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Effect of Sulphur and Zinc on Yield Attributes, Yield and Economics of Rice

Waikhom Jiten Singh[1*], Mahua Banerjee[1] and L. Nabachandra Singh[2]

[1]Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, WB-731236, India
[2]Department of Agronomy, College of Agriculture, Central Agricultural University Iroisemba, Imphal West, Manipur-795004, India

**Corresponding author*

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A B S T R A C T

A field experiment was conducted during *kharif* seasons of 2012 and 2013 at KVK Thoubal, Manipur to assess the effect of different levels of sulphur and zinc on yield of *kharif* rice (*Oryza sativa* L).The treatments consisted of four levels of suphur (0, 15, 20 and 25 kg/ha) and four levels of zinc (0, 5, 10 and 15 kg Zn/ha) laid out in factorial randomise block design and which were replicated thrice. Application of 20 kg S/ha recorded highest number of effective tillers/m^2 (233.99), filled grains/panicle (100.95), grain yield (56.3 q/ha), straw yield (64.8 q/ha) and harvest index (46.27%) over the remaining treatment. Regarding test weight also 20 kg S /ha recorded the highest value and least with control (0 kg S/ha). Application of 15 kg Zn/ha recorded highest number of effective tillers/m^2 (237.34), number of filled grains/panicle (99.21), test weight (23.63g), grain yield (55.90 q/ha), straw yield (64.70 q/ha) and harvest index (40.06%), but it was statistically at par with the 10 kg Zn/ha. Significant interaction effect of sulphur and zinc on number of tillers per m^2 of rice was observed in both the years and at pooled with the highest value was observed at $S_{20}Zn_{15}$ (265.70) but remained at par with $S_{15}Zn_{15}$. Significant interaction effect of sulphur and zinc on rice was observed in both years and in pooled mean with highest value of 67.6 q/ha and 71.70 q/ha in $S_{20}Zn_{15}$ for grain yield and straw yield respectively. But this treatment remains at par with $S_{15}Zn_{15}$ and $S_{20}Zn_{10}$ for straw yield. Regarding harvest index also, $S_{20}Zn_{15}$ recorded significantly highest value (48.53%). Regarding the net return highest value was observed at S_{20} Zn_{15} (Rs 29278.38), however highest B: C ratio was recorded with the treatment combination of S_{20} and Zn_5 (0.63).

Introduction

Rice (*Oryza sativa*) the staple food crop of Asia is cultivated approximately in 110 countries of the world and produced 385 million MT. Out of this, 90 % is produced in Asia. It is the major staple food of 70 % of Indian population and ranks second after wheat in the world. It is the staple food crop of southern, eastern and north eastern part of the country particularly in Manipur. In Manipur, rice is major predominated crop occupying about 80 % of the total cropped area of state. With increasing population, the demand of rice in India is increasing and is expected to reach 140 million tons by 2025 against the present production level of 100 million tons (Pandey *et al.,* 2008). Scope for horizontal expansion of production is limited as the cultivated area for the last two decades is almost constant 140$\pm$ 2 m ha (Gill and Singh 2009). The only possible means to meet the ever increasing demand of rice is vertical expansion of production with balanced fertilization.

Till today, the focus for production enhancement was on balanced fertilization of N, P and K but of late it has been realized that many secondary and micronutrients can further boost up the productivity substantially. Among different secondary and micronutrients sulphur and zinc are most important nutrient for rice as deficiency of these two are more common in India. Out of 142 million ha arable land in India, at least 57 million ha that is about 40 % of total, suffers from various degrees of sulphur deficiency (Tripathi, 2003). Sulphur is required for increasing productivity of crops especially legume, oilseed in India where more than 50 % of soil have been reported to be deficient in sulphur (Tewatia *et al.,* 2006).

Next to Sulphur, zinc is also reported deficient from many rice growing regions of the country. In India, analysis of 2.52 *lakhs* surface soil samples collected from different parts of the country revealed the predominance of zinc deficiency on divergent soils. Of these 49, 12, 4, 3, 33 and 41 % soils are tested to be deficient in available zinc, iron, manganese, copper, boron and sulphur respectively (Singh 2004 and Prasad 2006). According to Singh (2011), zinc deficiency in Indian soil is expected to increase from 42 % in 1970 to 63 % by 2025 due to continuous depletion of soil fertility. Almost 50 % of the world soil used for cereal production is zinc deficient (Gibbson 2006). Nene (1966), in India, firstly reported zinc deficiency in low land rice. Afterward it has been recognized as a wide spread and important nutritional problem throughout the rice growing world. According to Brar and Sekon (1976) zinc availability is reduced by flooding owing to the precipitation of zinc as ZnS (under intense reduce condition), $ZnCO_3$ (partial pressure of CO_2 coupled with decomposition of O.M.) and insoluble Zn $(OH)_2$ (in alkaline pH). According to Patrick *et al.,* (1985) zinc is main limited micronutrient of flooded rice. About 80-90 % of soil applied zinc is unavailable to plant due to its various harmful reactions with various soil components like organic matter, clay, sesquioxide etc. So chelated form of zinc (Zn EDTA) may be an alternative source of Zn in crop production (Basal and Nayyar 1989; Karak *et al.,* 2002).

In Manipur, proper investigation for delineation of secondary and micronutrient have not been taken up, but few experimental findings reported that, some pocket of Manipur is low to medium in availability of sulphur and zinc. According to Singh *et al.,* (2006), the available sulphur (0.15% $CaCl_2$ extractable S) range from 10 to 70 mg/kg in thirty seven surface (0-15cm) soil sample collected from different locations of Manipur. Again Sarkar *et al.,* (2002) reported available Fe, Mn was high, Cu and Zn were low particularly in sub surface horizon. Earlier, zinc deficiency was not a problem in Manipur, but now time has come to consider Zn status of the soil. According to Shukla *et al.,* (2016), out of 1860 soil sample collected from Manipur, 18.3 % soil are deficient in zinc.

The responses to the application of these two nutrients have been supported by many finding. Shah and Datta (1991) reported that application of zinc @ 10kg Zn/ha were sufficient to correct Zn deficiency in rice, although the highest grain yield was obtained with 40kg Zn/ha. Modest sulphur response was recorded with 25kgs S/ha application, when 40kg Zn/ha was applied together with S. In contrast, high sulphur level beyond 25kg S/ha decreased grain yield when it was applied with zinc. Positive response for application of sulphur and zinc on rice crop had also been reported by Ranjita (2010) on experiment conducted at CAU Campus, Imphal, Manipur.

Materials and Methods

The study was conducted in *kharif* season for the two consecutive years (2012 and 2013) at the Krishi Vigyan Kendra, Thoubal, Manipur, India located at $24^0$60.84'817''N latitude and 94°00.28'757''E longitude. The soils of the experimental plot had silty clay texture, pH 5.76, organic carbon 0.98 %. Weather conditions like rainfall, maximum and minimum temperature and relative humidity during the crop growth period (June to October) were 112.26 mm, 33.2^{o}C, 16.8^{o}C and 75.4 % during 2012 and 160.62 mm, 34.24^{o}C, 21.6^{o}C and 79.5 % during 2013, respectively. Paddy seeds were grown in a nursery bed following standard methods of nursery raising and transplanted to main field at an age of 25 days. Flooding method of irrigation was applied depending on rainfall pattern during the crop period to maintain water requirement. The treatment consisted of four levels of suphur (0, 15, 20 and 25 kg/ha) and four levels of zinc growth (0, 5, 10 and 15 kg Zn/ha) laid out in FRBD and which were replicated thrice. Sulphur and zinc were applied through bentonite sulphur and zinc EDTA as per treatment before transplanting. In all the treatments, constant dose of 60:40:30 kg; N: P: K /ha were applied. Half amount of N and whole amount of P_2O_5 and K_2O were given before transplanting as basal and remaining half were given in two equal doses at 30th DAT and 60th DAT.

Results and Discussion

Number of tillers/m^2, number of grains/panicle, test weight, grain yield, straw yield, harvest index and economics of rice

Number of tillers/m^2, number of grains/panicle and test weight varied significantly among the treatments. Number of tillers/m^2 and number of grains/panicle increased in the sulphur level up to 20 kg S/ha (Table 1). Tillering is the product of expanding auxiliary buds and is closely associated with nutritional condition of the mother culm during its early growth period, which get improved by application of sulphur as it improve use efficiency of other nutrient particularly nitrogen and phosphorus (Samaraweera 2009 and Asha Ram *et. al.*, 2014). On an average, the highest number of tillers/m^2 and number of grains/panicle at 20 kg S/ha was 17.75% and 8.58 % respectively higher than the lowest in control. Reduction in number of tillers/m^2 and number of grains/panicle was recorded at higher levels of S (25 kg/ha) compared to 20 kg S/ha. Test weight increased with increase in S level up to 20 kg S/ha and increase per cent was 4.02 % higher than control. Likewise, on an average, the highest grain yield, straw yield and harvest index at 20 kg S/ha were 32.47 %, 20.00 % and 5.57 % respectively higher than the lowest in control. Higher grain and straw yield due to S may be attributed to increase in growth and yield character of rice and to the stimulating effect of applied S in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency, which increase the yield. Our findings are supported by the results of Chandel *et. al.,* (2003), Qamar *et. al.,*(2014) and Rahman 2009.

Numbers of tillers/m^2, number of grains/panicle and test weight were significantly higher with 15 kg zinc ha^{-1} (Table 1) by 24.11 %, 8.21 % and 3.32 %

respectively over control, whereas it was statistically at par with 10 kg zinc ha^{-1}. Adequate level of zinc in soil increase tillering and consequently increased number of panicle/m^2 and again as zinc is responsible for pollen formation and seed production, number of grains/panicle is more in zinc applied plot than control. These findings have similarity with result of Meena and Shivay (2010) and Jat *et. al.*, 2011. Zinc as a synthesizer of protein and carbohydrate resulted into bolder seeds compared to control resulting into more test weight. The results are in accordance with finding of Balu *et. al.*, (2014). Highest value of grain yield and straw yield was recorded in 15 kg zinc ha^{-1} (Table 1) which was 39.05 % and 25.15 % respectively higher than control. Higher values of yield attributing characters resulted in higher values of grain yield. Maximum harvest index of 46.09 % was registered with 15 kg Zn ha^{-1} and minimum 43.57 % was observed in 0 kg Zn ha^{-1}. Significant increase in harvest index suggested that plant maintained a higher supply of photosynthates to reproductive parts as compare to vegetative biomass.

These findings have similarity with result of Meena and Shivay (2010) and Jat *et al.*, (2011). Zinc as a synthesizer of protein and carbohydrate resulted into bolder seeds compared to control resulting into more test weight. The results are in accordance with finding of Ram *et al.*, (2014). Highest value of grain yield and straw yield was recorded in 10 kg zinc ha^{-1} (Table 1) which was 23.88 % and 16.28 % respectively higher than control. Higher values of yield attributing characters resulted in higher values of grain yield. Maximum harvest index of 46.08 % was registered with 15 kg Zn ha^{-1} and minimum 44.37 % was observed in 0 kg Zn ha^{-1}. Significant increase in harvest index suggested that plant maintained a higher supply of photosynthates to reproductive parts as compare to vegetative biomass.

Table.1 Effect of sulphur and zinc on number of effective tillers/m2, number of filled grains/panicle and test weight, grain and straw yield and harvest index of rice (Pooled data of 2012-13 and 2013-14)

Treatment	Number of tiller/ m^2	Number of grains/ panicle	Test weight (g)	Grain Yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
S_0	198.72	92.97	22.88	42.5	54.00	43.83
S_{15}	223.69	96.16	23.42	50.50	61.1	45.10
S_{20}	233.99	100.95	23.80	56.30	64.80	46.27
S_{25}	211.67	94.43	23.17	46.40	57.70	44.44
SEm±	**3.86**	**1.07**	**0.13**	**0.90**	**0.80**	**0.14**
CD at 5%	**11.15**	**3.09**	**0.37**	**2.60**	**2.40**	**0.42**
Zn_0	191.23	91.68	22.87	40.20	51.7	43.57
Zn_5	213.17	95.51	23.25	47.40	58.80	44.54
Zn_{10}	226.32	98.11	23.53	52.20	62.30	45.43
Zn_{15}	237.34	99.21	23.63	55.90	64.70	46.09
SEm±	**3.86**	**1.07**	**0.13**	**0.90**	**0.80**	**0.14**
CD at 5%	**11.15**	**3.09**	**0.37**	**2.60**	**2.40**	**0.42**

Table.2 Interaction effect of sulphur and zinc on number of tillers/hill, number of grains/panicle and test weight of rice

	Number of tillers/ hill of rice.					Number of grains/ panicle of rice.						Test weight of rice (g).					
Treatments	Zn_0	Zn_5	Zn_{10}	Zn_{15}	Mean		Zn_0	Zn_5	Zn_{10}	Zn_{15}	Mean		Zn_0	Zn_5	Zn_{10}	Zn_{15}	Mean
S0	5.08	6.10	6.29	6.7	**6.04**	**S0**	87.15	92.36	95.91	96.00	**92.86**	**S0**	23.19	24.07	24.21	24.41	**23.97**
S15	6.08	6.65	7.12	6.94	**6.70**	**S15**	91.51	95.30	99.92	103.77	**97.62**	**S15**	24.08	24.32	24.33	24.71	**24.36**
S20	6.47	6.88	7.35	6.95	**6.91**	**S20**	93.45	96.87	103.04	101.55	**98.73**	**S20**	24.30	24.59	24.63	24.79	**24.56**
S25	6.72	7.22	7.73	5.81	**6.87**	**S25**	96.20	99.11	104.92	92.81	**98.26**	**S25**	24.44	24.79	24.77	24.17	**24.54**
Mean	**6.09**	**6.71**	**7.12**	**6.60**		**Mean**	**92.08**	**95.91**	**100.95**	**98.53**		**Mean**	**24.00**	**24.42**	**24.49**	**24.54**	
	S*Zn						**S*Zn**						**S*Zn**				
SEm±	**0.37**					**SEm±**	**3.00**					**SEm±**	**0.27**				
CD at 5%	**0.76**					**CD at 5%**	**6.13**					**CD at 5%**	**0.55**				

Table.3 Interaction effect of sulphur and zinc on grain yield, straw yield and harvest index of rice

	Grain yield of rice (q ha^{-1}).					Straw yield of rice (q ha^{-1}).						Harvest index of rice (%).					
Treatments	Zn_0	Zn_5	Zn_{10}	Zn_{15}	Mean		Zn_0	Zn_5	Zn_{10}	Zn_{15}	Mean		Zn_0	Zn_5	Zn_{10}	Zn_{15}	Mean
S0	33.82	44.70	48.01	51.70	**44.56**	**S0**	44.70	55.95	59.36	62.30	**55.58**	**S0**	43.05	44.42	44.70	45.31	**44.37**
S15	44.12	50.69	57.05	58.52	**52.60**	**S15**	56.00	61.79	66.28	66.75	**62.71**	**S15**	44.06	45.06	46.26	46.70	**45.55**
S20	48.33	53.80	61.12	57.50	**55.20**	**S20**	59.69	64.14	68.42	66.28	**64.63**	**S20**	44.76	45.60	47.15	46.45	**45.99**
S25	51.89	58.42	66.14	42.88	**54.83**	**S25**	62.49	66.74	70.86	64.47	**63.64**	**S25**	45.36	46.65	48.28	44.01	**46.08**
Mean	**44.55**	**51.90**	**58.08**	**52.65**		**Mean**	**55.72**	**62.15**	**66.23**	**62.45**		**Mean**	**44.31**	**45.43**	**46.62**	**45.62**	
	S*Zn						**S*Zn**						**S*Zn**				
SEm±	**3.93**					**SEm±**	**2.27**					**SEm±**	**0.49**				
CD at 5%	**8.03**					**CD at 5%**	**4.63**					**CD at 5%**	**1.00**				

Significantly highest tiller per plant, grains per panicle, grain yield, straw yield and harvest index was obtained with the treatment combination $S_{25}Zn_{10}$ (Table 2 and 3) but statistically on par with some other treatment combinations including $S_{20}Zn_{10}$ and $S_{25}Z_5$. But, for test weight $S_{20}Zn_{15}$ recorded highest value. Antagonistic effect of interaction was observed at highest levels of sulphur and zinc i.e. $S_{25}Zn_{15}$. Similar observation was also reported by Rasvel and Rivechandran (2013).

Regarding the net return per rupees invested highest value was observed at S_{20} and Zn_5 (Rs 0.54 and Rs 0.46 respectively).

From the above finding, it can be concluded that zinc and sulphur play a role in yield attributes and yield of transplanted rice. Even though the highest grain yield (66.14 q/ha) was observed in treatment combination $S_{25}Zn_{10}$ it is preferable to recommended lower dose of zinc and sulphur i.e. $S_{20}Zn_5$ (57.05 q/ha) as higher dose zinc for soil application is not cost effective.

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