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Response of different methods of zinc application on yield attributes, yield and economic profitability of Rice (*Oryza sativa* L.) in semi-arid region of Bihar

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Abstract
The nutrient Zinc (Zn) next to nitrogen (N) and phosphorus (P) is the most important nutrient that its deficiency is considered to be a serious widespread nutritional disorder of the world's paddy fields which causes yield reduction ultimately reduced the farmer's economy. The two years (2020-21 & 2021-22) of open field trial was conducted to explain the effect of Zn application in the ways of basal and foliar on growth, yield and economics of rice. The open field trial performed under 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 effective tillers per meter square (428.03), no of panicle per meter square (15.70) and grain yield (43.85 kg ha^{-1}) followed by basal application of RDF-NPK + foliar application of Zn @5% at 25 DAT (T_3) and farmers practice (T1: NPK-130:40:20 kg ha^{-1}). The highest grain yield recorded in treatment T_2 was reflected to satisfactory net return after two years of investigation *i.e*., Rs. 41208.00 ha^{-1} followed by treatment T_3 and T_1. The two years of investigation can be concluded that in order to produce better crop performances and economics, the basal application of RDF-NPK and Zn@ 5.0 kg ha^{-1} was effective in semi arid region of Bihar.

Keywords: Zinc, basal application, foliar application, yield, economic, rice

Introduction
The world population continues to increase and it is projected to reach 9.1 billion by 2050 (FAO, 2009) [1].This increase is projected to come mostly from the developing world (United Nations, 2009) [2]. Therefore, the pressing need to ensure increased food supply and food security on the limited amount of land in the region is obvious. Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world, grown in wide range of climatic zones, to nourish the mankind. Earlier studies reveal that judicious and proper use of fertilizers can markedly increase the yield and improve the quality of rice (Place *et al*., 1970) [3].

Micronutrients are essential for increasing crop production and enhancing animal and human health. About one third of agricultural soils in the world are estimated to be low in available zinc (Zn), resulting in poor crop yields and nutritional quality of the harvested grains (Alloway, 2008) [4]. Among the micronutrients, zinc (Zn) deficiency is considered as a major threat to the global and regional food security (Rana and Kashif, 2014) [5] as it is the most deficient micronutrient in soils worldwide (Shivay *et al*, 2008) [6] and more than 30% of soils have low Zn availability (Alloway,2004) [4]. In high rice consuming areas, zinc deficiency caused yield reduction and Zn malnutrition in humans (Tiong, 2014) [7]. Zn acts as an essential component of many enzymes and controls several biochemical processes in the plants required for growth (IRRI, 2000) [8]. Sudha and Stalin, 2015 reported, reduced rice grain yields with low zinc concentrations when there is low supply of zinc. Flood-irrigated rice is more prone to Zn deficiency (Rehman, 2012) [9] as submergence condition of rice cultivation influences electrochemical and biochemical reactions and alters pH, PCO_2 as well as the concentration of certain ions.

The grain and straw yield of in different rice genotypes significantly increased to the tune of 14 and 16% respectively with the application of zinc (Sudha and Stalin, 2015) [10]. Naik and Das, 2010 [11] reported that the application of zinc in low land rice soil of West Bengal caused an increase in yield of grain and straw respectively over the control to the tune of 37.8% and 20.9%.

The concentration of Zn in average soils ranged from 10 to 300 mg kg^{-1} (Mengel and Kirkby, 1987) [12]. In spite of the fact that the total soil Zn content is relatively high but a small fraction of it is available to plants (Nadeem *et al*., 2013) [13]. 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. Zinc concentration is decreased at high pH. If pH of soil increased then Zn concentration decreased 100 fold by one unit increased in pH (Nadeem *et al*., 2013) [14]. Adsorption of Zn to clay and $CaCO_3$ under high pH is the primary reason of reduced availability of Zn in calcareous soils (Broadley, 2007) [15]. In biological systems Zn is enjoying unique status of being the only metal which is the component of enzymes of all six enzyme classes, i.e., oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases. Zinc plays a very important regulatory role in various metabolic processes of plants including carbohydrate metabolism, cell wall development, gene expression, protein synthesis and respiration (Broadley, 2007) [15].

Rice is sensitive low Zn condition which is common in submerged paddy soils therefore; Zn deficiency frequently occurs (Hazra, 1987) [16]. Zinc deficient rice plants show poor ability root respiration during especially under flooded paddy soils (Slaton *et al*., 2001) [17]. Application of zinc salts e.g., zinc sulphate is a common practice to correct Zn deficiency. Efficient uptake and transport of micronutrients to the grains can be increased by foliar application of micronutrient containing fertilizers. Therefore, like other micronutrients, foliar application of Zn is considered as potential method to ameliorate Zn deficiency in cereal grains (Cakmak, 2008) [18]. Hence, this study was aimed to investigate the effects of different methods of Zn applied through soil and foliar on rice growth, yield and finally economic profitability.

Materials and Methods

Study area

Two years of 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. 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 24-33 ºC and 16-23 ºC, respectively. The soil of the experimental site was sandy loam in texture with alkaline pH (8.44), EC (0.32 dS m^{-1}), low in organic carbon content (0.38%), low in Nitrogen (214.2 kg ha^{-1}), medium in Phosphorus (11.5 kg ha^{-1}), medium in Potassium (129 kg ha^{-1}) and Low in Zinc (0.48 mg kg^{-1}).

Experimental Design

An experiment on response of different methods of Zn application 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 2020-21 & 2021-22 (Two season). The experiment was laid out in Randomized Block Design, replicated seven times involved three 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 at 180.0 m × 22.2 m.

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.

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.

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. Entire 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 @ 5% at 25 day after transplanting.

Data collection

Yield attributed and yield

Yield attributing characters i.e., effective tillers per meter square, No. of panicle per hills were recorded. The crops were harvested manually from 1 m^2 randomly selected 3 quadrate from each plot and recorded the grain yields.

Economic profitability

The net return was calculated by considering the variable as well as fixed inputs and prevailing market rates, the expenditure incurred on various inputs and operations. The fixed cost includes tillage, seed & seed sowing, irrigation, pesticide, harvesting and transportation. Similarly, variable costs included fertilizer. The cost of human labour used for tillage, seeding, irrigation, fertilizer and pesticide application, weeding and harvesting of crops was based on man power per days per hectare. Simultaneously, gross returns were worked out for each treatment based on quality and market prices (Minimum Support Price, Government of India) of the produce. The net returns were worked out by deducting the cost incurred from the gross return of the particular treatment.

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 (Gomez and Gomez, 1984) [19].

Results and Discussion

Yield attributes and yield

The pooled data regarding the yield attributes and yield presented in Table 1 indicated that the application of basal dose of RDF-NPK and Zn (T_2) significantly improved the effective tillers per meter square by 21.54% over farmer practice (control) whereas, the basal application of RDF-NPK and foliar application of Zn @ 5% (T_3) improved the effective tillers per meter square by 14.11% over farmer practice (T_1: control). Similarly, the No. of panicle per hills was recorded the highest in treatment T_2 which was statistically followed by T_3, and the lowest value of No. of panicle per hills was observed under farmers practice (T_1). The maximum improvement in yield attributes of rice by basal application of RDF-NPK & Zn compared to other treatments, might be due to increase in availability of essential nutrients as compared to other methods. Savithri *et al*., 1999 [20] and Umar Khan *et al*., 2003 [21] reported similar results. Similarly, Slaton *et al*., 2005b[22] reported that application of zinc significantly affected total number of tillers. Increased tiller production can be attributed to Zn induced enzymatic activity and auxin metabolism in plants. These results are similar to the findings of Singh *et al*., 2020 [23].

Yield attributes of rice were well reflected satisfactory yield (Table 1) of rice in treatment T_2 which was statistically followed by T_3 and farmers practices. An improvement in rice yield with the basal application of Zn and RDF-NPK by 7.74% & 24.22%, respectively over treatment T_3 & T_1. Similar results were reported by Shamim *et al*., 1991[24] who reported greater grain yield with soil application of Zn than foliar application. Kumar *et al*., 1997 [25] and Savithri *et al*., 1999 [20] also reported somewhat similar results.

Table 1: Response of different methods of Zn application on Yield attributes and yield of rice.

Treatments	Years		Pooled average
	2020-21	2021-22	
Effective tillers per meter square			
T_1	350.33a	354.00a	352.17a
T_2	425.00b	431.05b	428.03b
T_3	399.67c	404.10c	401.89c
No. of panicle per hills			
T_1	11.67a	12.60a	12.14a
T_2	15.00b	16.40b	15.70b
T_3	13.00c	14.52c	13.76c
Grain yield (q ha^{-1})			
T_1	35.10a	35.50a	35.30a
T_2	43.30b	44.40b	43.85b
T_3	40.20c	41.30c	40.70c
* Within variable means in the same column followed by different letters are significantly different from each other			

Economic profitability

Similar to grain yield, the basal and foliar application of Zn had produced significant effect on economic profitability in terms of net return in two years of study (Table 2). the pooled value of net return from rice production was recorded in treatment T_2: RDF-NPK and Zn which was 1.13 times and 1.45 times higher as compared to RDF-NPK and foliar application of Zn @ 5% (T_3) and farmer practice (T_1: control), respectively due to better crop growth and yield. The cost of cultivation was numerically the lowest in Farmers practice due to lower rate of RDF-NPK without Zn followed by T_3 and T_2. The gross return depends on yield of crop and the highest gross return was incurred in treatment T_2 followed by T_3 and the lowest value of gross return incurred from farmers practice due to the lower crop yield.

Table 2: Response of different methods of Zn application on economic profitability of rice.

Treatments	Years		Pooled average
	2020-21	2021-22	
Cost of cultivation (Rs. ha^{-1})			
T_1	42260.00a	43370.00a	42815.00a
T_2	46060.00a	47170.00a	46615.00a
T_3	44660.00a	45680.00a	45170.00a
Gross return (Rs ha^{-1})			
T_1	67690.00a	73420.00a	70555.00a
T_2	83670.00b	91976.00b	87823.00b
T_3	77680.00c	85552.00c	81616.00c
Net return (Rs ha^{-1})			
T_1	25430.00a	30050.00a	27740.00a
T_2	37610.00b	44806.00b	41208.00b
T_3	33020.00c	39872.00c	36446.00c
* Within variable means in the same column followed by different letters are significantly different from each other			

Conclusion

The two years of study concluded that the basal application of RDF- NPK and Zn (T_2) was produced significant effect on yield attributes, yield and net return in rice cultivation which were statistically followed by basal application of RDF-NPK + foliar application of Zn @5% at 25 DAT (T_3) and farmers practice (T_1: NPK- 130:40:20 kg ha^{-1}). Therefore, in order to produce better crop performances and economics the basal application of RDF-NPK and Zn was effective in semi arid region of Saran, Bihar.

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