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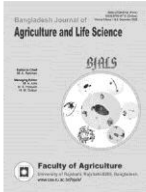

Response of Boro Rice to Sulfur and Zinc on Yield and Yield Components in High Barind Tract

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, University of Rajshahi, Bangladesh during the period from November, 2019 to May, 2020 to study the effect of different levels of sulfur and zinc fertilizer on the yield and yield components of Boro rice. The experiment was laid out in a Randomized completely Block Design (RCBD) with three replications. It was consisted of two factors: (i) sulfur levels viz 0 kg ha^{-1}, 6 kg ha^{-1}, 12 kg ha^{-1} and 18 kg ha^{-1} and (ii) zinc levels i.e. 0 kg ha^{-1}, 0.5 kg ha^{-1}, 1.5 kg ha^{-1} and 2.5 kg ha^{-1}. The treatment that contained 18 kg of sulfur per hectare produced the highest plant height, number of grains per panicle, and thousand grains weight, according to the findings of this study. The highest grain and straw yield were found when the field was treated with 18 kg sulfur ha^{-1}. Among the zinc levels, 2.5 kg zinc ha^{-1} produced the highest plant height, total tillers, effective tillers, grains $panicle^{-1}$ and yield. After application of 2.5 kg zinc ha^{-1}in the field, the grain and straw yield was showed highest result. So, it could be concluded that the maximum grain yield was gained when the field was fertilized with 18 kg sulfur ha^{-1} and 2.5 kg zinc ha^{-1}.

Introduction

Global climate change has emerged as one of the most serious threats to agriculture in Bangladesh, with rising temperatures, irregular rainfall patterns, and declining soil fertility posing significant challenges to food security. As a densely populated developing country with over 165 million people (BBS, 2022), Bangladesh heavily depends on rice as a staple food to ensure national food security. Rice accounts for approximately 70% of daily caloric intake and nearly 50% of the total protein intake of the population (Mottaleb et al., 2018). The per capita rice consumption in Bangladesh exceeds 170 kg annually, far above the global average of 57 kg (Yunus et al., 2019).

Among the three major rice-growing seasons in Bangladesh-Aus, Aman, and Boro-the Boro rice season contributes the highest share to national rice production due to its high yield potential and favorable irrigated conditions. However, sustainable productivity of Boro rice is increasingly threatened by micronutrient deficiencies in the soil, particularly sulfur (S) and zinc (Zn), especially in regions like the High Barind Tract, which suffers from low fertility, drought-proneness, and poor soil structure.

Sulfur is an essential secondary macronutrient involved in vital plant functions, including the synthesis of sulfur-containing amino acids (cysteine, methionine), chlorophyll formation, and enzymatic activity. Its deficiency impairs chlorophyll production, reduces tiller formation, and delays grain maturation, ultimately resulting in decreased rice yield and poor grain quality (Narayan et al., 2023).

Zinc, on the other hand, is a key micronutrient involved in enzyme activation, protein synthesis, and hormonal regulation in rice plants. Zinc is also essential for internodal elongation, spikelet fertility, and efficient use of nitrogen and phosphorus.

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Deficiency of zinc results in stunted growth, leaf chlorosis, increased spikelet sterility, and overall yield loss in rice (Saleem et al., 2022).

Despite the known importance of these nutrients, deficiencies of sulfur and zinc are widespread in the High Barind Tract due to continuous cropping, imbalanced fertilizer use, and low organic matter content. Strategic nutrient management is therefore essential to improve rice productivity in this agro-ecological zone. Considering these factors, the present study was undertaken to evaluate the effect of different levels of sulfur and zinc on the yield and yield components of Boro rice in the High Barind Tract, to identify the optimum combination of sulfur and zinc fertilization for maximizing Boro rice productivity under the region's specific agro-climatic conditions, and to assess the interaction effects of sulfur and zinc on the physiological and agronomic performance of Boro rice.

Materials and methods

Experimental site and soil

Geographically the experimental field is located at 24°17'-24°31' N latitude and 88°28'-88°43' E longitude with a height of 20 m above the sea level, belonging to calcareous dark grey floodplain soil and calcareous brown floodplain soils under the Agro-Ecological Zone 11(High Ganges River Flood Plain). The experimental plot was poorly drained soil with moderately slow permeable. The top soil was silty loam and slightly alkaline in reaction having pH of values of 7.5. The soil had enriched in organic matter 1.44%, total nitrogen (0.09%), available phosphorous (17.61 ppm), available potassium (0.2 ppm), available sulfur (9.36 ppm) and available zinc (0.33 ppm). The experimental area was under subtropical climate characterized by heavy rainfall during kharif season (April to September) and low temperature and scanty rainfall during the Rabi season (October to March). In the subjected area, the average relative humidity, temperature, and rainfall were (69.09-89.06%), (23.76-33.43)^0 C and (2.22-25.40) mm, respectively.

Experimental design and layout

The experiment comprised two factors namely, four sulfur levels viz. S_0 (0 kg ha^{-1}), S_1 (6 kg ha^{-1}), S_2 (12 kg ha^{-1}), S_3 (18 kg ha^{-1}) and four levels of zinc viz. Z_0 (0 kg ha^{-1}), Z_1 (0.5 kg ha^{-1}), Z_2 (1.5 kg ha^{-1}) and Z_3 (2.5 kg ha^{-1}). The experiment was laid out in a Randomized completely Block Design (RCBD) with three replications. total number of plots was 4×4×3=48. Each plot measured 4 m by 2.5 m, with blocks, major plots, and unit plots separated by 60 cm, 50 cm, and 30 cm, respectively.

Plant material

The BRRI dhan28 cultivar of boro rice was employed as a planting material. It was developed (1994) by Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. Its life cycle is about 145 days. The height of the rice plant is 90 cm and the grains are thin and white in color. Yield of BRRI dhan28 is 6.0-ton ha^{-1}. This variety moderately resistance to blast.

Crop production practices and data collection

The experimental plot was made ready for transplantation on 24 January 2020 with the help of power tiller and later on, the land ploughed and cross ploughed three times with country plough followed by laddering to obtain a desirable tilth. Spacing were given (25 cm × 15 cm) for transplanting. All kinds of weeds and stubble were removed from the field and the land was made ready for transplanting. The soil of the plot was kept moist without allowing standing water at the time of transplanting. Before transplanting all the plots were ready according to the design. Thirty-five days old seedlings were transplanted in the well puddled plots are three seedlings hill^{-1} on 30 January, 2020. The land was fertilized with 300 kg urea, 180 kg TSP, 150 kg MoP, 10 kg ZnO, and 20 kg $ZnSO_4$ ha^{-1}. Entire amount of TSP, MoP was applied during final land preparation. Urea was applied as in instalments as basal and top dressing at 25, 45, and 60 DAT. Zinc and sulfur were applied as per specified treatment. To minimize weed infestation, manual weeding through hand pulling was done three times during the entire growing season. First weeding was done at 20 DAT, the second weeding was done at 40 DAT and third weeding was done at 60 DAT respectively. Other intercultural operations like irrigation and drainage, inset pest and diseases control was done as per requirement. Maturity of crop was determined when 80 percent grains became golden yellow. The harvesting of BRRI dhan28 was done April 2022. Five hills (excluding border hills) were randomly selected from each plot and tagged for recording necessary data. After sampling, the whole plot was harvested at maturity. The harvested crop of each plot was bundled, tagged and then brought to the threshing floor. The harvested crop was threshed, cleaned and sun dried to record the yields of grain and straw plot-wise and converted into ton ha^{-1}.

Statistical analysis

All the recorded data on growth, yield and yield contributing characters were complied, tabulated and subjected to statistical analysis. Analysis of variance (ANOVA) was done with the help of computer package program STAT-VIEW software. The mean differences among the treatments were adjusted with Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984). Simple correlation co-efficient was done to determine the relationships between grain yield and components with the help of SPSS computer program.

Results

The frequency of fluctuation in plant height was observed based on the sulfur treatment. Table 1 reveals that treatment S_1 (18 kg/ha) had the maximum plant height (88.558 cm), while control treatment S_0 (0 kg/ha) had the lowest plant height (82.375 cm). The number of total tillers hill varied tremendously as a result of the sulfur treatment. Based on the findings displayed in (Table 1), the highest total tillers hill (15.400) was produced by the treatment S_1 (6 kg/ha). The treatment with the lowest total tillers hill (14.058) was S_0 (0 kg/ha). The deliberate use of sulfur had a significant impact on the number of effective tillers per hill, Table 1 reveals that treatment S_1 (6kg/ha) produced the most effective tillers $hill^{-1}$ (12.050), while treatment S_0 (0kg/ha) produced the least effective tillers $hill^{-1}$ (11.250). The number of grain $panicle^{-1}$ per unit area varied as a result of the treatment (Table 1). The treatment S_3 (18kg/ha) produced the greatest number of total grains $panicle^{-1}$(99.525), while the treatment S_1 produced the fewest (99.008). The highest number of total grain $panicle^{-1}$ was observed (6 kg/ha). The plant may have received metabolic energy from the sulfur nutrient, which improved the grain $panicle^{-1}$ with increased S fertilization. Because of the different treatments, there was a large amount of diversity in terms of grain yield (S). According to the findings that were reported in (Table 1), the grain yield that was obtained from the treatment S_3 (18kg/ha) was the highest (4.625), while the grain yield that was achieved from the treatment S_0 (0kg/ha) was the lowest (3.943). The treatment had a considerable impact on the overall yield of the straw. According to (Table 1), the treatment S_3 (18 kg/ha) had the greatest recorded straw yield (5.914), whereas the treatment S_0 (0kg/ha) had the lowest recorded straw yield (4.977). Sulfur had a significant impact on the amount of biological produce. According to what is shown in Table 1, the treatment that produced the highest biological yield (11.177) was S_3 (18 kg/ha), while the treatment that produced the lowest biological yield (9.525) was S_0 (0 kg/ha). Harvest index was not influenced by treatments (S). Highest harvest index (42.753%) was obtained from the treatment S_1 (6 kg/ha) and the lowest harvest index (41.033%) was gained inS_2 (12kg/ha) from (Table 1).

The experiment expressed that plant height vary significantly for the applied of different levels of zinc from (Table 2). The highest plant height (86.783cm) was found in treatment Z_3 (2.5kg/ha) and the lowest height (85.742cm) was seen from treatment Z_0 (0 kg/ha). Plant height can be significantly increased by sulfur through the formation of chlorophyll, which promotes vegetative growth. Zinc has a great impact on the no. of total tillers $hill^{-1}$. The highest number of total tillers $hill^{-1}$ (15.908) was gained at treatment Z_3 (2.5kg/ha) and the lowest number of total tillers $hill^{-1}$(13.983) was obtained from control treatment Z_0(0kg/ha). Effective tillers $hill^{-1}$ was influenced significantly by the application of zinc. The maximum numbers of effective tillers $hill^{-1}$ (12.167) was obtained at treatment Z_3 (2.5kg/ha) and the minimum numbers of effective tillers $hill^{-1}$ (10.808) was seen Z_0 (0kg/ha) presented in the (Table 2). Total number of grains $panicle^{-1}$was varied with different levels of zinc. The results shown in (Table 2) found that the highest number of grains $panicle^{-1}$ (103.525) was seen in the treatment Z_3 (2.5kg/ha) and lowest number of grains $panicle^{-1}$ (94.017) was observed in the treatment Z_0 (0kg/ha). The 1000 grain weight also varied significantly for Zn treatment. Resultsshown in (Table 2) exposed that the test weight (27.650g) was found from the treatment was obtained in Z_3 (2.5kg/ha) and the lowest 1000 grain weight (27.125 g) obtained from the treatment Z_1 (0.5kg/ha). There was significant variation observed concerning grain yield due to application of zinc. The results presented in (Table 2) shown that the highest grain yield (4.543) was obtained Z_3 (2.5kg/ha) and the lowest grain yield (4.093) was gained in Z_1 (0kg/ha). The straw yield of rice differs significantly for application of various levels of zinc. The maximum straw yield (6.153) was recorded

Z_3(2.5kg/ha) and the minimum straw yield (5.242) was recorded at Z_2 (1.5) from the (Table 2). The biological yield was influenced greatly by zinc (Table 2) shown that highest biological yield (11.082) was found from the treatment Z_3 (2.5 kg/ha) and the lowest biological yield (9.678) was gained in Z_1(0.5 kg/ha). Higher values of grain and straw yields under S and Zn fertilization may be the cause of the greater biological yield. Highest harvest index was found from (42.745) index was from treatment Z_3 (2.5kg/ha) and the lowest was obtained from (41.637) treatment Z_1(0.5kg/ha) given in the (Table 2).The pant height had a significant impact due to the interaction of sulfur and zinc. Apparently, the highest plant height (90.933cm) was seen in the interaction S_2Z_3; and the lowest plant height (81.067cm) was observed from the interaction S_0Z_1 from (Table 3).

Table 1. Effect of sulfur on yield and yield components of boro rice

Sulfur levels	Plant height (cm)	No of total tiller hill^{-1}	Panicle length (cm)	No of spikelets panicle^{-1}	No of grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Z_0	85.742	13.983b	21.625	9.717	94.017b	7.142	27.325	4.341ab	5.407b	10.741a
Z_1	86.150	13.922b	21.325	9.942	98.150ab	7.550	27.126	4.093b	5.466b	9.678b
Z_2	86.667	14.883ab	21.683	10.558	97.692ab	7.267	27.300	4.399a	5.242b	9.802b
Z_3	86.783	15.908a	21.833	9.217	103.525a	7.800	27.650	4.543a	6.153a	11.082a
CV(%)	5.03	12.60	6.18	15.06	6.39	8.69	6.36	7.94	7.94	8.16

In a column figures having similar (S) or without letter (S) do not differ significantly as per DMRT.

S_0= 0kg/ha, S_1= 6kg/ha, S_2= 12kg/ha, S_3= 18kg/ha, CV (%) = Coefficient of variance, LSD= Least significant difference

Table 2. Effect of zinc on yield and yield components of boro rice

Sulfur levels	Plant height (cm)	No of total tiller hill^{-1}	Panicle length (cm)	No of spikelets panicle^{-1}	No of grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Z_0	85.742	13.983b	21.625	9.717	94.017b	7.142	27.325	4.341ab	5.407b	10.741a
Z_1	86.150	13.922b	21.325	9.942	98.150ab	7.550	27.126	4.093b	5.466b	9.678b
Z_2	86.667	14.883ab	21.683	10.558	97.692ab	7.267	27.300	4.399a	5.242b	9.802b
Z_3	86.783	15.908a	21.833	9.217	103.525a	7.800	27.650	4.543a	6.153a	11.082a
CV(%)	5.03	12.60	6.18	15.06	6.39	8.69	6.36	7.94	7.94	8.16

In a columnfigures having similar (S) or without letter (S) do not differ significantly as per DMRTZ_0 = 0kg/ha, Z_1 = .5kg/ha, Z_2 = 1.5kg/ha, Z_3 = 2.5kg/ha, CV (%) = Coefficient of variance, LSD= Least significant difference

Table 3. Interaction effect of sulfur and zinc on yield and yield components of boro rice

Interaction	Plant height (cm)	No of total tiller $hill^{-1}$	No of effective tiller $hill^{-1}$	No of effective tiller $hill^{-1}$	Panicle length (cm)	No of Spikelets $panicle^{-1}$	No of Grains $Panicle^{-1}$	Unfilled grains $panicle^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0Z_0	82.467	15.233	10.900bc	4.433abc	20.767	9.667	99.233abcdef	7.067cde	36.900	3.620g	4.593def	10.053	43.320
S_0Z_1	81.067	14.033	11.100ab	4.000bed	20.567	9.667	95.767cdef	7.567abcd	26.033	3.643g	4.313f	9.120	45.327
S_0Z_2	82.033	13.667	12.333ab	3.500efg	21.133	10.133	98.767abcef	7.967abc	28.200	4.553cdef	4.553ef	8.583	43.460
S_0Z_3	93.933	13.300	10.667c	3.800def	21.767	10.133	104.333abc	6.900de	27.400	3.867fg	6.450a	10.343	39.907
S_1Z_0	85.800	14.867	11.067bc	4.233abcd	21.967	10.100	95.467cdef	7.867abcd	27.600	4.503abcde	5.447abcde	9.953	45.437
S_1Z_1	86.767	16.067	12.400ab	4.50a	21.500	9.667	107.533ab	8.533a	27.533	5.043a	5.547abcd	8.940	40.177
S_1Z_2	88.933	16.567	13.600a	3.933def	21.600	9.667	92.667def	7.200bcdc	27.333	4.970ab	5.300bede	10.690	41.830
S_1Z_3	84.333	14.100	11.133bc	4.467ab	22.300	8.533	100.367abede	8.100abc	25.500	4.127defg	6.007abc	11.083	43.017
S_2Z_0	86.900	18.100	10.533c	4.033abcd	22.667	9.433	92.167def	6.400c	27.667	4.117defg	6.013abc	11.660	41.897
S_2Z_1	88.300	12.100	12.067abc	3.500efg	22.533	10.767	108.900 a	6.367c	27.367	4.250cdef	5.973abc	10.083	38.507
S_2Z_2	88.667	14.867	11.167bc	3.133g	22.600	10.667	105.767abc	6.8333de	27.700	4.420bcdef	5.270	9.053	42.287
S_2Z_3	87.933	12.867	11.400bc	2.567h	21.033	8.667	90.500cf	8.133ab	27.133	4.737abc	5.897abc	10.940	41.440
S_3Z_0	87.800	15.433	10.733c	3.967cde	21.100	9.667	89.200 f	7.233bcde	27.570	4.420bcdef	5.523abcd	11.297	41.330
S_3Z_1	88.467	13.767	12.333bc	3.467fg	20.700	9.667	101.900abcd	7.733abcd	27.700	4.737abc	6.030abc	10.570	42.537
S_3Z_2	87.003	14.433	11.567bc	4.000bed	21.400	11.767	93.567 def	7.067cde	10.880	5.000a	5.843abc	10.880	40.333
S_3Z_3	90.933	15.667	13.167a	3.800def	22.233	9.533	97.400bedef	8.067abc	11.960	4.347cdef	6.260ab	11.960	44.643

In a column figures having similar (S) or without letter (S) do not differ significantly as per DMRT

S_0Z_0= (0kg/ha×0kg/ha)	S_1Z_0= (6kg/ha×0kg/ha)	S_2Z_0= (12kg/ha×0kg/ha)	S_3Z_0= (18kg/ha×0kg/ha)
S_0Z_1= (0kg/ha×0.5kg/ha)	S_1Z_1= (6kg/ha×0.5kg/ha)	S_2Z_1= (12kg/ha×0.5kg/ha)	S_3Z_1= (18kg/ha×0.5kg/ha)
S_0Z_2= (0kg/ha×1.5kg/ha)	S_1Z_2= (6+kg/ha×1.5kg/ha)	S_2Z_2= (12kg/ha×1.5kg/ha)	S_3Z_2= (18kg/ha×1.5kg/ha)
S_0Z_3= (0kg/ha×2.5kg/ha)	S_1Z_3= (6kg/ha×2.5kg/ha)	S_2Z_3= (12kg/ha×2.5kg/ha)	S_3Z_3= (18kg/ha×2.5kg/ha)

CV (%) = Coefficient of variance; LSD= Least significant difference

Interaction impact between sulfur and zine was seen non-significant (Table 3). However, the highest number of total tillers $hill^{-1}$ (16.567) was obtained from the interaction S_1Z_3; and the lowest number of tillers $hill^{-1}$ (12.100) was gained in S_2Z_1. Interaction effect between sulfur and zinc was found significant (Table 3).

However, the highest number of total tillers $hill^{-1}$ (13.600) was gained from the interaction S_1Z_2 and the lowest number of tillers $hill^{-1}$ (10.533) was obtained from S_2Z_0. Number of grain $panicle^{-1}$ was significant. (Table 3) showed that the highest number of grain $panicle^{-1}$ (108.90) was obtained from the interaction S_2Z_1 and the lowest number of grains $panicle^{-1}$ (89.200) was obtained from the interaction S_3Z_0. On a 1000 grain weight scale, the interaction effect of sulfur and zinc did not have a significant impact (Table 3). The interaction at S_0Z_0 produced the largest weight of one thousand grains, which came in at 36.900 g, while the interaction at S_0Z_1 produced the smallest weight of one thousand grains, which was discovered to be 3.600 grams (26.033g). There was not a discernible impact on grain production resulting from the interaction between zinc and sulfur (Table 3). According to the results that were found in table 3, the grain yield that was supplied by the interaction S_1Z_3 (5.043 t ha^{-1}) was the highest, while the grain yield that was given by the interaction S_0Z_0 was the lowest (3.620 t ha^{-1}). The combination between sulfur and zinc has a considerable impact on straw production. The interaction S_0Z_0 produced the maximum straw yield (6.450 t ha^{-1}), while the interaction S_0Z_0 produced the lowest straw yield (4.313 t ha^{-1}). Biological yield greatly varied due to interaction effect of sulfur and zinc. However (Table 3) presents that the highest biological yield (11.960 t ha^{-1}) was given at the interaction S_3Z_3 and the lowest biological yield (8.583 t ha^{-1}) was given at the interaction S_0Z_2. Sulfur and zinc interaction were revealed in the (Table 3). The interaction S_0Z_1 produced the highest harvest index (45.437), while the interaction S_2Z_1 produced the lowest harvest value (38.507).

Discussion

Sulfur is one of the essential nutrients that is require for the adequate growth and development of plants. Rice is one of the many plants that require sulfur as a vital nutrient. Numerous physiological processes that aid in the advancement and maturation of plants are mediated by it. Sulfur has a statistically significant effect on plant height, according to study data. This is because, sulfur is a fundamental part of amino acids and is necessary for the division of cells and cell elongation. Furthermore, it promotes the synthesis of proteins that support growth, helping plants to grow taller, (Kalala et al., 2016) found this to be true from study results.

The outcome of the study showed that number of tillers was significantly impacted by the different Sulfur levels. Sulfur increases the number of tillers as it helps in the growth of side shoots or branches that sprout from the main stem. Through having an impact in several physiological processes, including synthesis of nitrogen and enzyme activation, sulfur affects rice tillering. A study by Ram et al., (2014) found that adequate amounts of sulfur enhance the plant's ability for utilizing nitrogen, which encourages the growth of tillers. The element sulfur is also crucial for maximizing the number of tillers during the booting stage. Tanweer et al., (2014) expressed concern over this outcome. Sulfur is essential for improving rice tillering effectiveness. The number of efficient tillers was statistically significant in accordance with the different level of sulfur. This happens due to its participation in a number of biochemical processes. Amino acids, the organizing blocks of proteins, contain sulfur as a crucial component. The creation of new tissues, such as tillers, depends heavily on proteins, which are necessary for the growth and development of plants. This outcome is consistent with the research findings of Waikhom et al., (2012).

From the recorded data, it can be concluded that rice yield was statistically significant when applied different amount of sulfur. Rice plants depend on sulfur as a vital nutrient, and having sufficient amounts of this mineral has implications for a number of physiological functions that impact grain yield. Even though sulfur might not impact directly the amount of grains; rather, its effects on the health and development of the plant as a whole can influence total number of grains per panicle, filled grains per panicle and grain yield in numerous of ways, including protein synthesis, stress tolerance, hormone balance, and chlorophyll formation, which in turn ensures an increased rate of photosynthesis and a steady supply carbohydrates and energy-both of which are essential for grain to fill and growing up. Enzymes that take part in a number of metabolic activities, such as ingesting and digestion of nutrients, are activated by sulfur. This conclusion is in line with Chandel et al., (2022).

Zinc is one of the micronutrients recognized as an essential nutrient vital for plants. This nutrient is needed through the growing season for crops to reach their full potential. The height of the plants was statistically significant when considering the effect of different levels of zinc fertilizer application. The study demonstrated that highest plant height was measured from the treatment Zn_3 (2.5 kg/ha). this happened due to the involvement of zinc into different physiological activities like protein synthesis, nucleic acid metabolism, and the stimulation of enzymes all depend on it. A lack of zinc can cause crops, especially rice, to develop more slowly and produce fewer grains overall. this result makes a harmony with the findings of Bari et al., (2023).

The number of total tillers and effective was highly significant to the level of zinc. The study summarized that the number of total tiller and effective tiller was recorded from the treatment Zn_3 (2.5kg/ha), whereas it was vice versa in the treatment control (ZnO). the causes behind this phenomenon, zinc involves different activities which were convenient to production of tillers number as well as the overall effective tillers number. For numerous enzymes engaged in different chemical reactions, zinc serves as a cofactor. Plant hormones like auxins, which affect cell lengthening and distinctness, are synthesized in part by certain of these enzymes. Coordinating these hormonal impulses is necessary for proper tiller improvement, and zinc helps with this. The findings of the research by Mustafa et al., (2011) agreed with this. beside this zinc play a vital role in the basic stages of tiller growth, such as proliferation of cells and lengthening, zinc is required. A plant can create the tillers required for greater branching and eventually a greater number of tillers when its zinc levels are appropriate. This is because zinc supports the establishment of new cells.

The number of total grains and filled grains was recorded from the treatment Zn_3 (2.5 kg/ha). Several authors (Yadi and Dastan, 2011), expressed the same opinion that advancement application zinc in rice cultivation helps to increase the number of total grains as well as the number of filled grains. this happens due to the involvement of zinc in to grow into their reproductive organs, such as their flowers and grains. Normal pollen production, pollen tube elongation, and implantation depend on optimal zinc levels. As well as enzymes connected to the metabolism of carbohydrates and grain filling, among others, require zinc as a cofactor. For grain filling to function properly, starch must be efficiently converted from carbohydrates. Enzymes that contain zinc are involved in these activities and affect the weight and size of each of the grains.

The grain yield was substantially affected by the application of different levels of zinc. Several researchers (Samaraweera, 2009) concluded that application of optimum doses of zinc help to improve the increase the yield of rice through the development of effective tillers as well as the number of filled grains per spike. Zinc has an impact on the composition and functionality of chloroplasts, which are the cellular organelles in charge of photosynthesis that helps to accumulate carbohydrate and further helps in synthesis (Pedda Babu et al., 2007). In order to enhance total development, growth, and yield, optimal photosynthesis increases energy output. As well as plants need zinc in order to synthesize proteins. Given the high protein content of rice grains, sufficient zinc facilitates the production of reserve proteins, enhancing the nutrient content and possibly raising the grains market value. beside this it also responsible for the increasement of straw yield. several researchers Fageria et al., (2011) make the same opinion with this. So, by application of zinc fertilizer markedly raised plant height, influenced on effective tillers, increased number of grains as well as grain yield.

Conclusion

The overall results of the research work estimate that the greatest quantity of productive tillers as well as the quantity of grains panicle^{-1} were by sulfur and zinc fertilizer treatment S_3 (18 kg ha^{-1}) and Z_3 (2.5 kg ha^{-1}) fertilizer showed increased yield of rice.

Authors' Contribution

Conceptualization, LRS; Formal analysis LRS, FA, MMU, PD and CK; Methodology, LRS; Investigation, LRS, FA and MMU; Writing- original draft preparation, PD; Writing-reviewing and editing, CK and AAR; Supervision, MMU. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflicts of interests.

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