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NITROGEN, POTASSIUM, AND SILICON FERTILIZATION TO ACHIEVE LOWER PANICLE BLAST SEVERITY AND IMPROVE YIELD COMPONENTS OF RICE USING RESPONSE SURFACE METHODOLOGY

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Graphical abstract

Abstract

Rice blast is one of the most critical limiting factors for rice plant growth performance, and it occurs in 85 countries, causing 10-35% grain yield losses. Several findings have indicated the positive benefits of nitrogen (N), potassium (K), and Silicon (Si) fertilization on plant development, yield, and biotic stress relief. However, due to rice blast attacks, its growth, development, and yield may be restricted or limited by insufficient or unbalanced N, K, and Si fertilizers. This study was conducted to optimize the fertilization strategies for rice panicle blast control and improve rice grain yield. The methods used were Central Composite Design and Response Surface Methodology. The application of N, K and Si did not influence the number of spikelets per meter square, filled grain (%) and 1000- grain weight (g). An increase in K and Si significantly reduced the rice blast severity in the off-season 2021 and the main-season 2021/2022. On the other hand, only Si had influenced rice grain yield production. An increase in Si showed a positive linear trend in rice grain yield. Based on these results, panicle blast disease is expected to be controlled with the recommended rate of 104 N kg/ha, 42 P_2O_5, 80 kg K_2O, and an additional 200 Si kg/ha, which minimizes the rice blast severity (%) but at the same time maximizes the rice grain yield. The findings of this study provide a scientific base and technical advice for high-yield rice grain-growing under panicle blast disease hot spot areas.

Keywords: Central composite design, response surface methodology, rice yield, rice blast, optimal nutrients

Abstrak

Penyakit karah padi yang berlaku di 85 buah negara adalah salah satu faktor penghalang utama untuk prestasi pertumbuhan tanaman padi dan ianya menyebabkan kehilangan hasil padi antara 10-35%. Beberapa penemuan telah menunjukkan kesan positif pembajaan nitrogen (N), kalium (K), dan Silikon (Si) terhadap perkembangan tumbuhan, hasil, dan mengatasi tekanan biotik. Walau bagaimanapun, disebabkan oleh serangan penyakit karah padi, pertumbuhan, perkembangan, dan hasil padi mungkin disekat atau dihadkan oleh baja N, K, dan Si yang tidak mencukupi atau tidak seimbang. Kajian ini dijalankan untuk mengoptimumkan strategi pembajaan bagi kawalan penyakit karah tangkai padi dan meningkatkan hasil padi. Kaedah yang digunakan ialah Reka Bentuk Komposit Tengah dan Metodologi Permukaan Tindak Balas. Penggunaan N, K dan Si tidak mempengaruhi bilangan spikelet per meter persegi, bernas (%) dan berat 1000 biji (g). Peningkatan dalam K dan Si telah mengurangkan keterukan penyakit karah tangkai dengan ketara pada musim luar 2021 dan musim utama 2021/2022. Sebaliknya, hanya Si telah mempengaruhi penghasilan padi. Peningkatan dalam Si menunjukkan aliran linear positif dalam hasil padi. Berdasarkan keputusan ini, penyakit karah tangkai pada tanaman padi dapat dikawal dengan kadar 104 N kg/ha, 42 P_2O_5, 80 kg K_2O, dan tambahan 200 Si kg/ha, yang meminimumkan keterukan karah tangkai (%) tetapi pada masa yang sama memaksimumkan hasil padi. Penemuan kajian ini menyediakan asas saintifik dan nasihat teknikal untuk pengsyoran pembajaan penanaman.

Kata kunci: Reka bentuk komposit tengah, metodologi permukaan tindak balas, hasil padi, karah tangkai, nutrien optimum

1.0 INTRODUCTION

Rice is the highest-prioritized commodity on Malaysia's national food security plan and the most given priority on the national food security agenda. The Malaysian government spent RM2.3 billion on support and incentives, including input and price subsidies, in Malaysia's 2018 Budget Report [1]. Rice productivity has been difficult to rise despite these efforts, and the country has consistently produced 65% to 70% of its domestic needs for many years [2]. Malaysia's self-sufficiency level (SSL) could decrease gradually to 55.6% in 2025 [3]. The assumption was based on the current scenario with total fertilizer subsidy remaining the same (Urea, compound, and NPK fertilizer) because of no improvement in yield and no increment in fertilizer used. Moreover, the total consumption shows an increasing trend due to population growth at 2% per year. New fertilizer technologies affect rice production, and grain yields highly depend on appropriate fertilization [4]. In rice production, fertilizer management is a significant factor, and inadequate fertilizer application reduces crop yield, causes nutrient depletion, and depletes soil fertility [5]. Most nutrient inputs required to maintain current crop yields are commercial fertilizers, and commercial fertilizer nutrient inputs account for at least 30 to 50 percent of crop production [6]. In addition, proper and effective utilization of nutrients supplied by commercial fertilizers is critical for producing the nutritious food supply required to meet the demands of a growing and more wealthy global population. More precise fertilization recommendations based on soil, climate, and terrain are good strategies to lower the limiting rice yield gap [7]. Rice crop N fertilizer requirements should be determined by variety and climatic conditions to maximize rice yield while minimizing chemical fertilizer use [8].

Nutrients are essential for plant growth and development where nitrogen (N), phosphorus (P), and potassium (K) are the most critical nutrients for plants that are the primary macronutrients [9]. Nitrogen is an essential nutrient for plants since it is required for photosynthesis, growth and development, rice yield, quality, and biomass. N is a protein component and a key component of chlorophyll in photosynthesis, and it is found in a variety of plant organs [10]. P is applied to agricultural systems in large quantities and plays a role in complex molecular and physiological responses [11]. One of the essential components of nucleic acids, cell membranes, and enzymes is indispensable for diverse cellular processes like photosynthesis/carbohydrate metabolism, energy production, redox homeostasis, and signalling [12]. K is an activator of dozens of essential enzymes, such as protein synthesis, sugar transport, N and C metabolism, and photosynthesis, ensuring optimal plant growth [13]. N was the first limiting nutrient for rice growth and yield performance, followed by K and P [14, 15, 16]. The direct effect of N fertilization on rice grain yield by increasing the number of panicles, increasing stomatal conductance, photosynthesis, and transpiration rate.

Regardless of how vital N, P, and K are in rice growth and yield development, under the specific scenario, fertilizer treatments favoured pests [17] and disease attacks [9]. Despite increases in the expression of various defensive genes, nitrogen fertilization increases susceptibility. Increasing several metabolites (e.g., glutamine) could cause this improved defence, either directly or indirectly [18]. On well-fertilized plants, the intrinsic rate of natural increase was higher than on under-fertilized plants, and the brown planthopper (BPH) had a higher survival rate and matured quicker. Nitrogen had the most significant impact on BPH fitness attributes of all the fertilizer inputs [17]. Application of nitrogen above the recommended rate increased leaf blast disease incidence and total lesion area per plant. Leaf blasts were significantly more severe when N fertilizer was applied as a single application [19]. Deficiency and excessive use of N increased rice blast and bacterial leaf blight, thus controlling these diseases, required nutrient balance between N and K [20]. High N increases rice plant hopper (*Sogatella furcifera*) infestation behavior (feeding and oviposition), extends adult lifespan, and shortens generation reproduction time (nymph, pre-oviposition, and egg period), in rice plants [21]. The leaf K content and the K-N balance are critical for making the plant resistant to insect pests and disease attacks. K nutrition is critical for rice pest control (stem borer, leaf folder, whorl maggot, and *Leptocorisa oratorius*) and disease control (blast and brown spot) [22]. A study conducted on K fertilizer showed that the application of K reduced the rate of stem borer infestation and increased rice yield [23]. Adequate K provided a mechanism that did not favor the pest due to the presence of mono-potassium phosphate in rice plants [23]. Additionally, K nutrition improved culm and stalk strength. Yield advantage due to increased tillering capacity of the rice plant and spikelet production.

Crop disease management has become more challenging for producers with overwhelming demand to minimize synthetic chemical inputs, such as pesticides, fungicides, and herbicides used for crop protection [24]. Developing plants resistant to the most harmful pests and diseases are becoming more crucial [24]. However, crop plant disease resistance has been short-lived in many situations. New diseases, new races, and more aggressive pathotypes may emerge due to more extensive cropping. These changes require chemical control methods to avoid economic devastation since genetic resistance, biological control, and cultural strategies have proven insufficient. Despite that, the widespread use of the chemical has created its own set of problems, including chemical resistance [25]. Chemical methods have not adequately controlled the pest and diseases, and commercially resistant varieties are generally scarce. Current varieties are susceptible to these diseases, thus reducing their potential due to disease attacks. Cultural practices such as optimum fertilization of N and K could induce disease tolerance in plants [20].

Silicon (Si) has been shown to control several diseases. Si creates a physical barrier that can restrict fungal hyphae penetration [26], effectively enhancing plant resistance against fungal and bacterial pathogens by activating defense-related enzymes and activating the expression of defense-related genes [27]. Si amendments can provide more excellent resistance to pests in rice; plant damage by stem borers, leaf folders, and planthopper population size was dramatically reduced by Si fertilization [28]. Si treatment, in particular, has been shown to improve insect pest and disease resistance significantly in plants, resulting in increased production [29].

Blast disease (*Pyricularia oryzae* Carava [teleomorph: *Magnaporthe grisea* (Herbert) Barr]) is considered a significant rice disease in rice cultivation. Rice blast is a widely distributed rice disease found in any rice field. Rice blast disease occurs in 85 countries, causing 10-35% grain yield losses [30]. In Malaysia, blast outbreaks are sporadic and difficult to predict; thus, blast control in the field is difficult. Grain yield losses causing as much as 50-70% once being infected by rice blast in Malaysia are common [31, 32], and 50-70% in the Philippines have been reported [33, 34]. In Indonesia, about 12% of the total rice cultivation area was infected by rice blasts [35]. The most effective and economical approach for controlling blast disease in rice is resistant cultivars. Nonetheless, such cultivars have limited success due to the breakdown of resistance genes with increasing new pathotypes overcoming rice resistance. In addition to cultivar-specific resistance breeding, chemical control is the most widely used effective plant disease management method. Although they effectively control the fungal infections in rice, public concerns about the use of synthetic fungicides are growing.

Several findings have indicated the positive benefits of N, K, and Si fertilization on plant development, yield, and biotic stress relief. However, we know very little about the combined effects of these three nutrients (N, K, and Si) elements on rice panicle blasts in Malaysian rice cultivation. This study aimed to assess the efficacy of individual and combined N, K, and Si treatments on agronomic parameters and rice panicle blast.

2.0 METHODOLOGY

2.1 Experimental Materials and Design

MARDI Siraj 297 was used in this study. The seed was sown in seedling trays, preceded by seed treatment through soaking (24 hours) and pre-germination (one day before sowing). After the seed treatment, pre-germinated seeds were broadcasted in the nursery. The 18 days of old seedlings were transplanted (3 seedlings/hill) at a 30 cm x 18 cm distance between hills and rows. The seedlings that were of the same height were selected for uniformity purposes.

The experiment was arranged in a randomized complete block design replicated three times. Fields trials were conducted using N (Urea 46 %), K (MOP 60 %), and Si (25 %) at five levels (Table 1). A three-factor orthogonal quadratic rotation combination design was used to apply the N, K, and Si treatments (Table 2). A standard of 42 kg P_2O5 was applied for all treatments. The experiment was repeated for two seasons.

Table 1 Coding design table each N, K and Si factor level

Level	N (kg/ha)	K (kg/ha)	Si (kg/ha)
Code mark	X_1	X_2	X_3
Star on the arms (+1.68)	149.56	86.12	234
Upper level (+1)	138	80	200
Zero level (0)	121	71	150
Lower level (-1)	104	62	100
Under the arms (-1.68)	92.44	55.88	66
Change interval	28.56	15.12	84

Table 2 Quadratic orthogonal rotation combination design

Treatment	N(kg/ha)	K (kg/ha)	Si (kg/ha)
1	104	62	200
2	121	71	150
3	138	62	200
4	104	80	100
5	138	62	100
6	121	71	150
7	121	71	150
8	121	71	150
9	138	80	200
10	121	71	150
11	92.4	71	150
12	121	71	150
13	104	80	200
14	121	71	150
15	121	71	234
16	149.6	71	150
17	121	71	150
18	121	86.1	150
19	121	71	150
20	121	55.9	150
21	138	80	100
22	121	71	150
23	121	71	150
24	121	71	66
25	104	62	100

Field trials were performed in the off-season 2021 and main-season 2021/2022 at the Rice Research Centre, MARDI, Pulau Pinang, Malaysia. The 0-20 cm soil layer contains 22% clay, 30% silt, and 48% sand, and characteristically, the soil was loam. The soil pH was 4.6, a CEC of 13.6 meq/100g, a Total N of 0.22%, 29 ppm Available P, 0.70 meq/100g Exchangeable K 0.70, and 71 mg/kg Available Si. The plot size was 4 m x 4 m. Two weeks after transplant, 5 cm water depth was maintained in all plots for the crop season until 2-3 weeks before harvest. All crop management followed the guidelines of *Manual Teknologi Penanaman Padi Lestari* [36] except no chemical fungicides were applied during the experiments.

2.2 Measurement of Rice Grain Yield and Yield Components

Panicles were hand-threshed, and filled spikelets were separated from unfilled spikelets. The total number of filled and empty spikelets was added to determine the total number of spikelets per square meter. The percentage of filled spikelets was calculated based on the total number of filled grains and unfilled grains per panicle as per the given formula below. The % filled grains were counted manually from eight panicles from the main tiller of eight hills. The mean of ten randomly selected panicles was used to determine the percentage of filled grains.

% filled grain = (filled grains/total number of grains) x 100

The 1000-grain weight was determined from filled spikelets which were dried to 14% moisture content and weighed on a precision balance (ME3002, Mettler Toledo). Grain moisture content was measured with a digital moisture tester meter (Model SS-7, Satake). The 1000-grain weight was expressed in gram (g). The grain yield and straw yield were calculated based on the weight of 3 m x 3 m of each plot. The grain yield was converted per hectare (kg/ha). The final grain yield and straw yield followed the calculation as below

Grain yield=((PlotGy x [(100-MC)/86])/1000)x 10000/A

The PlotGy is grain yield per plot adjusted to 14% moisture, MC is grain moisture content, and A is harvested area.

2.3 Blast Disease Inoculation and Disease Assessment

The dominant pathotypes of *P. oryzae* were used for inoculation in this study, obtained from Pathology Lab, Rice Research Centre, MARDI Seberang Perai, Pulau Pinang. Mycelia of the *P. oryzae* were grown on oat meal agar (OMA) and the inoculum preparation was done as described by Hayashi *et al.* [37]. A total of 20 ml of distilled water was poured into a Petri dish, while the surface of sporulated plates was gently scraped with a paintbrush. The conidial suspension was filtered through a cheesecloth. Later, a conidial suspension of *P. oryzae* was counted to 1 x 10^5 conidial/ml using a hemocytometer. Inoculation was done during fully completed panicle development (65 DAT). Disease assessment was done based on panicle blast disease incidence by calculating the number of panicles with lesions covering completely around the node, neck or lower part of the panicle axis (% of infected panicles) according to the Standard Evaluation System of Rice [38].

2.4 Data Analysis

Design expert software (StatEase V.13) was used for statistical analysis.

3.0 RESULTS AND DISCUSSION

3.1 Effects of N, K, and Si on Rice Panicle Blast Severity

The analysis of variance of the experimental data suggested a linear model for panicle blast severity and the ANOVA analysis is presented in Table 3.

Table 3 ANOVA table for response surface model for rice panicle blast severity

Source	df	Mean Square	F-value	p-value
Model	4	212.87	7.404	0.0001
A-Season	1	242.88	8.447	0.0057
B-Nitrogen	1	55.59	1.933	0.1712
C-Potassium	1	264.83	9.2114	0.0040
D-Silicon	1	288.19	10.023	0.0028
Residual	45	28.75		
Lack of Fit	25	35.15	1.695	0.1159
Pure Error	20	20.74		
Cor Total	49			

There were significant effects of seasons, K and Si, on panicle blast severity. Higher panicle blast severity (29 %) in off-season 2021 than in the main-season 2021/2022 (25 %) (Figure 1) could be due to lower temperature, higher humidity, and rainfall [39] that contribute to the increase in rice blast development which favours in the off-season.

K increased significantly reduced the rice panicle blast severity (Figure 2). In particular, K deficiency in plants has been associated with lower cell-membrane resistance, increasing the risks of pathogenic attacks [40]. K provides strength to plant cell walls and is involved in the lignification of sclerenchyma tissues [41]. Thus, applying K has improved rice blast resistance in rice plants by strengthening rice panicles' cell walls to prevent the fungus from penetrate the plant tissue. However, in the plants' root and stem wheat, the elements of Si and K were antagonistic, and an increase in Si content in root and stem hindered the K content of both plant parts, except in reproductive parts shows a synergism effect [42]. Thus, the application of Si (Figure 3) and K positively impacted rice panicles in contributing to lower panicle blast disease. The mechanisms by plants to control diseases are believed by the act of Si that is mainly deposited in the epidermal cells forming silicified cells and a cuticle–Si double-layer structure, which can enhance the mechanical strength and stability of the host plant cell wall, thereby delaying and resisting the invasion and expansion of pathogens [43].

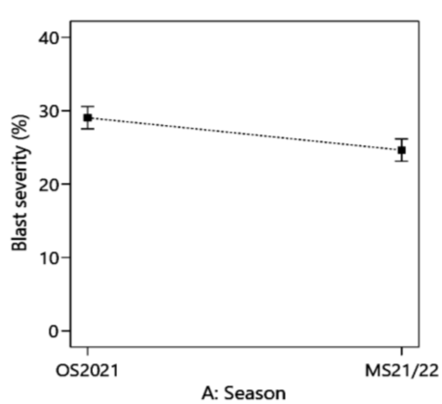

Figure 1 Blast severity affected by seasons

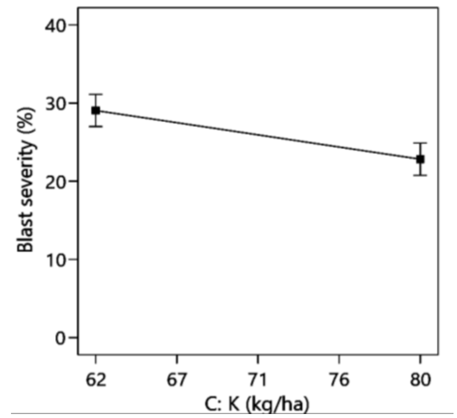

Figure 2 Blast severity affected by K application

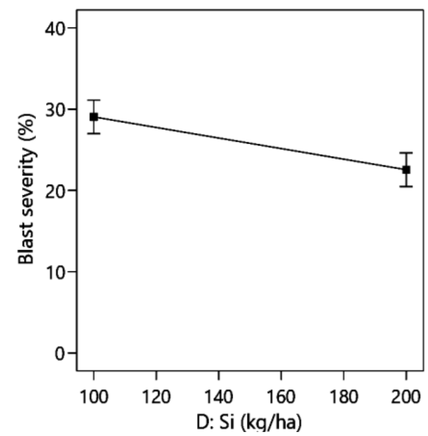

Figure 3 Blast severity affected by Si application

According to the significance level in Table 3, K and Si showed a negative linear with rice blast severity; the response surface is shown in Figure 4 (off-season 2021) and Figure 5 (main-season 2021/2022). The general trend for average two-season rice cultivation is that with the lowest N (104 kg/ha) and the highest K (80 kg/ha) and Si (200 kg/ha), the blast severity was 14.1 %.

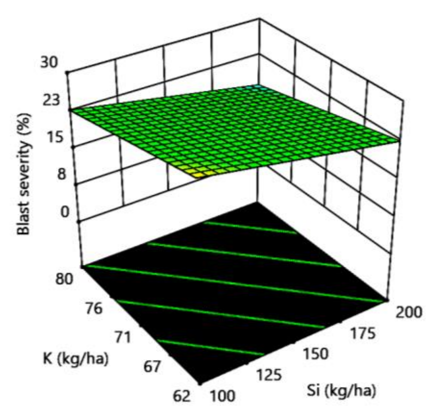

Figure 4 Effect of N, K and Si on rice panicle blast severity (off-season 2021)

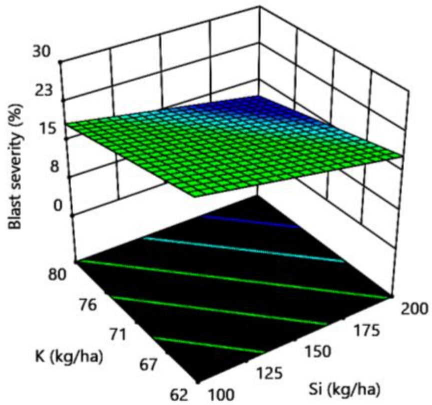

Figure 5 Effect of N, K and Si on rice panicle blast severity (main-season 2021/2022)

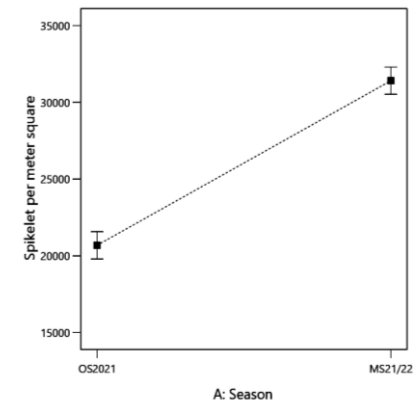

Figure 6 Spikelets per meter square affected by seasons

3.2 Effects of N, K, and Si on Spikelet Per Meter Square

The analysis of variance of the experimental data suggested a linear model for spikelet per meter square and the ANOVA analysis is presented in Table 4.

Table 4 ANOVA table for response surface model for spikelet per meter square

Source	df	Mean Square	F-value	p-value
Model	4	367400000	37.74	< 0.0001
A-Season	1	1437000000	147.62	< 0.0001
B-Nitrogen	1	14650000	1.51	0.2263
C-Potassium	1	17240000	1.77	0.19
D-Silicon	1	775900	0.0797	0.779
Residual	45	9735000		
Lack of Fit	25	9075000	0.8593	0.6444
Pure Error	20	10560000		
Cor Total	49			

Spikelet per meter square is the spikelet per panicle multiple with the number of rice panicles in a meter square. Application of N, K, and Si did not influence the number of spikelets per meter square. Spikelet number is affected by temperatures rather than nutrients application [44, 45, 46] . On the other hand, rice panicles depend on rice tillering capability, and rice tillers are affected by the phosphorous (P) application [41]. In this study, equal P fertilizer was applied for all treatments. Thus, it could be the reason insignificant for N, K, and Si on the number of spikelets per meter square (Figure 6). However, lower rice blast severity in the main-season 2021/2022 (31,408) could be the reason for the more significant spikelets number per meter square than in off-season 2021 (20,686).

3.3 Effects of N, K, and Si on Filled Grain (%)

The analysis of variance of the experimental data suggested a linear model for filled grain and the ANOVA analysis is presented in Table 5.

Table 5 ANOVA table for response surface model for filled grain

Source	df	Mean Square	F-value	p-value
Model	4	249.42	56.10	< 0.0001
A-Season	1	988.15	222.25	< 0.0001
B-Nitrogen	1	3.51	0.7884	0.3793
C-Potassium	1	0.1511	0.0340	0.8546
D-Silicon	1	5.89	1.33	0.2557
Residual	45	4.45		
Lack of Fit	25	3.96	0.7826	0.7220
Pure Error	20	5.06		
Cor Total	49			

Grain filling is the final stage in rice growth that determines the rice grain's final weight, and these factors are essential to grain yield. Lower hormones concentrations in the grains leading to a lower division rate of endosperm cells, fewer endosperm cells, and a slower grain filling rate contribute to poor grain filling [47]. In this study, N, K, and Si did not enhance the filled grain, and this could be because the rice blast disease could change or blockage hormones mechanism in rice grain for maximum grain filling. However, lower panicle blast severity in the main-season 2021/2022 could be the reason of higher filled grain in the main-season 2021/2022 (75.7%) compared to off-season 2021 (66.8%) (Figure 7).

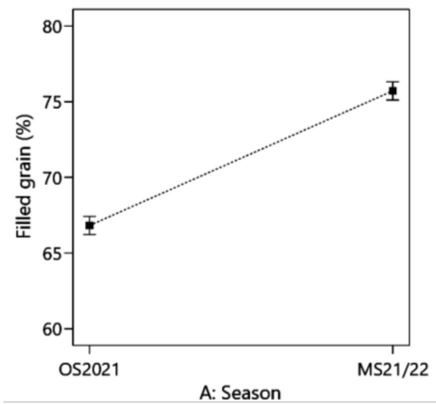

Figure 7 Filled grain (%) affected by seasons

3.4 Effects of N, K, and Si on 1000-Grain Weight (g)

The analysis of variance of the experimental data suggested a linear model for 1000-grain weight (g) and the ANOVA analysis is presented in Table 6.

Table 6 ANOVA table for response surface model for 1000-grain weight (g)

Source	df	Mean Square	F-value	p-value
Model	4	19.90	87.07	< 0.0001
A-Season	1	78.82	344.88	< 0.0001
B-Nitrogen	1	0.0333	0.1458	0.7044
C-Potassium	1	0.0070	0.0305	0.8621
D-Silicon	1	0.7353	3.22	0.0796
Residual	45	0.2285		
Lack of Fit	25	0.2059	0.8014	0.7031
Pure Error	20	0.2569		
Cor Total	49			

The size of the spikelet hull determined the final rice grain size and is controlled by multiple genes with at least 22-grain size-related QTL associated with grain length, width, and thickness [48]. Changes in grain size are affected by multiple molecular and genetic aspects that lead to dynamic cell division, expansion, and differentiation changes [49]. N, K, and Si are supposed to regulate any related genes or hormones underlying grain size to enhance the rice grain hull to accommodate a bigger grain size. However, N, K, and Si did not influence the 1000-grain weight in this study. Thus, applying these nutrients could not positively affect 1000-grain weight because they are strong genetics fixed rather than nutrients. Higher 1000-grain weight (g) in the main-season 2021/2022 than in the off-season 2021 (Figure 8) may be related to higher panicle blast severity showed in the off-season 2021 that could hinder the cell elongation and cell expansion in spikelet hulls.

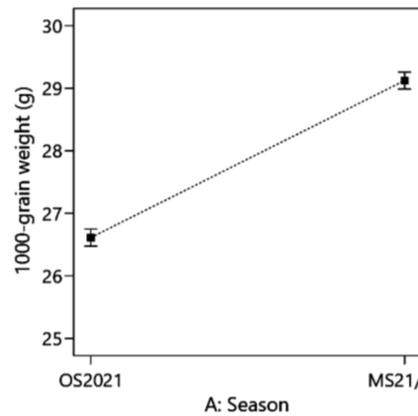

Figure 8 The 1000-grain weight (g) affected by seasons

3.5 Effects of N, K, and Si on Grain Yield (t/ha)

The analysis of variance of the experimental data suggested a linear model for grain yield and the ANOVA analysis is presented in Table 7.

Table 7 ANOVA table for response surface model for grain yield

Source	df	Mean Square	F-value	p-value
Model	4	9.16	74.50	< 0.0001
A-Season	1	35.28	286.86	< 0.0001
B-Nitrogen	1	0.0777	0.6321	0.4308
C-Potassium	1	0.1684	1.37	0.2480
D-Silicon	1	1.13	9.15	0.0041
Residual	45	0.1230		
Lack of Fit	25	0.1348	1.25	0.3102
Pure Error	20	0.1082		
Cor Total	49			

There were a significant effect of season and Si on grain yield. The average rice grain yield was higher in the main-season 2021/2022 (3.3 t/ha) than in the off-season 2021 (1.7 t/ha) by 94%. Higher rice grain yields because of more significant spikelets per meter square, filled grain, 1000-grain weight, and lower blast severity in the main-season 2021/2022 (Figure 9).

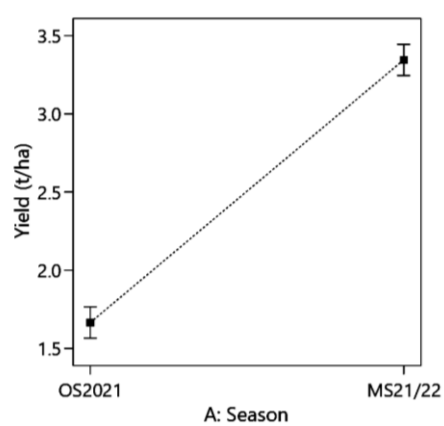

Figure 9 The rice grain yield (t/ha) affected by seasons

The application of Si showed a significant positive linear trend in rice grain yield (Figure 10). The application of Si increased by an average (two seasons experimental trial) of 16%, from 100 kg Si/ha (2.5 t/ha) to 200 Si kg/ha (2.9 t/ha).

Nitrogen, phosphorous, and potassium recommendation for rice cultivation in Malaysia is 120-138 N kg/ha, 70 kg P_2O_5, and 80 K_2O kg/ha [36]. While, Si recommendation between 200 – 400 kg/ha [28, 50, 51, 52, 53, 54] for rice blast control. Based on the highest rate of Si (200 kg/ha), improved rice grain yield significantly. The response surface showed that the lowest N (104 kg/ha) and K (62 kg/ha) could provide comparable rice grain yields of 2.07 t/ha (off-season 2021) and 3.81 t/ha (main-season 2021/2022) than a combination of a higher rate of N and K (Figure 11 and Figure 12). These results suggest that low N and K with the highest Si could benefit rice cultivation for controlling rice blast, especially under hot spot rice blast areas.

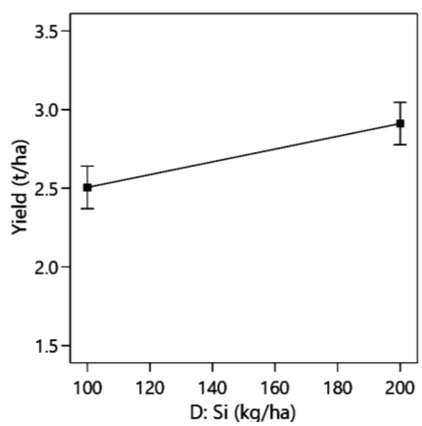

Figure 10 The rice grain yield (t/ha) affected by Si application

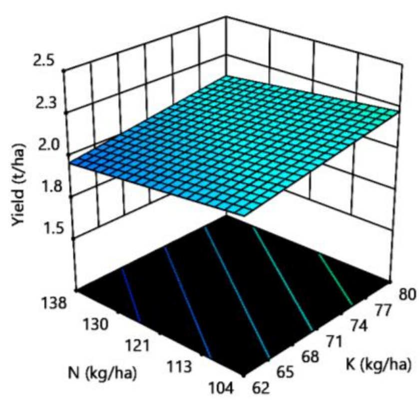

Figure 11 Effect of N, K and Si on rice grain yield (off-season 2021)

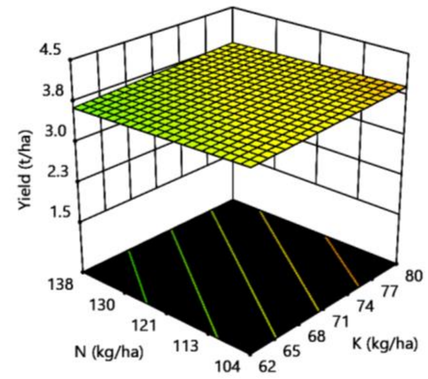

Figure 12 Effect of N, K and Si on rice grain yield (main-season 2021/2022)

The benefits of silicon fertilization on rice cultivation have been detailed and measured, including increased yields and better disease, pest, and fertility management. When all advantages are evaluated, it is not unreasonable to believe that the cost of Si, including the application, outweighs the cost of Si [55]. In addition, it also contributes to reducing the amount of fungicides required and the necessity for environmentally friendly plant disease management measures [56].

Finally, the rice panicle blast disease management is expected to be controlled with the recommended rate of 104 N kg/ha, 42 P_2O_5 (standard application), 80 kg K_2O, and 200 Si kg/ha, which minimizes the percentage of rice panicle blast severity (Figure 13) but at the same time maximizes the rice grain yield (Figure 14). This recommendation could limit the rice blast severity at 16 % (of-season 2021) and 12 % (main-season 2021/2022). This maximizes the rice grain yield of 2.2 t/ha (off-season 2021) and 3.9 t/ha (main-season 2021/2022).

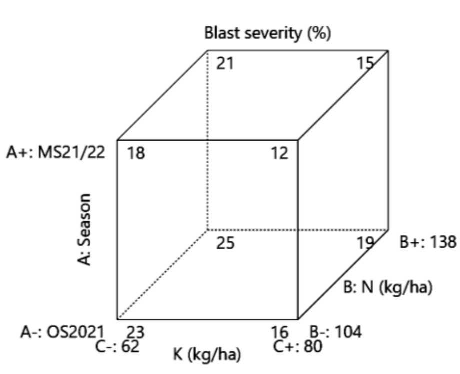

Figure 13 A model graph to optimize the N and K at the level of 200 Si kg/ha for rice panicle blast control

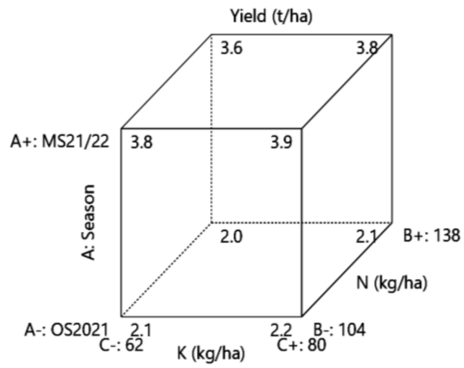

Figure 14 A model graph to optimize the N and K at the level of 200 Si kg/ha for maximize the rice grain yield

4.0 CONCLUSION

The research work was used to determine the optimal rate of N, K, and Si for rice cultivation in controlling panicle blast disease, especially in hot spot areas and maximizing the rice grain yield. The methods used were Central Composite Design and Response Surface Methodology. The application of N, K and Si did not influence the number of spikelets per meter square, filled grain (%) and 1000-grain weight (g). An increase in K and Si significantly reduced the rice panicle blast severity in the off-season 2021 and the main-season 2021/2022. On the other hand, only Si had influenced rice grain yield production. An increase in Si showed a positive linear trend in rice grain yield. Based on these results, the optimal value indicated that rice panicle blast disease management is expected to be controlled with the recommended rate of 104 N kg/ha, 42 P_2O_5, 80 kg K_2O, and an additional 200 Si kg/ha, which minimizes the rice blast severity (%) but at the same time maximizes the rice grain yield.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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