c	17.233bc	27.70cd	27.92ab	117.68cd	115.58cd
T 12	K 20g+Si 3g	117.84gh	118.06cd	16.19ef	16.60cd	27.37ef	27.29de	115.37cde	115.44cd
T 13	K20g+Zn 2g	117.66ij	117.72ef	16.31ef	16.130ef	26.97ij	26.75gh	114.65de	114.66cd
T 14	K20g+Zn 4g	117.70hi	117.65de	15.16gh	16.45de	27.48dej	27.19ef	116.34cd	115.44cde
T 15	K20g+Zn 6g	117.48ij	117.31e	15.69efgh	16.157ef	26.95ij	26.90gh	115.83cd	115.8cd
T 16	K30g+Si 1g	117.74gh	117.01hi	15.57efgh	16.153ef	27.34ef	27.01fg	114.91de	114.29cd
T 17	K30g+Si 2g	119.32bc	118.19cd	20.22bc	18.48b	28.21bc	28.22bc	121.97b	117.96bc
T 18	K30g+Si 3g	118.09fg	117.35ef	15.44efgh	16.50de	27.55de	26.68gh	114.31ef	116.30cd
T 19	K30g+Zn2g	117.50ij	117.28gh	14.73ghi	15.93fg	27.06hi	26.79gh	115.74cd	114.67cd
T 20	K30g+Zn 4g	117.31j	116.96hi	15.08ghi	16.16ef	27.38ef	27fgh	115.70cd	114.83cd
T 21	K30g+Zn 6g	118.17ef	116.78kl	15.12gh	14.39i	27hi	25.767k	114.48de	111.27ef
T 22	K40g+Si1g	118.07fg	116.93ij	11.83j	12.44j	25.72n	26.05jk	110.80i	110.80f
T 23	K40g+Si 2g	117.94g	116.98hi	15.37ef	15.61hi	27.11gh	26.69gh	114.15ef	114.84c
T 24	K40g+Si 3g	117.88gh	117.22gh	16.18ef	16.48de	27.22fg	26.73g	115.49cd	114.00cd
T 25	K40g+Zn2g	118.04fgh	117.10hi	16.64ef	16.63cd	27.14gh	27.20ef	115.59cd	113.86cd
T 26	K40g+Zn 4g	118.09fghi	116.91j	15.33fg	15.75gh	27.04hi	26.91gh	114.20ef	114.23cd
T 27	K40g+Zn 6g	117.72hi	116.97hi	14.48hi	16.43de	27.20fgh	26.71ghi	116.26c	114.26cd
T 28	Si1g+Zn2g	117.71hi	117.70cde	15.89ef	17.23bc	27.05hi	27.66bcde	116.25cd	115.50c
T 29	Si1g+Zn 4g	117.89ghj	117.32ef	15.29gh	15.88fg	27.12gh	27.01fgh	114.19ef	114.31cd
T 30	Si1g+Zn 6g	118.04fg	116.88j	15.53ef	15.95fg	26.92jk	26.92gh	114.68de	114.19d
T 31	Si2g+Zn 2g	117.76gh	117.23gh	15.86ef	16.38de	27.16gh	27.17ef	115.16cd	114.42c
T 32	Si2g+Zn4g	118.28ef	116.76kl	15.25gh	15.95fg	26.93ij	27.18e	115.74cd	113.15de
T 33	Si2g+Zn6g	118.15ef	117.49de	15.44ef	17.36bc	27.49de	27.19ef	115.62cd	114.18cd
T 34	Si3g+Zn 2g	117.67ij	116.61l	15.38ef	15.74gh	27.46de	26.92g	113.77fg	108.91gh
T 35	Si 3g+Zn 4g	118.29efi	116.93ij	16.22ef	16.47de	26.74kl	26.87gh	112.58gh	110.99fg
T 36	Si 3g+Zn 6g	118.24ef	116.63lm	16.29ef	16.08ef	26.50lm	26.52hi	112.33hi	108.83h
T 37	Nativo	116k	115.91m	12.02ij	12.45j	26.01mn	26.10ij	95.40j	95.89i
	SEM	0.4146	0.3915	1.0366	0.7687	0.3153	0.3195	1.6750	2.1427
	LSD0.05	0.8265	0.7805	2.0664	1.5323	0.6285	0.6370	3.3390	4.2713

Means followed by same letter are not significantly different ($p < 0.05$).

Additionally, the combination achieved the maximum number of grains per panicle, with 128.19, compared to 95.40 in the control. The second-best treatment was silicon at 1 g/L, which recorded a plant height of 120.03 cm, similar to the combination of potash and silicon, and higher than the 116 cm observed with Nativo fungicide. The number of tillers was also highest in the potash at 20 g/L and silicon at 1 g/L treatment, with 23.08

compared to 12.02 in the control.

These results suggest that the combination of potash at 20 g/L and silicon at 1 g/L is the most effective nutrient application for enhancing paddy yield characteristics.

The second-highest panicle length of 28.43 cm was recorded with silicon at 1 g/L, compared to 26.02 cm with the chemical treatment. The combination of potash at 20 g/L and silicon at 1 g/L demonstrated a more positive effect on the agronomic traits of rice compared to all other treatments.

In 2020, the combination of potash at 20 g/L and silicon at 1 g/L resulted in the highest plant height of 119.83 cm, followed by silicon at 1 g/L with 119.14 cm and potash at 30 g/L and silicon at 2 g/L with 118.19 cm. The maximum number of tillers (21.24) was recorded with the combination of potash at 20 g/L and silicon at 1 g/L, followed by silicon at 1 g/L with 20.69 and potash at 30 g/L and silicon at 2 g/L with 18.48. The highest panicle length (28.31 cm) was achieved with potash at 20 g/L, followed by silicon at 1 g/L with 28.29 cm and potash at 30 g/L and silicon at 2 g/L with 27.63 cm. The greatest number of grains per panicle (122.61) was observed with the combination of potash at 20 g/L and silicon at 1 g/L, followed by silicon at 1 g/L with 120.86 and potash at 30 g/L and silicon at 2 g/L with 117.96. Fungicide treatments resulted in the lowest plant height (115.91 cm), minimum number of tillers (12.45), panicle length (26.10 cm), and grains per panicle (95.89).

In 2019, the combination of potash at 20 g/L and silicon at 1 g/L achieved the highest 1000-grain weight of 19.93 g, compared to 14.81 g with the chemical nativo. This combination demonstrated a 34.57% increase in 1000-grain weight, followed by silicon at 1 g/L with 19.18 g and potash at 30 g/L and silicon at 2 g/L with 19.10 g. These results indicate that the combination of potash at 20 g/L and silicon at 1 g/L was particularly effective in improving yield-enhancing traits.

In 2020, the combination of potash at 20 g/L and silicon at 1 g/L also recorded the highest 1000-grain weight of 19.58 g, with a 32.43% increase. Silicon at 1 g/L was the second-best treatment with a 1000-grain weight of 18.93 g, compared to 14.81 g with the chemical application. Potash at 30 g/L and silicon at 2 g/L recorded 18.79 g for 1000-grain weight. In 2019, the highest yield (1959.4 kg/acre) was observed with the combination of potash at 20 g/L and silicon at 1 g/L, compared to 1607.2 kg/acre with the control. The highest yield increase (21.89%) was achieved with this combination, followed by silicon at 1 g/L with 1898 kg/acre. Potash at 30 g/L and silicon at 2 g/L showed a yield of 1875.6 kg/acre compared to 1607.2 kg/acre with nativo.

In 2020, the combination of potash at 20 g/L and silicon at 1 g/L again yielded the highest amount at 1902.8 kg/acre, compared to 1613.2 kg/acre with the chemical nativo. This combination recorded the highest yield increase (17.96%), followed by silicon at 1 g/L with a yield of 16.66%. The third-best treatment was potash at 30 g/L and silicon at 2 g/L with a yield of 1871.6 kg/acre. These results highlight that nutrient applications are effective in managing rice blast disease, reducing the reliance on harmful pesticides, and mitigating residual effects on paddy, thus supporting export quality.

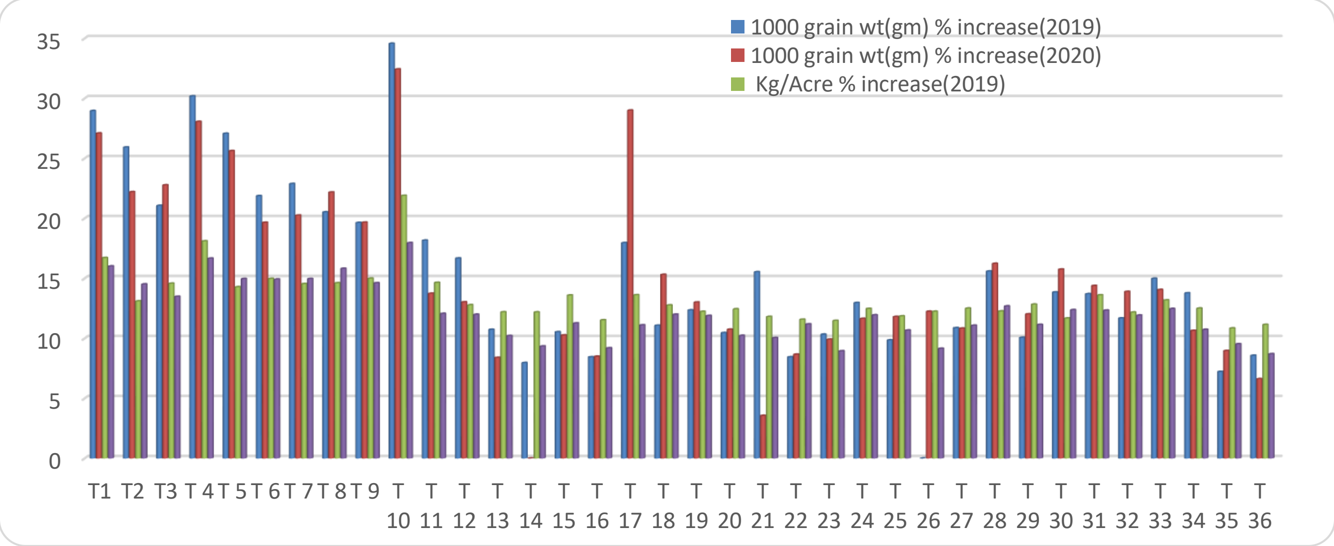

Figure 2. Effects of different treatments of nutrients on yield enhancing characters.

The impact of various treatments on yield-enhancing traits was evaluated, yielding variable results (Figure 2). The combination of potash at 20 g/L and silicon at 1 g/L consistently demonstrated the highest increases in both 1000-grain weight and paddy yield per acre in 2019 and 2020. In 2019, this combination resulted in a 34.57% increase in 1000-grain weight. Similarly, in 2020, the increase was 32.43%, outperforming all other treatments. Other treatments showed comparatively lower percentages of increase in 1000-grain weight and paddy yield per acre.

In 2019, the highest plant height (120.03 cm) was recorded with the potash at 20 g/L and silicon at 1 g/L combination, compared to the control. In 2020, the same combination achieved the highest plant height (119.32 cm), surpassing the chemical treatment which recorded 115.91 cm. The combination also led to the maximum number of tillers (21.24), the greatest panicle length (28.31 cm), and the highest number of grains per panicle (122.61) compared to the chemical treatment, which recorded 12.45 tillers, 26.10 cm panicle length, and 95.89 grains per panicle.

In the greenhouse experiments of 2019, the combination of potash at 20 g/L and silicon at 1 g/L achieved the highest 1000-grain weight of 19.93 g, compared to 14.81 g with the chemical treatment. In 2020, the same combination resulted in a 1000-grain weight of 19.58 g, compared to 14.82 g with the control.

These results underscore the effectiveness of the potash and silicon combination in enhancing key agronomic traits and improving rice yield.

DISCUSSION

Rice blast disease is a highly destructive affliction that leads to substantial yield losses and is prevalent in all major rice-growing regions, including Pakistan. The disease's impact on wheat in Bangladesh has further heightened its importance. Traditionally, management strategies have relied on developing resistant varieties and applying fungicides where resistant varieties are not available. This study introduces a nutrient-based approach to managing rice blast disease, which not only offers an alternative to fungicides but also enhances paddy yield. Utilizing eco-friendly nutrient applications is a viable strategy as chemicals can adversely affect ecosystems, lead to pathogen resistance, and leave residual effects on crops, impacting export quality.

Our findings indicate that the combination of potash (20 g/L) and silicon (1 g/L) was the most effective treatment for managing rice blast disease. This aligns with previous studies, such as Jones et al. (1991), who reported effective disease control with similar treatments. Korndorfer and Lepsch (2001) found that potassium silicate was effective against rice blast, and Correa Victoria et al. (2001) noted a 15% disease reduction with various silicon sources. Our study observed up to 78.67% and 77.69% disease reduction with silicon at 1 g/L across both years. Paudel et al. (2019) also highlighted silicon's role in inducing plant resistance against rice blast. Zinc treatments, particularly the combination of zinc (2 g/L) and silicon (1 g/L), showed disease reductions of 72.39% and 73.4% in 2019 and 2020, respectively, supporting Waqas et al. (2023), who reported up to 73% reduction in conidia formation with foliar zinc applications. Prabhu *et al*. (2001) and Alvarez and Datnoff (2001) found that silicon accumulation in shoots correlated with reduced disease incidence, reinforcing our results.

Nativo fungicide, while showing maximum disease reduction (82.38% in 2020 and 80.76% in 2019), may have residual effects that impact crop export quality. Our findings suggest that nutrient applications are a eco-friendlier and more cost-effective alternative.

Regarding yield-enhancing traits, the combination of potash (20 g/L) and silicon (1 g/L) consistently recorded the highest plant height, number of tillers, panicle length, and grains per panicle in both years. Zinc (2 g/L) combined with silicon (1 g/L) also showed significant improvements, supporting the findings of Waqas *et al*. (2023) and Shukri *et al*. (2020), which noted zinc's benefits for yield. Potash (20 g/L) and silicon (1 g/L) led to the highest 1000-grain weight in both years, corroborating results from Maekawa *et al*. (2001) and Seebold *et al*. (2000), who observed improvements in growth and yield with silicon applications. The application of these nutrients not only reduces rice blast disease but also boosts plant growth and per-acre yield.

In 2019, a combination of potash 20g/L and silicon 1g/L has attained the highest 1000 grain weight (19.93g) compared with chemical 14.81g and also highest 1000 grain weight % increase 34.57g. Similarly results recorded in 2020 highest 1000 grain weight 19.58g and 32.43% increases 1000 grain weight compared with chemical Nativo findings supporting by Korndorfer and Lepsch (2001) noted 10% increase yield by the application of silicon.

In 2019, a combination of potash 20g/L and silicon 1g/L has achieved the highest yield (1959.4 kg/acre) compared with chemical 1607.2 kg/acre and also highest yield increase 21.89%.. Similarly in 2020 highest yield 1902.8 Kg/acre and 17.96% increase yield recorded in the in the same treatments supporting the findings of Seebold et al. (2000). These findings indicated that application of nutrients also enhances the 1000 grain weight and per acre yield.

Nutrient applications, particularly the combination of potash (20 g/L) and silicon (1 g/L), offer a promising alternative for managing rice blast disease. This approach is cost-effective, reduces dependency on harmful pesticides, and enhances both plant growth and yield, making it a viable option for sustainable rice production.

CONCLUSION

The findings of our study conclude that applying nutrients—either singly or in combination—offers a feasible, cost-effective, and environmentally friendly approach for managing rice blast disease and enhancing paddy yield. While fungicide applications have demonstrated relatively better results in disease control, they also pose residual effects that can hinder rice exports. In contrast, potash, silicon, and zinc are essential nutrients with antimicrobial properties that improve plant vigor and induce a resistance cascade against diseases.

Given the importance of rice as an export commodity, nutrient applications present a viable strategy for disease management. This approach not only benefits rice crops but can also be adapted for managing diseases in other important crops. Overall, our findings advance the understanding of disease management and contribute to improved rice yields, thereby supporting the enhancement of the country's rice export.

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