Zinc Fertilization: Effects on Nutrients Availability and Productivity of Rice (*Oryza sativa* L.)

ABSTRACT

In India, zinc is considered as the fourth important yield limiting nutrient after nitrogen, phosphorus and potassium and it is essential for increasing crop production and enhancing animal and human health. To address these challenges, zinc fertilizations (basal & foliar) are practised for enhancing the soil health and crop productivity. The two years (2020-21 & 2021-22) on farm trial established at farmers field of district Saran, Bihar with the aim to compare the methods of zinc fertilization on plant available nutrients and crop productivity. An on farm trial was laid out in randomised block design involved seven replication of three different treatments *viz*., T_1: NPK- 130:40:20 kg ha^{-1} (Farmer's Practice), T_2: RDF (NPK-120:60:40 kg ha^{-1} + Zn @ 5.0 kg ha^{-1} and T_3: RDF (NPK-120:60:40 kg ha^{-1}) + foliar spray of 0.5 % $ZnSO_4$ at 25 DAT. The pooled results of two years trial revealed that basal application of RDF-NPK and Zn (T_2) significantly improved the soil organic carbon by 16.22%, plant available N by 11.96 %, plant available P by 15.32%, plant available K by 10.99% and plant available Zn by 24.00 % as compared to farmers practice. The crop productivity was also improved by 24.22% and 14.43% in treatment having basal application of Zn (T_2) and foliar application of Zn (T_3), respectively over farmers practice (T_1). A positive polynomial relationship was obtained between soil organic carbon and plant available zinc due to soluble complexes form by zinc with soil organic matter. Thus, the basal fertilization method of zinc @ 5.0 kg ha^{-1} along with RDF-NPK is potentially recommended over foliar method and farmer practices to semi arid region of Bihar.

Key words: Zinc, nutrient availability, productivity and rice

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than 50% of the world's population including regions of high population density and rapid growth. The global population is 7.55 billion presently and is expected to reach 9.10 billion by the year 2050 [1]. Human consumption accounts for 85 percent of total production of rice compared with 72 percent of wheat [2]. At present, rice production alone consumes nearly 24.7

MT. of fertilizer ($N+P_2O_5+K_2O$) which accounts for approximately 14.0 % of the total global fertilizer consumption in a year and in India it accounts for 31.8% of the total fertilizer consumption [3].

Crops grown in arid or semi-arid regions are mostly exposed to low soil fertility and exhibit multiple nutrient deficiencies due to low soil organic matter and alkaline calcareous nature of soil that limit the crop production [4].The nutrient deficiency can be corrected by applying appropriate micronutrient containing fertilizers. The nutrients can be applied to the crop plants by a variety of ways like soil application and foliar spray. Every method of application has its advantages and disadvantages [5], depending upon the soil and climatic conditions of the area.

Micronutrients are essential for increasing crop production and enhancing animal and human health. In India, zinc is considered as the fourth important yield limiting nutrient after nitrogen, phosphorus and potassium [6]. The critical limit of available zinc in the soil, suitable for rice growth is 0.6 mg kg^{-1}. Soil application of zinc increased the grain yield [7], and plant available nutrients [8].

Zinc deficiency is a well known nutritional and health problem in human populations where rice is the dominating staple food crop [9]. Among nutrient deficiencies, Zn deficiency has been identified as a most serious agricultural issue in the world. Forty three percent of Indian soils [10] are identified deficient in zinc. The main reason of deficiency of plant available zinc in soil is the precipitation or adsorption of zinc with various soil components, depending on the soil 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 [11]. Soil and foliar applications of zinc may increase grain zinc concentration in rice, soil zinc application has been reported to increase grain yield whereas foliar application of zinc increased grain concentration of zinc [12]. Hence, this study was aimed to investigate the effects of zinc fertilization on plant available nutrients and crop productivity of rice.

2. MATERIALS AND METHODS

2.1. Study area

An on-farm trial was established during 2020-21 & 2021-22 at farmer’s fields of district Saran, Bihar, under the supervision of Krishi Vigyan Kendra, Manjhi, Saran, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India. The area falls in the subtropical, humid agro-climatic zone of

Bihar. The average annual rainfall of the area is about 800-1100 mm and mean monthly maximum & minimum temperature varies from 24-33ºC and 16-23ºC, respectively. The soil of the experimental site was sandy loam in texture. The initial properties of experimental soil were given in table 1.

Table 1. Initial fertility status of soil during two years (2020-21 & 2021-22) of study.

Soil parameters	Years		Average value
	2020-21	2021-22	
pH (1:2.5)	8.44	8.42	8.43
Electrical Conductivity (dS/m)	0.32	0.33	0.33
Soil organic carbon (%)	0.37	0.36	0.37
Available N (kg/ha)	214.20	213.00	213.60
Available P(kg/ha)	11.50	12.40	11.95
Available K (kg/ha)	129.00	130.10	129.55
Available Zn (mg/kg)	0.48	0.47	0.48

2.2. Experimental Design

An experiment on Zn fertilization was established at seven farmer fields of Saran district of Bihar under supervision of Krishi Vigyan Kendra, Manjhi, Saran (Dr. Rajendra Prasad Central Agricultural University, Pusa Samastipur) during *kharif*, 2020-21 & 2021-22 (Two season). The experiment was laid out in Randomized Block Design and replicated seven times involved three Zn fertilization treatments *i.e.,* T_1: NPK- 130:40:20 kg ha^{-1} (Farmer's Practice), T_2: RDF (NPK-120:60:40 kg ha^{-1} + Zn @ 5.0 kg ha^{-1} and T_3: RDF (NPK-120:60:40 kg ha^{-1}) + foliar spray of 0.5 % $ZnSO_4$ at 25 DAT. A total of twenty one plots were established with each plot sized of 180.0 m × 22.2 m.

2.3. Nursery raising

The seed was treated with fungicide SAAF (Carbendazim + Mencozeb) @ 3g/kg seed before sowing to protect the crops from seed borne diseases. Seed of rice variety Sahbhagi was raised in nursery by "Wet bed method". Seed beds of 8 × 1.25 m size were prepared in dry condition. In addition 1 kg of nitrogen, 1 kg of phosphorus and 0.5 kg of potash were also applied @ 1000 sq. m through Urea, DAP and MOP, respectively at the time of last ploughing. Further, top dressing was done with @ 1.0 kg N/1000 sq. m in the form of urea at 10 days after sowing. Need based irrigation and weeding was also done.

2.4. Field preparation

The experimental field was ploughed immediately after the harvest of previous wheat crop by a tractor drawn harrow in summer to expose weeds and the eggs of harmful insects. The field was prepared by following two cross disc harrowing and two cross tiller operations and finally the field was levelled by planking. Thereafter, the field was flooded with water and puddled by tractor. After puddling field was levelled finally.

2.5. Nutrients application

Irrespective of treatments, the recommended doses of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) were used 120 kg, 60 and 40 kg per hectare, respectively. N, P, K were applied in the form of urea, di-ammonium phosphate and muriate of potash. Whole dose of P and K fertilizers was applied at the time of field preparation. The nitrogen fertilizer was applied in four equal splits *i.e.,*1/4 at basal dressing, 1/4 at mid-tillering, 1/4 at active tillering and 1/4 at panicle initiation in rice cropping. Zinc fertilizers were applied in the form of zinc sulphate @ 5.0 kg ha^{-1} as basal dose. The foliar application of Zn was applied @ 0.5% at 25 days after transplanting of paddy.

2.6. Data collections

2.6.1. Soil properties

Soil analysis was done before the commencement of experiment and after harvesting of crop by standard procedure. Firstly, three representative soil samples from 0-15 cm depth were collected for analysis of physical and chemical properties. The pH of soil was measured with the help of a pH meter, maintaining the soil-water ratio of 1:2.5 as described by Jackson [13]. The electrical conductivity (EC) in the clear extract of soil-water ratio of 1:2.5 was determined with the help of conductivity meter [13].The organic carbon content in soil samples was estimated by Walkely and Black [14] method as suggested by Jackson [13]. Available N of soil was measured by Modified macro-Kjeldahl method [15]. Available P was determined by the ascorbic acid procedure using a blue filter (660 mμ) as suggested by Olsen *et al.* [16]. Available potassium were analysed after extraction of soil with neutral normal 1N NH_4OAc (pH 7.0) as suggested by Tondon [17]. Available zinc (Zn) was estimated by Diethylene Triamine Penta Acetic Acid solution (0.005 M DTPA + 0.1 M TEA+0.01 M $CaCl_2$; pH 7.3) as suggested by Lindsay and Norvell [18].

2.6.2. Crop productivity

The crops were harvested manually from 1 m^2 randomly selected 3 quadrate from each plot and recorded the crop productivity in terms of quintal per hectare.

2.7. Data Analysis

The data generated from the present investigation were subjected to statistical analysis using the statistical package SPSS 13.0. The least significant difference (LSD) at 5% for testing the significant difference among the treatment means [19].

3. RESULTS AND DISCUSSION

3.1. Soil pH, EC and organic carbon

A significant effect of zinc fertilization on soil pH, EC and soil organic carbon (SOC) was observed in two years of investigation of rice (Table 2). The pooled value of pH revealed that the basal application of Zn fertilization produced significant effect whereas, the foliar application of Zn and farmers practice produced almost similar effect on soil pH. The treatment T_2 (basal application of RDF- NPK and Zn) and T_3 (basal application of RDF-NPK + foliar application of Zn @ 0.5% at 25 DAT) lowered the pH values by 0.97 & 0.99 times as compared to farmers practice (T_1). When compared with initial value (average of two years), the pH value was lowered by 0.12 times in both the treatment T_2 and T_3. Basal application of Zn fertilization (T_2) lowered the pH value by 0.98 times as compared with foliar application of Zn fertilization (T_3). In contrast, the EC value was raised by 1.20 & 1.17 times in treatment T_2 & T_3, respectively as compared to T_1 but statistically similar to each other. When compared with initial value, the EC value was raised by 1.27 & 1.24 times in treatment T_2 & T_3, respectively.

Soil organic carbon (SOC) was significantly affected by zinc fertilization in two years of study (Table 2). The basal application of zinc (T_2) maintained the highest per cent of increment i.e., 16.22 over farmers practice which was statistically at par with foliar application of zinc (T_3). In comparison with initial value, the similar per cent increment in SOC was recorded in treatment T_2 and T_3. When comparisons with basal and foliar application zinc, the basal application of zinc was improved the SOC by 4.88% over foliar application of zinc. Comparatively the higher production of carbonic acid in zinc treated plots after decomposition of root biomass that hastens the soil organic carbon and lowering the soil pH.

Table 2. Zinc fertilization: effect on availability of nutrients in soil after harvesting of rice.

Treatments	**Years**		**Pooled average**
	2020-21	**2021-22**	
pH (1:2.5)			
T_1	8.39b	8.40b	8.40b
T_2	8.10a	8.26a	8.18a
T_3	8.28b	8.37b	8.33b
EC (dS/m)			

T_1	0.35b	0.35b	0.35b
T_2	0.41a	0.42a	0.42a
T_3	0.40a	0.41a	0.41a
SOC (%)			
T_1	0.38b	0.37b	0.37b
T_2	0.42a	0.43a	0.43a
T_3	0.40ab	0.41ab	0.41ab
Available N (kg/ha)			
T_1	216.70b	215.50b	216.10b
T_2	241.60a	242.30a	241.95a
T_3	231.50a	233.10a	232.30a
Available P (kg/ha)			
T_1	11.90b	12.90b	12.40b
T_2	14.30a	14.30a	14.30a
T_3	14.20a	14.10a	14.15a
Available K (kg/ha)			
T_1	136.20b	135.80b	136.00b
T_2	151.50a	150.40a	150.95a
T_3	147.80a	147.90a	147.85a
Available Zn (mg/kg)			
T_1	0.50b	0.49b	0.50b
T_2	0.62a	0.61a	0.62a
T_3	0.53b	0.53b	0.53b

* Within variable means in the same column followed by different letters are significantly different from each other

3.2. Plant available nutrients (N, P, K and Zn)

Availability of primary soil nutrients was also significantly influenced by different methods of zinc fertilization in rice (Table 2), the maximum availability of nitrogen (N), phosphorus (P) and potassium was estimated with treatment having basal application of zinc fertilization (T_2) which was statistically at par with foliar application of zinc (T_3). An improvement in available N, P and K was recorded by 11.96, 15.32 and 10.99% in treatment having basal application of Zn (T_2) over farmers practice (T_1). When compared with initial value of plant available N, P and K the highest increment in availability of N, P and K was estimated in treatment T_2 by 13.27, 19.67 and 16.52%. Among the zinc fertilization, the basal application of zinc was considered superior treatment in respect of plant available nutrients. These results were confirmed with the findings of Ghoneim [8] and Haldar and Mandal [20] for available N, Ghoneim [8] and Lonergan *et al.* [21] for available P, and Ghoneim [8] and Wu *et al.* [22] for available potassium.

The basal application of zinc also maintained the highest availability of zinc as compared to rest of the treatments, and the improvement was recorded by 16.04 and 24.24% as compared to foliar application of zinc and farmer practice, respectively. As compared with initial value, an increment was recorded by 28.13 & 1.42% in treatment T_2 & T_3, respectively. A positive correlation (Figure 1) was observed between SOC and available Zn due to that reason the available Zn was improved under treatment having basal application Zn. The availability of zinc increased significantly with increase in soil organic carbon because zinc forms soluble complexes with soil organic matter. Sharma *et al.* [23] reported that the positive correlations of soil zinc and organic carbon. Sidhu and Sharma [24] also reported that the available micronutrients including Zn increased with increase in organic carbon.

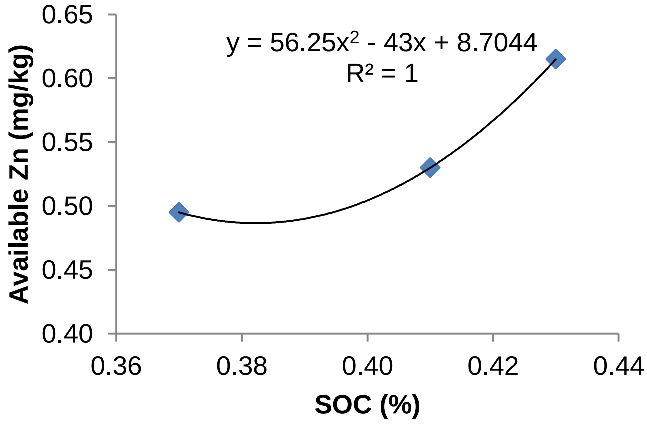

Figure 1. Polynomial correlation between SOC and available Zn.

3.3. Crop productivity

The zinc fertilization well reflected to satisfactory crop productivity (Figure 2) of rice. The treatment having basal application of zinc (T_2) recorded the highest productivity of rice which was statistically followed by foliar application (T_3) and farmers practices (T_1). An improvement in rice yield with the basal application of Zn and RDF-NPK by 7.74% & 24.22% over treatment T_3 & T_1, respectively. Similar results were reported by Sharma *et al.* [23] who reported greater grain yield with soil application of Zn than foliar application.

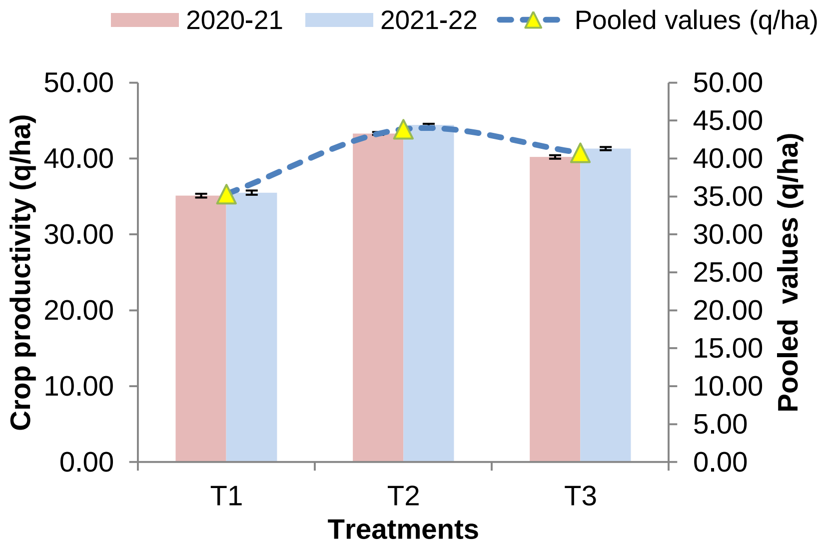

Figure 2. Zinc fertilization: effects on productivity of rice. Vertical bars indicate ± S.E. of mean of the observed values.

4. CONCLUSION

On the basis of two years on farm trial data, we conclude that the basal application of zinc along with RDF-NPK improved the soil organic carbon and plant available nutrients like nitrogen, phosphorus, potassium and zinc and also produced satisfactory crop productivity. Therefore, in order to maintain the soil nutrients and better crop productivity, the basal application of RDF-NPK and basal application of Zn @ 5.0 kg ha^{-1} is recommended over rest of the treatments for semi arid region of Bihar.

5. ACKNOWLEDGEMENT

The support of Directorate Extension Education, Dr. Rajendra Prasad Central Agricultural University Pusa, Bihar and Agricultural Technology Application Research Institute, Patna, Bihar for providing basic infrastructure for this study is duly acknowledged.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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