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Influence of Sulfur and Silicon on Growth and Yield of Rice (*Oryza sativa* L.)

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ABSTRACT

The field experiment was conducted during *kharif* season of 2022 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (UP) India. To study the response of sulfur and silicon on growth and yield of Rice. The soil of experimental plot was sandy loamy in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.35%). Findings showed that the higher plant height (117.68 cm), higher number of tillers/hill (14.75), higher plant dry weight (102.23 g/plant), higher crop growth rate (76.8 g/m^2/day), number of panicles/hill (12.01), higher number of grains/panicle (140.05), higher 1000 seed weight (23.91 gm), higher grain yield (6.87 t/ha) and higher straw yield (14.53 t/ha) were significantly influenced with application of Sulfur 30 kg/ha + Silicon 120 kg/ha. Higher gross return (INR 1,73,066.00/ha), higher net return (INR 1,24,238.00/ha) and higher B:C ratio (2.54) were also recorded in treatment 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha).

Keywords Rice, Sulfur, Silicon, Growth parameters, Yield, Economics.

INTRODUCTION

Rice is one of the chief grains to the people (*Oryza sativa* L.) as their primary food source and more than two million people depend on its cultivation for their livelihood. The battle against world hunger and poverty is reportedly being led by rice. In terms of food crops grown worldwide, rice production is dominated by India. It is India's primary source of food and covers in fact the vast area for cultivation (43.39 m ha), producing 104.32 million tonnes annually at a productivity of 2404 kg/ha. This suggests that in order to maintain our current level of food self-sufficiency by 2030, we will need to raise productivity by 4.03 t/ha to fulfil the rising demand for 130 m tonnes of milled rice. The problem of the food deficit can be resolved by increasing rice output the dominant crop of the country West Bengal, Andhra Pradesh, Chhattisgarh, Tamil Nadu, Karnataka, Assam, Maharashtra, Orissa, Punjab and Gujarat are the principal rice-producing states in the nation. With a yearly production of 41.68 lakh tonnes, rice is farmed in Karnataka on

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an area of 14 lakh ha (Anon 2020).

Nutrients are among the most important inputs in crop production as it constitutes a portion in the cost of cultivation and the deficiency of any nutrient causes more reduction in yield. Good nutrient management practices help to get more yields with minimum cost. The nutrients can be supplied through organic or inorganic sources or both. Rice responds better to higher doses of nutrients, any deficiency at critical stages lead to maximum reduction in yield and suppression of plant disease Elmer and Datnoff (2014). Application of nutrients coinciding with peak nutrient requirement of the crop helps to get maximum yield particularly, at panicle initiation and heading stage. Not only major nutrients but micro and beneficial nutrients play a significant role in uptake, translocation and assimilation of nutrients through their influence on several enzymatic and physiological roles in plant system Pati (2016).

About 90% of the organic sulfur (S) in a plant is used in the metabolism, enzymatic, and metabolic processes for the production of amino acids, proteins, and other compounds. Due to increased removal of S, its deficit is rapidly developing in places where pulses and oilseeds are grown.

Cultivated and winter cover crop contribution amendments on global warming potential in rice paddy soil during cultivation. Several studies have suggested the positive effects of Si on yield (Kim and Sang 2013, Emam *et al.* 2014).

The amount of nitrogen available affects rice's need for sulfur. The addition of N has no effect on the yield or protein content of plants when S becomes limiting. Early on in the growth of rice plants, sulfur is needed to produce higher yield and economics Jawahar and Vaiyapuri (2013). However, most plants' roots absorb sulfur from the oxidized sulphate.

Since rice needs a lot of silica to thrive, silicon is typically regarded as one of the most crucial beneficial ingredients for rice cultivation. The essentiality of silicon as a nutrient for stronger plants is exceedingly challenging to demonstrate due to its pervasiveness in the environment. According to estimates, rice plants extract around 20 kg of silica from the soil each year. Most beneficial effects from silicon are realized through the formation of silicon gel, which is deposited on the surface of leaves, stems and other organs of rice crops (Fallah 2012).

Keeping these points in view, the present study entitled "Influence of Sulfur and Silicon on growth and yield of rice (*Oryza sativa* L.)", was carried out at the Department of Agronomy's Crop Research Farm at the Sam Higginbottom University of Agriculture Technology and Sciences in Prayagraj. Uttar Pradesh during *kharif* season of 2022.

MATERIALS AND METHODS

Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh, conducted the experiment during the *kharif* of 2022. It can be found at location coordinates are 25.24' 42'' N latitude, 81.50' 56'' E longitude and 98 m elevation above mean sea level (SL). Ten treatments, each replicated three times were used in the experiment's Randomized Block Design. The plot size of each treatment was 3m × 3m. Factors are three levels of sulfur (10,20,30 kg/ha) and three levels of silicon (40, 80, 120 kg/ha). The rice crop was sown on 20 June 2022 by maintaining a spacing of 22.5 cm × 10 cm. Harvesting was done taking 1 m^2 area from each plot. And from it five plants were randomly selected for recording growth and yield parameters. The treatment details are as follows, T_1 -(Sulfur 10 kg/ha + Silicon - 40 kg/ha), T_2 -(Sulfur 10 kg/ha + Silicon - 80 kg/ha), T_3 – (Sulfur 10 kg/ha + Silicon - 120 kg/ha), T_4 -(Sulfur 20 kg/ha + Silicon - 40 kg/ha), T_5 -(Sulfur 20 kg/ha + Silicon - 80 kg/ha), T_6 -(Sulfur 20 kg/ha + Silicon - 120 kg/ha), T_7 -(Sulfur 30 kg/ha + Silicon - 40 kg/ha), T_8 -(Sulfur 30 kg/ha + Silicon - 80 kg/ha), T_9 -(Sulfur 30 kg/ha + Silicon - 120 kg/ha), T_{10}-(N 120 kg/ha + P 60 kg/ha + k 60 kg/ha) control. The observations were recorded for plant height, dry weight, Number of tillers/hill, crop growth rate, number of panicles/hill, number of grains/panicle, test weight, grain yield and straw yield. The data were subjected to statistical analysis by analysis of variance method (Gomez and Gomez 1976).

RESULTS AND DISCUSSION

Factors for growth

Plant height – The significantly higher plant height (117.68 cm) was noticed in treatment-9 (Sulfur 30 kg/ha + Silicon 120 kg/ha) as mentioned in Table 1. However, treatment-8 (Sulfur 30 kg/ha + Silicon 80 kg/ha) was statistically equivalent to treatment 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). One of the crucial growth and development indicators is the height of the rice plant. The administration of sulfur treatments caused a noticeably larger plant height Ram *et al.* (2014), which may be related to how it affected the metabolism of growing plants. This could effectively account for the observed response to sulfur application. It participates in the manufacture of some alkaloids, enzymes, co-enzymes, and proteins as well as a positive shift in plant metabolism. It also participates in the producing the chlorophyll, enzymes and co-enzymes. Additionally, the application of silicon will lead to continued growth parameters in rice at Alborz Mountain Range Jafari (2013). By making the plant taller while using silicon, the leaves and stem became more upright, reducing self-shading and enhancing photosynthetic rate.

Table 1. Influence of sulfur and silicon on growth parameters of rice.

Sl. No.	Treatment combinations	Plant height	Number of tillers/ hill	Plant dry weight
1	Sulfur 10 kg/ha + Silicon 40 kg/ha	108.88	12.11	84.74
2	Sulfur 10 kg/ha + Silicon 80 kg/ha	109.37	13.05	85.67
3	Sulfur 10 kg/ha + Silicon 120 kg/ha	111.73	12.97	87.39
4	Sulfur 20 kg/ha + Silicon 40 kg/ha	111.23	13.33	88.59
5	Sulfur 20 kg/ha + Silicon 80 kg/ha	113.27	14.35	91.23
6	Sulfur 20 kg/ha + Silicon 120 kg/ha	116.41	14.41	94.20
7	Sulfur 30 kg/ha + Silicon 40 kg/ha	115.99	14.71	97.45
8	Sulfur 30 kg/ha + Silicon 80 kg/ha	116.91	15.26	98.65
9.	Sulfur 30 kg/ha + Silicon 120 kg/ha	117.68	16.22	102.23
10	Control (120:60:60 NPK kg/ha)	108.74	11.41	82.41
	F test	S	S	S
	SEm (±)	0.55	0.67	1.95
	CD (p=0.05)	1.63	1.99	5.79

Number of tillers/hill – The significantly higher number of tiller/hill (16.22) was observed in treatment-9 (Sulfur 30 kg/ha + Silicon 120 kg/ha) as mentioned in Table 1. However, treatment-8 (Sulfur 30 kg/ha + Silicon 80 kg/ha) was statistically equivalent to treatment- 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). The significantly higher number of tillers were observed as a result of the use of sulfur 30 kg/ha. Tillering is the result of expanding auxiliary buds and is closely related to the mother culm's nutritional status in the early stages of development. Sulfur application improves the mother culm's use of other nutrients, especially nitrogen and phosphorus. Additionally, a further rise in the number of tillers/ hill may be caused by greater phosphorus availability and other advantageous effects of silicon on rice growth. The application of silicon raised the area of leaf, which improved photosynthetic rate and reduced chlorophyll decomposition (Gerami *et al.* 2012). It also raised source and sink strength and offered disease resistance (Gu *et al.* 2011).

Dry weight/plant– The significantly higher plant dry weight (102.23 gm) was observed in treatment 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha) as mentioned in Table 1. However, treatment-8 (Sulfur 30 kg/ ha + Silicon 80 kg/ha) was statistically at par with treatment 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). The movement of dry materials to the shoot and root was not constant, as the life cycle progresses, the proportion of shoots increases until maturity. At every growth stage, sulfur was critical in directing towards the shoot using photosynthesize, although the plant initiation and maturity stages showed the most notable change. It suggests that sulfur plays a significantly larger role in the photosynthetic signalling pathway, particularly following the commencement of the reproductive stages. One of the causes of the enhanced production of dry matter in the rice crop could be the continuing photosynthetic activity brought on by silicon fertilization. Similar outcomes are in line with Muriithi *et al.* (2010).

Table 2. Influence of sulfur and silicon on yield and yield attributes of rice.

Sl. No.	Treatment combinations	No. of panicles/ hill	No. of grains/ panicle	Test weight	Grain yield (t/ha)	Straw yield (t/ha)
1	Sulfur 10 kg/ha + Silicon 40 kg/ha	7.89	105.56	17.27	5.06	9.76
2	Sulfur 10 kg/ha + Silicon 80 kg/ha	8.69	112.87	18.21	5.64	10.64
3	Sulfur 10 kg/ha + Silicon 120 kg/ha	8.57	123.00	20.02	6.02	12.02
4	Sulfur 20 kg/ha + Silicon 40 kg/ha	8.39	119.33	18.85	5.43	10.43
5	Sulfur 20 kg/ha + Silicon 80 kg/ha	9.34	126.03	20.11	5.88	12.21
6	Sulfur 20 kg/ha + Silicon 120 kg/ha	9.74	132.41	21.06	6.48	12.82
7	Sulfur 30 kg/ha + Silicon 40 kg/ha	9.89	124.32	20.89	6.24	12.86
8	Sulfur 30 kg/ha + Silicon 80 kg/ha	11.37	135.64	22.80	6.63	13.57
9	Sulfur 30 kg/ha + Silicon 120 kg/ha	12.01	140.05	23.91	6.87	14.53
10	Control (120:60:60 NPK kg/ha)	8.18	115.20	18.86	5.04	9.22
	F test	S	S	NS	S	S
	SEm (±)	0.65	1.75	1.45	0.10	0.75
	CD (p=0.05)	1.93	5.11	--	0.28	2.24

Yield attributes

Number of panicles/hill– The significant and higher number of panicles/hill (12.01) were observed in treatment 9 with (Sulfur 30 kg/ha + Silicon 120 kg/ ha), which was significantly superior over rest of the treatments as mentioned in Table 2. However, treatment-8 (Sulfur 30 kg/ha + Silicon 80 kg/ha), was found to be statistically equivalent to treatment-9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). A sufficient supply of silicon is reported to have increased the number of panicles, the no. of grains/ panicle, the percentage of ripening and the posture of rice plants that receives light, as well as improved the availability and utilization of phosphorus by rice plants. Silicon is regarded as a crop-related component that is necessary for the sustainable production of rice. Si is taken by rice plants as PAS in far greater amounts than the macronutrients Patel *et al.* (2018) found similar findings.

Number of grains/panicle – The significant and higher number of grains/panicle (140.05) were observed in treatment-9 with (Sulfur 30 kg/ha + Silicon 120 kg/ha), which was significantly superior over rest of the treatments as mentioned in Table 2. However, treatment 8 (Sulfur 30 kg/ha + Silicon 80 kg/ha), was found to be statistically equivalent to treatment-9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). The use of sulfur may be the cause of the noticeably larger quantity of grains per panicle. Through the production of chlorophyll, certain amino acids like methionine, cystine, and cysteine, as well as some plant hormones like thiamine and biotin, sulfur is very helpful for boosting rice output. However, high-intensity cropping and the use of sulfur-free fertilizers caused sulfur deficiency in Indian soil.

Test weight (gm) – The maximum test weight (23.91 g) was observed in treatment 9 with (Sulfur 30 kg/ha + Silicon 120 kg/ha), and the minimum test weight (17.27 gm) was observed in treatment 1 (Sulfur 10 kg/ha + Silicon 40 kg/ha) as mentioned in Table 2. However, there was no discernible difference between the treatments. The benefit of silicon in enhancing photosynthetic activity and plant nutrition may be the cause of the increase in thousand grain weight as a result of the use of silicon.

Yield

Grain yield (t/ha) – The significant and higher grain yield (6.87 t/ha) were observed in treatment 9 with (Sulfur 30 kg/ha + Silicon 120 kg/ha) as mentioned in Table 2, which was significantly superior over rest of the treatments. However, treatment 8 (Sulfur 30 kg/ha + Silicon 80 kg/ha), was found to be statistically equivalent to treatment-9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). The increased yield was mostly caused by the use of sulfur, which affected the rate

Table 3. Influence of sulfur and silicon on economic analysis of rice. •Data was not subjected to the statistical analysis.

Sl. No.	Treatments	Cost of cultivation	Gross return	Net return	B:C ratio
1	Sulfur 10 kg/ha + Silicon 40 kg/ha	42,828	1,20,786	77,958	1.82
2	Sulfur 10 kg/ha + Silicon 80 kg/ha	44,828	1,34,080	89,252	1.99
3	Sulfur 10 kg/ha + Silicon 120 kg/ha	46,828	1,44,506	97,678	2.09
4	Sulfur 20 kg/ha + Silicon 40 kg/ha	43,828	1,29,460	85,632	1.95
5	Sulfur 20 kg/ha + Silicon 80 kg/ha	45,828	1,42,072	96,244	2.10
6	Sulfur 20 kg/ha + Silicon 120 kg/ha	47,828	1,55,292	1,07,464	2.25
7	Sulfur 30 kg/ha + Silicon 40 kg/ha	44,828	1,50,512	1,05,684	2.36
8	Sulfur 30 kg/ha + Silicon 80 kg/ha	46,828	1,64,400	1,17,572	2.51
9	Sulfur 30 kg/ha + Silicon 120 kg/ha	48,828	1,73,066	1,24,238	2.54
10	Control (120:60:60 NPK kg/ha)	39,828	1,19,246	79,418	1.99

of photosynthesis and glucose metabolism Jugal *et al.* (2016). It could be because of the use of sulfur, which improves soil physico-chemical characteristics, crop growth and crop development conditions. These findings were in line with those made by Kumar *et al.* (2014). Additionally, the application of calcium silicate boosted rice yields in histosols primarily due to the availability of accessible Si and not due to the provision of other nutrients, which may explain the further rise in grain yield.

Straw yield (t/ha) – The significant and higher stover yield (14.53 t/ha) were observed in treatment 9 with (Sulfur 30 kg/ha + Silicon 120 kg/ha) as mentioned in Table 2, which was significantly superior over rest of the treatments. However, treatment 8 (Sulfur 30 kg/ha + Silicon 80 kg/ha), was found to be statistically equivalent to treatment 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha). S may have increased rice growth and yield characteristics as well as a stimulating influence on the production of chloroplast protein, which increased photosynthetic efficiency and increased grain and straw output. The findings of Qamar *et al.* (2014) support our conclusions. In addition, Si is connected to shoot and straw and the amount of Si in the straw grew as Si application increased. Si can accumulate in straws for a variety of reasons, including transpiration, growth time, growth rate. With Malav and Jugal *et al.* (2016), comparable outcomes were seen and different source and levels of sulfur on yield, S uptake and protein content in rice growth in sequence on analfisol Kumar *et al.* (2014).

Economic analysis

Gross returns (INR/ha) – Highest gross return (1,73,066.00 INR/ha) was obtained in treatment 9 (Sulfur 30 kg/ha + Silicon 120 kg/ha) as compared to other treatments shown in Table 3.

Net returns – Highest gross return (1,24,238.00 INR/ha) was obtained in treatment-9 (Sulfur 30 kg/ha + Silicon 120 kg/ha) as compared to other treatments shown in Table 3.

Benefit cost ration – Benefit cost ratio (2.54) was found to be highest in treatment 9 with (Sulfur 30 kg/ha + Silicon 120 kg/ha) as compared to other treatments shown in Table 3.

CONCLUSION

It was concluded that with the use of sulfur 30 kg/ha along with the silicon 120 kg/ha (Treatment 9), has performed positively and improved growth and yield parameters. Higher grain yield, net returns, benefit cost ratio and gross returns were also recorded with application of Sulfur 30 kg/ha + Silicon 120 kg/ha (Treatment 9). These findings are based on one season therefore, further trials may be required for further confirmation.

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