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Abhay Singh
M.Sc. Scholar, Department of Agronomy, Naini Agriculture Institute, SHUATS Prayagraj, Uttar Pradesh, India

Vikram Singh
Professor, Department of Agronomy, Naini Agriculture Institute SHUATS, Prayagraj, Uttar Pradesh India

Shruti G George
Ph.D., Scholar, Department of Agronomy, Naini Agriculture Institute, SHUATS Prayagraj, Uttar Pradesh India

Corresponding Author:
Abhay Singh
M.Sc. Scholar, Department of Agronomy, Naini Agriculture Institute, SHUATS Prayagraj, Uttar Pradesh, India

Effect of zinc and sulphur on growth and yield of rice (*Oryza sativa* L.)

Abhay Singh, Vikram Singh and Shruti G George

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Abstract
A field experiment was conducted at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P) during *Kharif*, 2023. The soil of the experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), organic carbon (0.75%), available N (269.96 kg/ha), available P (33.10 kg/ha), and available K (336 kg/ha). The treatments applied were of zinc and sulphur. The experiment was laid out in Randomized Block Design with ten treatments each replicated thrice. Based on the objectives taken maximum plant height (117.14 cm), number of total tillers (5.02), days to 50 percent panicle emergence (57.33), days to maturity (97.33), plant dry weight (60.85 g/plant), effective tillers/m^2 (392.54), panicle length (28.41 cm), grain yield/hill (28.63 g/hill), filled grains/panicle (252.45), grain yield (3.95 t/ha), straw yield (6.83 t/ha) were recorded significantly higher in treatment combination of 8 kg/ha zinc + 45 kg/ha Sulphur. Similarly, the maximum gross returns (₹ 123440.00/ha), net returns (₹ 83472.00/ha), and benefit: cost ratio (2.09) were recorded higher in treatment combination of 8 kg/ha zinc + 45 kg/ha Sulphur.

Keywords: Sulphur, Zinc, growth, yield, rice, and kharif

Introduction
In India, rice is the most important and extensively grown food crop. Rice (*Oryza sativa L.*) is the premier food crop of India and therefore, national food security system largely depends on the productivity of rice ecosystems. Among the rice growing countries India ranks first in area (43.8 M ha) and second in production (105.0 MT), next only to China (Agricoop.co.in). However, the average productivity of rice in India is only 3.2 t /ha against the global average of 4.0 t /ha. Increasing productivity and production are essential to meet the food requirement of the burgeoning population. In order to attain the desired yield potential through agronomic manipulations and adopting appropriate management practices for raising not only the yield but also improvement of quality characteristics of rice is an area of research, which needs immediate attention. The productivity and quality of rice depends on environmental conditions and agronomic management practices of the area. Rice plant takes all the major and micro-nutrients from all the organic or inorganic sources. It has been observed that inspite of liberal application of N, P and K there was no or negligible improvement in the yield of crops. Sulphur, zinc and boron has been recognized as the key elements which play a dominant role individually as well as increase the efficiency of other major nutrients in realizing the higher yields. Sulphur is an essential plant nutrient and represents one of the three in the list of secondary nutrient elements. Sulphur content of majority of Indian soils is low because of low organic matter build up, increased removal of sulphur by adoption of high yielding fertilizer responsive crop varieties increased cropping intensity and increased loss of sulphur through leaching and erosion. Moreover use of sulphur free fertilizers during the last three decades aggravated the situation and has created a wide gap between the sulphur supply and sulphur requirements in the soil system. Three amino acids, cysterine, cystine and methionine contain sulphur. It is hence essential for protein production. Sulphur is involved in the formation of chlorophyll, activation of enzymes in the formation of glucosides and the SH-sulphydryl linkages. It is a part of co-enzyme A., pyrophosphate, vitamins such as biotin and thiomine (B1). Sulphur improves crop yield and quality of rice, because of its association with sulphur containing amino acids and proteins.

Amongst the seven micronutrient elements (Fe, Mn, Cu, Zn, B, Mo and Cl) essential for plant growth, zinc has assumed extensively important place in Indian Agriculture. Increasing incidences of Zn deficiency over the past several years have been due to various reasons. These include increased crop demand on soils ability to supply Zn fast enough as a result of improved cultivars and management, use of urea in place of acid fertilizer ammonium sulphate, increased use of phosphate fertilizers and the resulting P induced Zn deficiency; and the use of alkaline irrigation water without proper drainage. It is anticipated that further increase in incidences with the advent of rice with Zn dense grains for human nutrition which Zinc is believed to promote RNA synthesis. It plays an important role in the formation of Indole-3- acetic acid and starch formulation.

It mainly functions as a divalent cation by coupling enzymes with corresponding substrates and forming tetrahedral chelates with various organic substances including polypeptides. The deficiency of the essential element, zinc in the plant disrupts those processes for which the zinc is essential, with the result that plant growth, development, yield and quality of the produce suffer. Recently Zn deficiency has been found to be very common and it is becoming increasingly significant in crop production. The susceptibility of crop plants to Zn deficiency varies greatly with the variation of plant species and varieties. Its wide spread deficiency has become serious nutritional problem in rice, limiting its yield. Zinc deficiency causes decrease in the level of photosynthesis. Flower and fruit setting is considerably reduced. Zinc deficiency has been attributed mainly to adoption of fertilizer responsive high yielding varieties, use of zinc free inorganic fertilizers and gradual rise in pH of most of the rice fields.

Material and Methods

Experimental sites and soil

The experiment was conducted during the *Kharif* season 2023, at the Crop Research Farm (CRF), Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P.) which is located at 25°39' 42"N latitude, 81° 67 56" E longitude, and 98 m altitude above the mean sea level (MSL). This area is situated on the right side of the river *Yamuna* by the side of Prayagraj Rewa Road about 5 km away from Prayagraj (U.P) city.

The soil been collected from the experimental sites was tasted in laboratory and the result are been observed

Sand	20.00%
Silt	60.00%
Clay	16.40%
Textural class	Sandy loam

Zinc and Sulphur on the growth and yield of Rice was carried out at Crop Research Farm Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences Prayagraj during 2023 *kharif* Season.

Treatments used for the experiment

The level of Zinc and Sulphur is being used in the particular experiment *viz.* Zinc (4, 6, 8 kg/ha) and Sulphur (15, 30, 45 kg/ha) was separately maintained. The experiment was laid out in Randomized block design in three replication.

The Rice was transplanted by maintaining 15 x 15 cm spacing in plot area 9 m^2. The seeds were treated with thiram 4g per kg seed and the dose of Zinc and Sulphur was applied according to the treatment was laid in the treatments (T_1) Zinc 4 kg/ha + Sulphur 15 kg/ha, (T_2) Zinc 4 kg/ha + Sulphur 30 kg/ha, (T_3) Zinc 4 kg/ha + Sulphur 45 kg/ha, (T_4) Zinc 6 kg/ha + Sulphur 15 kg/ha, (T_5) Zinc 6 kg/ha + Sulphur 30 kg/ha, (T_6) Zinc 6 kg/ha + Sulphur 45 kg/ha, (T_7) Zinc 8 kg/ha + Sulphur 15 kg/ha, (T_8) Zinc 8 kg/ha + Sulphur 30 kg/ha (T_9) Zinc 8 kg/ha + Sulphur 45 kg/ha, (T_{10}) control each treatment carried out in three plot, total 30 plots.

The irrigation time, frequency and quantity were identical among treatment once after sowing and then every 15-20 days interval.

Analysis of yield attributes

In the study the yield per plot was measured by harvesting each plot pots of rice from each treatment, the sample were then air dried and weighted and each plot was a replication. Among them, five representative plants were selected from each treatment for testing, and each plant was a replication. The number of tilers per plant and number of days of 50% flowering and days of maturity and number of filled grain per penical and test weight were determined.

Result and Discussion

Plant height

Significantly higher plant height (117.14 cm) was recorded with application of 8 kg/ha zinc + 45 kg/ha Sulphur. However, 6 kg/ha zinc + 30 kg/ha Sulphur (105.98) was statistically at par with 8 kg/ha zinc + 45 kg/ha Sulphur.

The increase in these plant height may be attributed to the favourable effects of sulphur on N-metabolism, cell division, photosynthetic process and chlorophyll formation. This was similaraly observed by Yadav *et al.* (2013); Sharma *et al.* (2014) and Gill and Sharma, (2017).

Number of tillers per plant

At 100 DAT there was no significant effect observed on number of tillers maximum number of tillers (12.04) was recorded with application of 8 kg/ha zinc + 15 kg/ha Sulphur. Fallowing by 8 kg/ha zinc + 45 kg/ha Sulphur

The incorporation of sulphur may have aided in increasing the meristematic activity of the plant resulting in better development of the number of leaves and size resulting in higher number of tillers.

Days to 50 percent panicle emergence

Days to 50% panicle emergence was recorded significantly lowest in 8 kg/ha zinc + 45 kg/ha Sulphur (57.33 days). However, 6 kg/ha zinc + 45 kg/ha Sulphur (60.66 days) and 8 kg/ha zinc + 15 kg/ha Sulphur (60.33 days) recorded statistical parity with 8 kg/ha zinc + 45 kg/ha Sulphur

Days to maturity

8 kg/ha zinc + 45 kg/ha Sulphur recorded significantly lowest (97.33) Days to maturity. However, 6 kg/ha zinc + 30 kg/ha Sulphur (101.33) and 6 kg/ha zinc + 45 kg/ha Sulphur (102.33) were statistically at par with 8 kg/ha zinc + 45 kg/ha Sulphur.

Plant dry weight

At 100 DAT, the maximum dry matter accumulation (60.85 g/plant) was recorded with application of 8 kg/ha zinc + 45 kg/ha Sulphur. However, 8 kg/ha zinc + 15 kg/ha Sulphur (57.91 g/plant) and 6 kg/ha zinc + 45 kg/ha Sulphur (59.44 g/plant) were statistically at par with 8 kg/ha zinc + 45 kg/ha Sulphur.

The higher shoot dry matter could possibly be due to the increased crop growth and development resulting from better absorption and utilization of sulphur nutrients from the soil leading to an increase in the plant height, number of leaves and tillers.

Number of Effective Tillers/meter^2

The significantly highest effective tillers/m^2 was found in 8 kg/ha zinc + 45 kg/ha Sulphur recording 392.54 tillers/m^2. However, 4 kg/ha zinc + 45 kg/ha Sulphur (357.69 tillers/m^2), 6 kg/ha zinc + 30 kg/ha Sulphur (381.36 tillers/m^2) and 8 kg/ha zinc + 30 kg/ha Sulphur (383.64 tillers/m^2) were statistically at par with 8 kg/ha zinc + 45 kg/ha Sulphur.

The probable reason for high yielding varieties has high tillering capacity. Similar findings are also reported by Yadav *et al.* (2004). Wang *et al.* (2016) reported that the unequal distribution of photo- synthetically active radiation (PAR) was the source of heterogeneity in individual tiller yields, in that early emerging superior tillers pre-empted the uppermost light source, and shaded the late emerging tillers under limited light conditions.

Test weight

There was no significant effect of treatment combination on test weight of rice. Maximum test weight was recorded in 8 kg/ha zinc + 15 kg/ha Sulphur (25.63 g). Minimum test weight was recorded in 6 kg/ha zinc + 15 kg/ha Sulphur (23.9 g).

These enhanced growth parameters could be ascribed to zinc's role in the synthesis of tryptophan, nitrogen metabolism and production of growth hormones such as indole acetic acid. The above results are in tandem with the work of Sonkar *et al.* (2012) and Singh *et al.* (2017).

Grain yield/hill

The data showed the significantly highest grain yield/hill was observed in 8 kg/ha zinc + 45 kg/ha Sulphur recording 28.63 g/hill. However, 8 kg/ha zinc + 15 kg/ha Sulphur (28.21 g/hill) and 6 kg/ha zinc + 30 kg/ha Sulphur (26.71 g/hill) were statistically at par with 8 kg/ha zinc + 45 kg/ha Sulphur.

The higher grain yield/hill under variety might be due to the optimum utilization of nutrient. The hybrids of short duration high yielding have the potential to give the maximum grain yield then rest of the varieties. The other reason of the high yield of variety is due to the better growth attribute resulting to produce higher grain yield. Similar findings were reported by Ranjitha *et al*. (2013).

Seed Yield (t/ha)

The significantly maximum seed yield of rice (3.95 t/ha) was observed in the treatment combination of 8 kg/ha zinc + 45 kg/ha Sulphur. However, 8 kg/ha zinc + 30 kg/ha Sulphur (3.76 t/ha) and 8 kg/ha zinc + 15 kg/ha Sulphur (3.25 t/ha) were statistically at par 8 kg/ha zinc + 45 kg/ha Sulphur.

Stover Yield (t/ha)

The significantly maximum stover yield of rice (3.89 t/ha) was observed in the treatment combination of 8 kg/ha zinc + 45 kg/ha Sulphur. However, 6 kg/ha zinc + 45 kg/ha Sulphur (6.13 t/ha) and 8 kg/ha zinc + 30 kg/ha Sulphur (5.72 t/ha) were statistically at par 8 kg/ha zinc + 45 kg/ha Sulphur.

Harvest index (%)

Significantly higher Harvest index of rice was observed in the treatment combination of 8 kg/ha zinc + 30 kg/ha Sulphur (39.66%). Treatment combination 8 kg/ha zinc + 15 kg/ha Sulphur (38.33%) and 8 kg/ha zinc + 45 kg/ha Sulphur (38.80%) were statistically at par with 8 kg/ha zinc + 30 kg/ha Sulphur.

The increase in the yield parameters was due to the sulphur supplementation and availability in the vegetative and reproductive growth of the plant aiding in its chlorophyll formation, photosynthetic process and activation of enzymes and grain formation. The findings deduced are in line with the works carried out by Akter *et al.* (2013); Hosmath *et al.* (2014) and Das *et al.* (2022) who also reported the highest seed yield in soybean due to sulphur's application

Table 1: Effect of Zinc and sulphur on growth attributes of rice

Treatment combinations	Plant Height	No. Of tillers/plant	Plant dry weight (g)	Effective tillers/meter2	Panicle length
4 kg/ha zinc + 15 kg/ha Sulphur	113.47	9.74	55.27	309.35	23.34
4 kg/ha zinc + 30 kg/ha Sulphur	113.17	11.27	57.96	349.35	22.56
4 kg/ha zinc + 45 kg/ha Sulphur	117.65	8.14	51.18	357.69	20.33
6 kg/ha zinc + 15 kg/ha Sulphur	110.25	11.2	54.16	299.35	26.67
6 kg/ha zinc + 30 kg/ha Sulphur	116.94	10.27	55.36	381.36	24.89
6 kg/ha zinc + 45 kg/ha Sulphur	110.54	9.04	59.44	322.64	23.34
8 kg/ha zinc + 15 kg/ha Sulphur	111.47	12.04	57.91	314.64	26.59
8 kg/ha zinc + 30 kg/ha Sulphur	113.50	10.07	56.12	383.64	20.32
8 kg/ha zinc + 45 kg/ha Sulphur	121.14	11.95	60.85	392.54	28.41
Control	119.14	8.3	50.87	253.30	22.56
F test	S	NS	S	S	S
SEm±	0.56	0.23	1.32	11.53	0.42
CD (P = 0.05)	1.72	-	3.54	36.94	2.45

Table 2: Effect of zinc and sulphur on Yield and Harvest index of rice

Treatment combinations	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
4 kg/ha zinc + 15 kg/ha Sulphur	2.07	4.83	30.00
4 kg/ha zinc + 30 kg/ha Sulphur	2.32	4.92	32.04
4 kg/ha zinc + 45 kg/ha Sulphur	2.25	4.76	28.09
6 kg/ha zinc + 15 kg/ha Sulphur	2.25	5.03	30.91
6 kg/ha zinc + 30 kg/ha Sulphur	2.27	5.62	28.77
6 kg/ha zinc + 45 kg/ha Sulphur	3.01	6.13	32.93
8 kg/ha zinc + 15 kg/ha Sulphur	3.25	5.23	38.33
8 kg/ha zinc + 30 kg/ha Sulphur	3.76	5.72	39.66
8 kg/ha zinc + 45 kg/ha Sulphur	3.95	6.83	38.80

Control	1.21	3.45	25.97
F test	S	S	S
SEm±	0.55	0.30	0.89
CD (P = 0.05)	1.65	1.11	2.54

Conclusion

As per my research trial, the treatment combination of 8 kg/ha zinc and 45 kg/ha Sulphur was found to be more productive and also economically feasible. Although the findings are based on one season, further research is needed to confirmthe findings and their recommendation.

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