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Original Research Article

The Effect of Zinc Fertilization on Rice Productivity and Economics in Acid Alfisol of Jharkhand, India

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Keywords

Zinc, Sterility percentage, Yield, Rice and BCR

A B S T R A C T

A field study was conducted to evaluate the effect of zinc (Zn) Fertilizer application to soil alone and in combination with foliar application on yield, yield components and nutrient Concentration. The field experiment was carried out at Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University (BAU), Ranchi during 2012 and 2013 kharif season The treatments consisted of control (T_0), 5 kg Zn ha^{-1}(T_1), 10 kg Zn ha^{-1} (T_2) and 5 kg Zn ha^{-1} + 2 foliar sprays (T_3). The basal dose of NPK at the rate of 80:40:30 kg ha^{-1} respectively, was applied to all treatments. The treatments were arranged in randomized complete block design with three replications. Results showed that soil alongwith foliar application of Zn of produced significant impact on the grain yield and its components i.e., number of grains per spike, 1000-grain weight and sterility percentage. The lowest grain yield (3.9 t ha^{-1}) was recorded with control treatment and maximum yield was observes in treatment T_2 (4.38 t ha^{-1}) which is at par with T_3 (4.37 t ha^{-1}). Maximum net benefit was found in treatment T_3 (Rs 5490) and maximum benefit cost ratio was found in T_1 (3.6).

Introduction

In general, soils used for cereal production in the world containing low levels of plant available micronutrient, reduces not only grain yield, but also nutritional quality. Low fertile soils are brought under cultivation due to high population pressure. Micronutrient deficiency is being paid more attention in recent times in areas where intensive agriculture is practiced. Depletion of micronutrients in soil has been accelerated by increase of intensive cultivation with increased dependence on inorganic fertilizer and decreasing emphasis on the use of organic manures and in addition with use of high yielding varieties.

Rice is one of the most important food grain crops of the world and it is the second most widely consumed in the world after wheat. Zinc deficiency is a well known nutritional and health problem in human populations where rice is the dominating staple food crop (Stein, 2010). Among nutrient deficiencies, Zn deficiency has been identified as a most serious agricultural issue in world. Forty three percent of Indian soils and twenty percent of Jharkhand soils (Shukla *et al*.,2014) are deficient in zinc

Zinc is an essential element for normal growth and metabolism of plant plays an important role in membrane integrity, synthesis of carbohydrates, enzymes activation such as dehydrogenase, carbonic anhydrase, superoxide dismutase, alkaline phosphatase etc. (Singh *et al*.,2005).

The main reason of deficiency of plant available Zn in soil is the precipitation or adsorption of Zn with various soil components, depending on the pH, organic matter, pedogenic oxides and redox potential. Soil zinc found in soil solution, as the free ion Zn^{2+} associated with organic and inorganic ligands, on exchanged sites of soil, bound by organic matter and occluded in oxides and hydroxides of Al and Fe (Havlin *et al*., 2005).

Soil and foliar applications of Zn may increase grain Zn concentration in rice, soil Zn application has been reported to increase grain yield whereas foliar-Zn application increased grain concentration of Zn (Wissuwa *et al*., 2008). Khan *et al.,* (2008) reported that zinc sulphate application increased the number of spikelets per spike, spike length, grain per spike, thousand grain weights.

Keeping in view the importance of zinc nutrition and its use efficiency in rice, a field experiment was conducted to study the effect of Zn fertilization rice productivity.

Materials and Methods

A field experiment was conducted during 2012-2013 at Department of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Ranchi, Jharkhand, India. The soil used in the experiment belongs to Alfisol. Before imposition of zinc treatments, the soils used in the experiment had the following properties viz., pH 4.68, EC 0.395 dSm^{-1}, organic carbon 0.41%, KMnO4-N 330 kg ha-1 , Bray –P1 30.63 kg ha^{-1} , NH4OAc- K 140.5 kg ha^{-1} and DTPA Zn 1.08 mg kg^{-1}.

Four rates of zinc were applied and the rates of 0 (T_0), 5.0 (T_1), 10 (T_2) and 5 kg Zn ha^{-1} + 2 foliar sprays @0.5% of $ZnSO_4$. H_2O at tillering and before flowering stage (T_3) were applied using zinc sulfate monohydrate.

Half of nitrogen, total phosphorus and total potassium was applied as basal dose in the form of Urea, DAP and MOP (80:40:30) at the time of transplanting and one fourth of nitrogen was top dressed after 25 DAT and rest one fourth after 50 DAT in the form of urea in split doses.

At the time of foliar spray the pH of zinc sulphate solution was adjusted to neutrality by adding lime. The experimental design was performed using Randomized Block Design (RBD).

Soil samples were collected randomly from four different places from each plot and then made a composite sample. At maturity, weight of 1000 seeds, length of the panicle, total number of grains per panicle, number of unfilled grains per panicle has been counted. Grain yield and straw yield has been measured and sterility percentage, harvest index and BCR were calculated.

Results and Discussion

Yield attributing parameters

The yield parameters having an overall reflection into the final grain yield assume great importance and hence the impact of different level of Zn application also seems to be worth analyzing. The yield attributing parameters like total number of grains, number of unfilled grains, sterility percentage, panicle length, number of spike per panicle and 1000 grain weight recorded under different levels of Zn application have been presented in table 1.

Data presented in Table 1, (Fig 1) revealed that foliar application of zinc significantly improve 1000 grain weight. Increase in 1000 grain weight due to foliar application of Zn was also reported by Khan *et al*., (2008) and Asad and Rafique (2008).

Foliar application of Zn increased the total number of grains per panicle as reported by Karim *et al*. (2012) and Khan *et al*. (2008). Foliar application of Zn has been reported to increase the viability of pollen grains ultimately reducing the sterility percentage. (Karim *et al*., 2012).

From the sterility point of view, the levels of Zn application contributed towards reducing the sterility percentage. The level T_1 could bring about significant reduction in sterility percentage, the highest reduction recorded in case of T_3.

The impact of different levels of Zn application on panicle length was non significant. Similarly, the number of spike per plant was also found independent of the levels of Zn application as the nominal increase in number of spike per plant was non significant.

Yield and harvest index

The pooled data (Table2, Fig 2) revealed significantly superior grain yield under the levels of zinc application (T_1, T_2 and T_3) over the control (T_0). The response of crop to different levels of zinc application, in terms of grain yield seems to be positive.

Differences among the levels were non significant. Application of Zn is helpful for increasing the grain yield as reported Boorboori *et al*., (2012) and Khan *et al*., (2008).

The straw yield under T_1 was superior over the control but the straw yield obtained under T_2 and T_3 were at par with control. Among the levels (T_1, T_2 and T_3), all were at par with each other. It is noted here that application of Zn could significantly increase the straw yields only under the Zn application level ZL1 whereas subsequent two levels exhibited reduced straw yield compared to ZL1, but was still higher than control (ZL0). Naik and Das (2010), Shaheen *et al*., (2007) and Khan *et al*., (2008) reported that the straw yield increased with Zn application.

The harvest index, an indicator of partitioning of plant metabolites into different plant parts, the highest harvest index was recorded in case of T_2. However, the differences in harvest index were non-significant. Similar result was also observed by Keram *et al*., 2013 in wheat crop.

The most notable thing is that the foliar application of zinc could not improve the partitioning and thus, partitioning behavior of crop under T_2 was better than T_3. It give an inference that the level of Zn application into the soil at a rate of 10 kg Zn ha^{-1} under ZL2 could be supposed to be better in partitioning than the rest of the levels of Zn applications as also reported by supported by Narwal *et al*. (2010).

Apart from all such observation, it is also true that dose of soil Zn application level T_3 was 5 kg less than that of the dose under T_2, both giving the same grain yield. Hence, T_3 could now be considered the best among all the levels of Zn application wherein the under dose of 5 kg per ha (compared to T_2) is compensated by two foliar application of 0.2 % Zn.

Table.1 Effect of Zn treatments on yield attributes of rice (*Oryza sativa* L.) on the basis of two years average data (2012and 2013)

	1000 Grain weight (g)	Panicle length (cm)	No. of spike per plant	Total number of grains per panicle	Number of unfilled grains per panicle	Sterility (%)
T0	22.3	22.9	11	143	13.7	9.9
T1	22.9	23.1	11	150	13.4	9
T2	24.3	23	11.5	154	12.7	8.4
T3	24.8	22.9	12	156.5	11.3	7.3
CD at 5 %	1.4	NS	NS	5.7	NS	1.4
CV %	6.9	4.3	6	4.5	19.1	18.9

Table.2 Effect of Zn treatments on yield and content (plant and soil) of rice (*Oryza sativa* L.) on the basis of two years average data (2012and 2013)

	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index	Zn content (mg kg-1)		
				Brown rice	Straw	Soil
T0	3.9	8.85	30.4	21.6	67.7	2.43
T1	4.26	9.76	30.5	21.9	67.4	2.98
T2	4.38	9.34	31.9	22.5	73.7	3.73
T3	4.37	9.54	31.6	25.1	74.7	4.64
CD at 5 %	3.4	7.4	NS	1.2	4.7	0.21
CV %	9.6	4.8	8.4	6.4	7.9	7.45

Table.3 Economic analysis of rice grain yield regarding application of Zn on the basis of two years average data (2012 and 2013)

	Yield (q/ha)	**Yield Advantage (q/ha)**	**Cost of output (Rs.)**	**Cost of input (Rs.)**	**Net benefit (Rs.)**	**B:C**
T1	42.6	3.6	5460	1200	4260	3.6
T2	43.8	4.8	7260	2400	4860	2
T3	43.7	4.7	7110	1620	5490	3.4

Fig.1 Crop response to different levels of zinc on yield and sterility percentage in rice

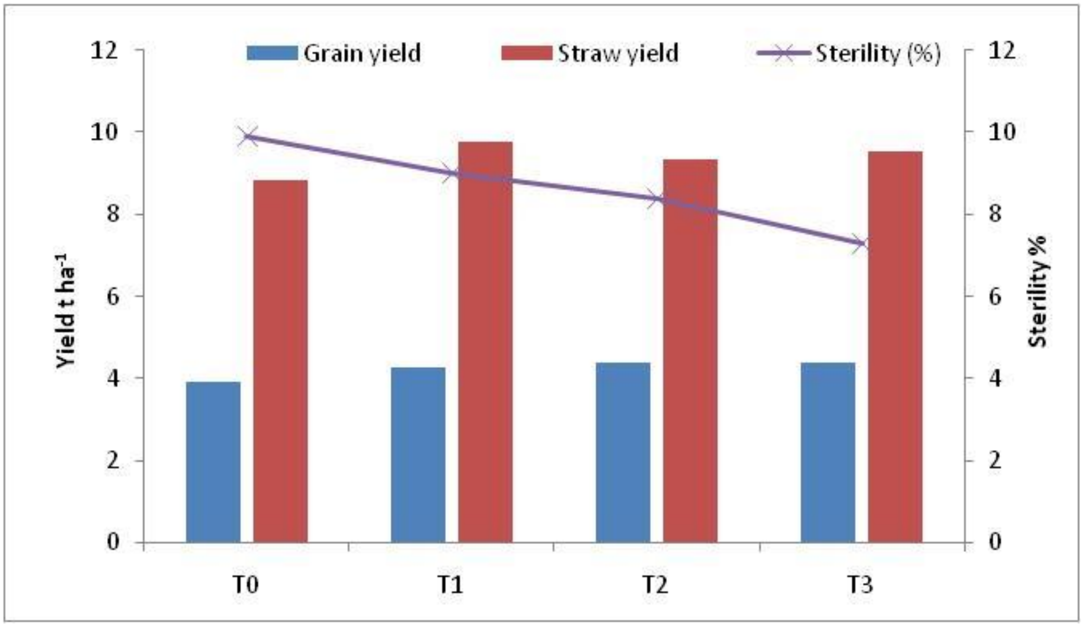
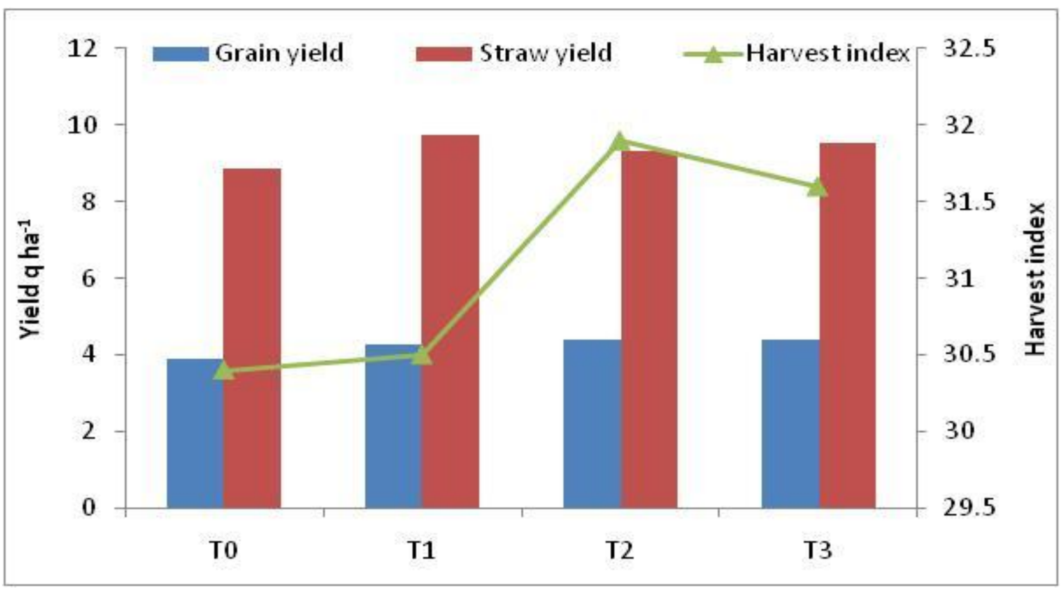


Fig.2 Crop response to different levels of zinc on yield and harvest index in rice



Zn content in grain and straw

Zn content (Table2) in straw was non significantly increased by different levels of Zn application whereas in case of brown rice only the contribution of T_3 was significant and T_1 and T_2 were at par with each other and with control. Graham *et al.,* (1999) reported that concentrations of zinc in rice grain ranged from 15.9 to 58.4 mg kg^{-1}. Highest brown rice Zn content was observed in level T_3 (25.1 mg kg^{-1}) where Zn was applied as soil and foliar also. Foliar application of Zn was found effective in increasing whole grain Zn contents as reported by various workers (Phattarakul *et al*., 2011 and Zhang *et al*., 2012).

Soil Zn content

Soil sample was taken for Zn content analysis after harvesting (Table2). The levels of Zn application (T_1 to T_3) could maintain significantly higher soil Zn content than soil Zn content under control (T_0). Among all levels, T_3 has been found to bring about the highest positive impact with respect to soil Zn content and its utilization by the rice plant.

Economic analysis

An economic analysis (Table 3) demonstrated that application of Zn @ 5 kg ha^{-1}+two foliar sprays produced the highest net return of Rs.5490/- with benefit cost ratio (BCR) of 3.4 followed by 10 kg Zn ha^{-1} (Rs. 4860.00/-) with BCR of 2.0. It is obvious from the results that Zn @ 5 kg ha^{-1} 5 kg ha^{-1}+two foliar sprays proved economical and cost-effective.

In conclusion, application of Zn to soil in addition with foliar @5 kg Zn ha^{-1} + 2 foliar sprays (0.5% at tillering and before flowering) is helpful in enhancing the grain Zn content, reducing sterility percentage and increasing the net benefit by reducing the cost of input.

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