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INFLUENCE OF ZINC NUTRITION ON YIELD, YIELD ATTRIBUTING CHARACTERS AND ECONOMICS OF RICE CULTIVATION

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ABSTRACT

Field experiment was conducted during four consecutive *kharif* seasons of 2016-2019 at Regional Agricultural Research Station, Karjat, Maharashtra on clay loam soil to study the potential of zinc and sulphur nutrition on yield, yield attributing characters and economics of rice. Application of 100% recommended dose of fertilizer (RDF) + soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting significantly increased plant height (106.60 cm), number of tillers (12.5), length of panicle (21.30 cm), kernel $panicle^{-1}$ (107.35), 100 kernel weight (24.32 g) and also registered higher magnitude of grain yield (50.65 q ha^{-1}) and dry matter (56.74 q ha^{-1}) of rice. The higher net return and benefit:cost ratio (1.37) was exhibited with application of 100% recommended dose of fertilizer (RDF) + soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting, however, the 100% RDF and the absolute control treatments were registered the lower gross and net return.

(Keywords: Rice, zinc, soil application, yield, economics)

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for 50% of the world population and grown on 43.79 M ha area with production of 112.91 MT and productivity of 2.57 t ha^{-1} (Anonymous, 2019). According to Vision 2050 , India will require 137.3 MT of rice by 2050 and there may be decline in rice area by 6–7 Mha by 2050 due to urbanization, competitive crops and industrialization etc. Among nutrient deficiencies, Zn deficiency has been identified as a most serious agricultural issue in world which is a well known nutritional and health problem in human populations where rice is the dominating staple food (Stein, 2010). In addition to high yielding cultivars and heavy fertilizer inputs, Zn deficiency in rice may also induced by several other factors including high soil pH, excess bicarbonate and low redox potential. Yoshida *et al*. (1970) studied several methods for correcting Zn deficiency in rice and concluded that soil or foliar application of $ZnSO_4$ was as effective as dipping seedling roots in 1 % ZnO suspension but, the cost of the later method was cheaper.

Zinc is involved in growth, enzyme activation, metabolism of carbohydrate, lipids, nucleic acids, gene expression, regulation, protein synthesis and reproductive development of plants. Its availability to plants limits due to inherently infertile soils, micronutrient depletion by intensification of cultivation and poor mobility of Zn into and within the plant. To overcome these problems, it is essential to identify efficient agronomic management methodologies to increase the availability of zinc. Zn exists in various pools with different rates of solubility, mobility and plant availability (Adriano, 2001). This partitioning of Zn is influenced by soil pH, clay content, organic matter and sesquioxides. Therefore, zinc application methods and sources are aimed at improving Zn availability for plant uptake. Zn can be applied to soil, seed and leaves (Johnson *et al*., 2005) and by dipping seedlings into a fertilizer solution. Zinc fertilization to cereal crops improves productivity and Zn concentration (Phattarakul *et al*., 2012) in grain and thus improves grain nutritional value for human beings. To mitigate this limiting effect, this study was aimed to investigate the application of Zn by different methods such as soil application, foliar application, deeping seedling roots in solution on zinc nutrition, yield and yield attributing characters and economics of rice.

MATERIALS AND METHODS

Field experiment was conducted at Regional Agricultural Research Station, Karjat, Maharashtra, India during *kharif* seasons of 2016-2019. The study area is geographically located at $18^0$91' N latitude and $73^0$32' E longitude at an altitude of 51.75 m above mean sea level (MSL). The soil of the experimental field is clay loam in texture a member of *fine loamy mixed isohyperthermic* family of *Typic Haplutepts* subgroup. The available nitrogen (141.12 kg ha^{-1}) was low, medium in available phosphorus

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(13.78 kg ha^{-1}) and potassium (321.40 kg ha^{-1}), Organic carbon was 9.8 g kg^{-1}, pH (1:2.5 soil water suspension) 6.7, EC 0.19 dS m^{-1}, diethylene triamine penta acetic acid (DTPA) extractable Zn (0.34 mg kg^{-1}) determined by Lindsay and Norvell (1978) and SO_4-S (19.13 mg kg^{-1}) in soil was estimated by Chesnin and Yien (1951). After chemical analysis of straw and grain samples, Zn and S nutrient uptake was calculated by multiplying Zn and S concentrations with their respective plot yield of grain and straw of rice crop by using the following formula as described by Sharma *et al*. (2012).

$$NU = \frac{NC \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

Where;

NU = Nutrient uptake,

NC = Nutrient content (%)

The experiment was laid out in randomized block design, replicated thrice using cv. KJT-3 the test variety with twelve treatments (Table 1). The recommended dose of fertilizer viz., 100:50:50 kg NPK ha was applied to all the plots except absolute control where N was applied through urea (46 % N) in three splits *viz*., half at basal and remaining at active tillering and panicle initiation stages, P through single super phosphate (16 % P_2O_5) and K was applied in the form of MOP (60 % K_2O) at the time of transplanting. The Zn applied in this study was in the form of as $ZnSO_4.7H_2O$ and ZnO through root dipping @ 0.5%, soil application @ 15 and 30 kg ha^{-1} at the time of transplanting and 30 DAT; foliar spray @ 0.5 and 1 % at establishment of seedlings and 30 DAT to the respective treatments.

All other cultural practices were kept same and uniform for all treatments. Randomly five plants were selected to measure the plant height in cm from the base of the plant to the tip of the ear of main tiller at harvest stage, length of panicle and number of tillers hill^{-1} was counted. At crop harvesting, rice plants were manually harvested from 1 m^2 area in the center of each plot. These plants were used to determine grain yield and its components after separating into straw and grains. Dry weight of straw was determined after oven-drying at 70°C to constant weight. Economics was calculated based on the cost of prevailing market rate of inputs and yield of rice. Gross and net returns were calculated along with benefit: cost ratio.

RESULTS AND DISCUSSION

The grain and straw yield of rice significantly increased to the tune of 15 and 16% respectively with the application of zinc. The results are in confirmation with Sudha and Stalin (2015). They reported that the grain yield (4623 to 7434 kg ha^{-1}) and straw yield (6657 to 10041 kg $^{-1}$) of different rice of genetypes significantly increased with the application of Zn in which grain and straw yield were increased by 14 and 16 per cent respectively. A significant increase in grain and straw yield of rice was obtained with the application of recommended dose of fertilizer (RDF) + application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} through soil at the time of transplanting. The better response of rice to $ZnSO_4.7H_2O$ was due to being more water soluble as compared to ZnO, which is less soluble in water. Slaton *et al*. (2005) also reported that Zn fertilizer $ZnSO_4.7H_2O$ having 100% water soluble Zn (WSZn) produced significantly more rice grain than ZnO containing only 14% WSZn. Water soluble Zn is more mobile and can easily absorbed by rice plant roots. Giordano and Mortvedt (1972) reported that the movement of Zn fertilizer after 4 weeks after application of $ZnSO_4.7H_2O$ was 20 mm and for ZnO was 5 mm. Higher yield could be attributed to higher N availability and other micronutrient cations into the soil (Pooniya *et al*., 2018). KJT-3 exhibited highest HI which is directly linked with efficient partitioning of photosynthates between harvesting and non-harvesting parts, besides, the economic produce has close association with plant development. Consequently, the differences in photo synthates' partitioning besides varying sink and source relationships of different genotypes perhaps led to a significant variation in HI (Choudhary and Suri , 2018).

Plant height, tillers number, length of panicle, crop growth rate and root volume of a plant depends on the genotype, environment as well as the plant nutrition. Plant height is an important morphological attribute; it is a function of combined effects of genetic makeup of a plant, soil nutrient status, seedling vigor and the environmental conditions under which it is grown. Crop growth rate of rice was found to be significantly influenced by zinc application through (Table 1). The significantly highest plant height was observed with Zn application through soil. The higher magnitude of plant height (106.60 cm) was recorded from the treatment receiving 15 kg Zn ha^{-1} through soil application which differs significantly from the other treatments. Minimum plant height was recorded with absolute control (T_1).

The tillers hill^{-1} of rice plant as affected by different methods of Zn application and significantly maximum number of tillers recorded with the application of 15 kg Zn ha^{-1} through soil application over control. Tillering capacity is one of the most important rice components which are responsible for yield production. Maximum numbers of tillers hill^{-1} of 12.5 were recorded for T_7 (RDF+Soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting) followed by T_8 (RDF+Soil application of $ZnSO_4.7H_2O$ @ 30 kg ha^{-1} at the time of transplanting and 30 DAT); while the minimum tillers numbers was recorded in T_1. The increased of tillers number by soil application of Zn may be attributed due to increase of nutrients availability in soil compared with other treatments. Further, adequate supply of zinc that might had increased the uptake and availability of other essential nutrients, which resulted in improvement of plant metabolic process and finally increased the crop growth. These results are in accordance with Naik and Das (2007), who reported adequate supply of zinc produced more number of productive tillers m^{-2}. The combined application of Zn with organic manures and foliar application with respect to increment in plant growth, yield and productivity of pulse crops also reported by Yashona *et al.* (2018)

The panicle length, grains panicle^{-1} and 1000 grain weight in rice were found higher following zinc application through soil. The results indicated that Zn application @ 15 kg ha^{-1} through soil (T_7, T_8 and T_6) significantly increased the number of panicles m^{-2} compared with T_1 (Table 1). The highest length of panicles (21.30cm), grains panicle^{-1} (107.35) and 1000 grain weight (24.32g) were recorded in T_7 followed by T_8 and T_6, while, the minimum length of panicles of rice plant was recorded in T_1. Application of $ZnSO_4.7H_2O$ exhibited higher length of panicles, grains panicle^{-1} and 1000 grains weight over absolute control. Increase in yield attributes and yield of rice with Zn through soil application enhanced rice grain yield as compared to foliar spray might be due to higher Zn uptake, resulting into higher biomass production (Guo *et al.*, 2016) and photosynthates translocation to reproductive parts. Significant enhancement in plant height, leaf area, total dry matter production, number of branches at harvest, harvest index and seed yield hectare^{-1} of lathyrus with the combine application of zinc and iron at the rate of 0.5% each at 25 and 40 DAS was also reported by Pise *et al.* (2019).

Zn concentrations and uptake

Zn concentration in grain and straw were increase significantly by application of zinc. Among different methods, the soil application method recorded highest Zn in grain and straw. Regarding Zn uptake, the application of $ZnSO_4.7H_2O$ through soil significantly improved the Zn uptake in grains and straw which is directly associated with higher biomass productivity of the cultivar. Total Zn uptake (191.31g ha^{-1}) by rice was registered significantly highest to the tune of +20.54 and +7.73 g ha^{-1} in grains and straw with application of $ZnSO_4.7H_2O$ which was improved by Zn fertilization compared to absolute control. In case of Zn concentration in grain, significantly lowest Zn concentration was recorded in absolute control followed by RDF both in grains and straw and registered highest Zn concentrations in grain (52.55 g ha^{-1}) and in straw (138.76 g ha^{-1}), and recorded highest Zn uptake with application of $ZnSO_4.7H_2O$. It indicates that higher biomass production by respective treatment led to higher Zn uptake both in grains and straw (Pooniya *et al.*, 2018). Under waterlogged situations, Zn deficiency is more acute due to reduced Zn availability and its uptake, besides suppression caused by high levels of Fe^{2+} and Mn^{2+} concentrations (Shivay *et al.*, 2010). Kutman *et al.* (2010) reported positive interaction of Zn × N in cereals and this positive interaction lead to improvement in Zn uptake through roots and its translocation to the sink.

S concentration and uptake

Sulfur fertilization increased crude protein and sulfur concentration in rice grain. Thus, sulfur fertilization increased both grain yield as well as sulfur concentration in rice grain. A positive relationship between grain yield and sulfur concentration in rice grain due to sulfur fertilization was reported by Randall *et al.* (2003). Total S uptake increased from 20.69 to 48.98 kg ha^{-1}. The total S (48.98 kg ha^{-1}) uptake by rice was recorded highest with RDF+soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting which was significantly higher than RDF and absolute control. Among the Zn fertilization, soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting recorded higher S concentration in rice grain (25.84 kg ha^{-1}) and straw (23.18 kg ha^{-1}). Increases in S uptake due to S application were reported by Sarkar *et al.* (2007) and by Laksmanan and Prasad (2004). This combined analysis suggests that for better output and for balanced nutrition combined application is advocated.

Economics of Zn application in rice

The gross return and net return was higher with the application of 100% RDF + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting as basal dose (Rs. 1,03,278/- and Rs. 28,056/-, respectively). The application of RDF along with zinc nutrition was effective to enhance the economic yield and in turn increased the net return. Lowest gross and net returns were in 100% RDF alone without zinc application (Rs. 89,692/- and Rs. 23,070/-, respectively) and in absolute control (Rs.70,061/- and Rs.10,498/-, respectively) due to less cost of cultivation and lesser yield. Higher B:C ratio of 1.37 was with the application of 100% RDF + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting.

On the basis of results of present investigation it can be safely concluded that among the different treatments 100% NPK (Recommended dose of fertilizer) with the application + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting as basal dose increased yield and yield attributing characters of rice uptake of Zn and S in turn which increased the yield of the crop. The zinc nutrition as basal acquired the higher net return, gross return and benefit:cost ratio, which were adjudged as best treatments under submerged condition of medium black soil of Konkan region of Maharashtra.

Table 1. Effect of zinc fertilization on yield and yield attributes and productivity of rice crop (pooled data)

Treatments	Plant height at harvest (cm)	No. of tillers $hill^{-1}$	Panicle length (cm)	No. of grains $panicle^{-1}$	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1- Absolute Control	84.1	9.9	16.8	84.84	16.66	34.36	38.49
T_2- RDF (100:50:50 NPK kg ha^{-1})	96.9	11.4	19.4	97.61	21.21	44.02	48.98
T_3- RDF + Root dipping of rice seedlings before transplanting @ 0.5% ZnO solution	98.1	11.5	19.6	98.95	22.03	45.38	49.91
T_4- RDF+Root dipping of rice seedlings before transplanting @ 0.5% $ZnSO_4.7H_2O$ solution	100.0	11.8	20.0	100.80	22.18	45.46	50.22
T_5- RDF+Soil application of ZnO @ 15 kg ha^{-1} at the time of transplanting	97.9	11.5	19.6	98.62	22.85	46.59	51.66
T_6- RDF+Soil application of ZnO @ 30 kg ha^{-1} at the time of transplanting and 30 DAT	103.6	12.2	20.7	104.33	23.34	48.65	54.89
T_7- RDF+Soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting	**106.6**	**12.5**	**21.3**	**107.35**	**24.32**	**50.65**	**56.74**
T_8- RDF+Soil application of $ZnSO_4.7H_2O$ @ 30 kg ha^{-1} at the time of transplanting and 30 DAT	104.9	12.3	21.0	105.67	23.67	49.37	54.77
T_9- RDF+ Foliar application of ZnO @ 0.5% after establishment of seedlings	97.9	11.5	19.6	98.78	21.59	44.19	48.75
T_{10}- RDF+ Foliar application of ZnO @ 1% after establishment of seedlings and 30 DAT	99.0	11.6	19.8	99.79	21.87	44.85	49.10
T_{11}- RDF+ Foliar application of $ZnSO_4$. $7H_2O$ @ 0.5% after establishment of seedlings	100.2	11.8	20.0	101.14	22.47	45.84	50.81
T_{12}- RDF+ Foliar application of $ZnSO_4$. $7H_2O$ @ 1% after establishment of seedlings and 30 DAT	102.3	12.0	20.5	103.15	22.71	46.44	51.67
S E ± (m)	0.81	0.10	0.16	0.81	0.17	1.15	1.41
C D @ 5 %	2.37	0.28	0.47	2.37	0.49	3.45	4.22

Table 2. Effect of zinc fertilization on uptake of nutrients and economics of rice (pooled data)

Treatments	Zn Concentration (g ha^{-1})		Total Zn uptake (g ha^{-1})	S Concentration (kg ha^{-1})		Total S uptake (kg ha^{-1})	Cost of cultivation (Rs.)	Total Gross returns (Rs.)	Net returns (Rs.)	B:C Ratio
	Grain	Straw		Grain S	Straw S					
T_1	9.31	24.73	34.01	11.58	9.21	20.69	59563	70061	10498	1.18
T_2	12.77	33.82	46.59	16.48	13.50	29.87	66622	89692	23070	1.35
T_3	18.15	47.47	65.62	17.42	14.15	31.46	68247	92347	24100	1.35
T_4	29.24	76.85	106.08	18.47	15.33	33.70	68622	92554	23932	1.35
T_5	36.81	97.15	133.96	19.38	16.26	35.56	72972	94893	21921	1.30
T_6	42.90	115.25	158.15	20.40	17.62	37.92	79322	99278	19956	1.25
T_7	49.58	132.17	181.75	25.84	23.18	48.98	75222	103278	28056	1.37
T_8	52.55	138.76	191.31	22.73	19.67	42.34	83822	100561	16739	1.20
T_9	23.11	60.67	83.78	18.33	15.28	33.52	68047	89995	21948	1.32
T_{10}	26.15	68.15	94.30	18.33	15.07	33.31	69072	91223	22151	1.32
T_{11}	30.05	79.30	109.36	19.17	16.10	35.19	68422	93362	24940	1.36
T_{12}	36.95	97.88	134.84	23.05	20.33	43.22	69822	94623	24801	1.36
S E± (m)	6.50	5.53	13.90	0.57	0.50	0.87	-	-	-	-
C D @5%	19.24	16.36	41.17	1.90	1.66	2.92	-	-	-	-

T_1- Absolute Control, T_2- RDF (100:50:50 NPK kg ha^{-1}), T_3- RDF + Root dipping of rice seedlings before transplanting @ 0.5% ZnO solution, T_4- RDF+Root dipping of rice seedlings before transplanting @ 0.5% $ZnSO_4.7H_2O$ solution, T_5- RDF+Soil application of ZnO @ 15 kg ha^{-1} at the time of transplanting, T_6- RDF+Soil application of ZnO@ 30 kg ha^{-1} at the time of transplanting and 30 DAT, T_7- RDF+Soil application of $ZnSO_4.7H_2O$ @ 15 kg ha^{-1} at the time of transplanting, T_8- RDF+Soil application of $ZnSO_4.7H_2O$ @ 30 kg ha^{-1} at the time of transplanting and 30 DAT, T_9- RDF+ Foliar application of ZnO@ 0.5% after establishment of seedlings, T_{10}- RDF+ Foliar application of ZnO @ 1% after establishment of seedlings and 30 DAT, T_{11}- RDF+ Foliar application of $ZnSO_4.7H_2O$ @ 0.5% after establishment of seedlings and T_{12}- RDF+ Foliar application of $ZnSO_4.7H_2O$ @ 1% after establishment of seedlings and 30 DAT

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