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Effect of zinc application on yield, growth characters and nutrient uptake by paddy (*Oryza sativa*. L)

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Abstract
A pot culture study entitled "Effect of zinc through agronomic fortification in paddy" was conducted during kharif 2017-2018 at Dept. of Soil Science and Agricultural Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The significantly highest yield and growth characters were observed in the treatment of soil application of RDF+ $ZnSO_4$ @ 25 kg ha^{-1}. The higher N, K, Zn, Fe and Mn content and uptake was recorded with the soil application of RDF+ $ZnSO_4$ @ 25 kg ha^{-1}. But the highest P and Cu content and uptake was observed in the treatment of recommended dose fertilizer (RDF) due to antagonistic effect of zinc with these elements. It is concluded that, the soil application of $ZnSO_4$ @ 25 kg ha^{-1} + RDF (100:50:50 kg ha^{-1} N, P_2O_5, K_2O) at the time of sowing recorded highest paddy grain and straw yield, growth characters and nutrient uptake.

Keywords: Agronomic fortification, rice, zinc, yield, nutrient uptake

Introduction

Rice (*Oryza sativa* L.) being the staple food for almost two thirds of the population plays a pivotal role in Indian economy. It serves as a major source of calories for about 60 per cent of the world population. India ranks first in the world in area of rice cultivation with 42.96 million ha and second in production with 158.75 million tonnes [4].

In plants, zinc plays a vital role as a catalytical, structural, and regulatory cofactor of many enzyme reactions. Zinc is necessary for the metabolism of carbohydrates, protein synthesis, the biosynthesis of growth hormones, in particular of indole acetic acid, and the maintenance of the integrity of cell membranes [3]. Plants suffering from acute zinc deficiency exhibit stunted growth, chlorosis of leaves, shortened internodes and petioles, and clustering of small malformed leaves at the top of the plant (classic rosette symptom of dicotyledons) [2]. The deficiency symptoms first appears on young leaves as zinc is an immobile nutrient in plants. Zinc deficient leaves remains small with extended necrotic spots and interveinal chlorosis on the upper leaf surfaces. The most noticeable symptoms in rice are; leaf wilting due to loss of turgidity, basal leaf chlorosis, delayed development, leaves bronzing and in some cases death of the rice seedlings.

In humans zinc is a component of a large number of enzymes (>300) and participates in various metabolic processes such as synthesis and degradation of carbohydrates, proteins, and nucleic acids. Zinc plays a vital role in the functioning of the nervous, reproductive, and immune systems and is important in the physical growth and cognitive development of children [1]. Numerous health problems such as retarded growth, skeletal abnormalities, delayed wound healing, increased abortion risk and diarrhoea are formed due to zinc deficiency [13]. Approximately one- third of the world's population is suffering from zinc deficiency [6]. The situation is even more adverse in developing countries where more than half of the children and pregnant women are suffering from iron and zinc deficiencies. This situation is largely attributed to the high consumption of cereal based foods viz., rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.), in these countries [11].

Cereals are the major source of zinc for the world's population, especially for the poor people living in rural areas. However, zinc contents of cereal-based foods are quite inadequate to meet human demands. The problem is especially acute for rice consumers, as rice (*Oryza sativa* L.) has the lowest zinc content among the cereals. Considerable variation in brown rice zinc has been found among different rice genotypes. Ranges of 13.5 to 58.4 mg Zn kg^{-1} have been reported for a large rice germplasm at International Rice Research Institute (IRRI) which averaged only 25.4 mg zinc kg^{-1} compared with 35.0 mg zinc kg^{-1} in wheat (*Triticum aestivum* L.) [16].

Materials and Methods

A pot culture experiment was conducted during kharif season of 2017-18 at Department of Soil Science and Agricultural Chemistry, Dr. PDKV, Akola. The soil for filling the pots where collected from long term fertilizer experiment unit, Dr. PDKV, Akola which was deficient in zinc. The experimental soil which was collected from LTFE unit was slightly alkaline in reaction, medium in organic carbon, moderately calcareous in nature, low in available N, medium in available P, very high in available K, marginal in available S, and sufficient in micronutrients but deficient in zinc. The certified seed of paddy (SYE-1) were sown in kharif season by drilling method at rate of 100 kg ha^{-1} (20 seeds per pot). Basal dose of nitrogen, phosphorous and potassium was applied through urea, single super phosphate and murate of potash except absolute control treatment (T_1). For T_3 treatment $ZnSO_4$ was applied @ 25 kg ha^{-1}. Foliar treatments were applied according to the treatments such as T_4 treatment was applied through $ZnSO_4$ @ 0.5% at the time of 50% flowering, T_5 treatment was applied through two foliar spray of $ZnSO_4$ @ 0.5% at 50% flowering and at dough stage, T_6 treatment was applied through foliar spray of Zn-EDTA @ 0.25% at 50% flowering stage and T_7 treatment was applied through two foliar spray of Zn- EDTA @ 0.25% at 50% flowering and dough stage.

Results and Discussion

The results obtained from the present investigation have been presented under following heads.

Growth characters

Plant height

At 120 DAS observation RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) treatment was significantly higher and it was on par with other treatments except absolute control (T_1) and RDF (T_2).

The foliar application of $ZnSO_4$ and Zn EDTA with varying concentration did not affect the plant height significantly because the application time was at 50% flowering and dough stage. At this stage, vegetative growth period of paddy was completed so it did not affected in plant height significantly. But soil application influenced the plant growth and was significantly higher over other treatments. In the study it was seen that plant height was increased by 3.2%, 7.3% and 17.2% at 30, 60 and 120 DAS observations respectively on RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) than RDF (T_2) treatment.

The increase in plant height of paddy due to zinc through soil application corroborate with the findings of Kadam (2018) [8]. She reported that application of zinc through soil application increased the growth attributes of paddy over foliar application. She obtained maximum height of plant up to 32.33 cm at harvest stage by soil application of RDF + $ZnSO_4$ @ 25 kg ha^{-1}. Khan *et al.* (2007) also suggested that there was an increase in plant height due to zinc application [10].

Dry matter accumulation

Maximum dry matter accumulation (12.28 g $plant^{-1}$) was observed in RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) which also contributed to total dry matter accumulation (61.40 g pot^{-1}) per pot. But this values were found to be at par with treatments such as RDF + $ZnSO_4$ two foliar spray @ 0.5% at 50% flowering and dough stage (T_5), RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage (T_7), RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage (T_4), RDF + Zn EDTA @ 0.25% spray at 50% flowering stage (T_6). The lowest dry matter accumulation (7.16 g $plant^{-1}$, 35.83 g pot^{-1}) was found in the absolute control (T_1) treatment. Whereas, foliar application of either $ZnSO_4$ 0.5% or Zn EDTA 0.25% with RDF and with different stages of application *ie*, one foliar spray at 50% flowering stage and with two foliar spray at 50% flowering and at dough stage was found to be significantly at par with each other and also with the soil application of zinc as $ZnSO_4$ @ 25 kg ha^{-1} (T_3) but all this treatments were significantly higher dry matter over RDF indicating that addition of $ZnSO_4$ or Zn EDTA either by foliar or soil application was beneficial to increase the dry matter accumulation. Similar trend of treatment differences was observed in dry matter accumulation per pot.

The apparent and significantly higher dry matter accumulation in rice plant was obtained with soil application of RDF + $ZnSO_4$ (T_3) compared to the values obtained in other treatments in this study, might be due to better nourishment derived from the soil as a result of balanced fertilization which improved soil nutrient status. Reason may be due to the zinc addition in combination with RDF as soil application provided distribution of zinc within rice plant through xylem and translocated in phloem, which increases vegetative tissue formation resulted in the improved photosynthetic activity, which shows boosted growth of plant parts and increment in dry matter. These results were in support with the results of Kadam *et al.* (2018) [8]. Yin *et al.* (2016) also suggested that there is an increase in biomass of paddy through the soil application as compared to foliar application [17].

Number of tillers

Tillers are the grain bearing part and it possesses the leaves. The application of zinc either as soil or foliar application through $ZnSO_4$ or Zn EDTA was found to be non significant. But the maximum number of tillers (7.33 tillers $plant^{-1}$) was found in the soil application of zinc as RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3). And the lowest number of tillers (5.53 tillers $plant^{-1}$) was seen in absolute control (T_1) treatment.

Over all plant growth is directly reflected in production of tillers in rice plant. Therefore, counting of tillers provides adequate basis for measuring the treatment differences owing to various micronutrient treatments. The application of zinc with RDF might have increased the use efficiency of added nutrient and supplied it continuously to the plant throughout the crop growth period and promoted various physiological activities in plant which is considered to be indispensable for proper growth and development. Zinc also helped in formation of growth hormones and auxin metabolism which helped the plant for increase in tillers. These findings are in accordance with Kadam (2018) [8]. Khan *et al.* (2007) also concluded that application of zinc increased the number of tillers significantly over control treatment [10].

Number of seeds

The number of seeds (195.66 seeds $plant^{-1}$) were significantly superior in RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) than other treatments which was about 32.80% higher over RDF (T_2) treatment which shows that application of zinc increased its reproductive potential. The lowest number of seeds (128.33 seeds $plant^{-1}$) was found in the absolute control (T_1) treatment. The favourable response of zinc application on number of seeds has also been reported by Talib *et al*. (2017) in paddy and reported that there is an increase in number of seeds per panicle with application of zinc [15]. Ghasal *et al.* (2015) also reported the increase in grains per panicle with increase in zinc doses in basmati rice [5].

Yield

The significantly higher seed yield (23.30 g pot^{-1}) of paddy was observed in the treatment of soil application RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) and it was on par with RDF + two foliar application of $ZnSO_4$ @ 0.5% at 50% flowering and dough stage (T_5), RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage (T_7), RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage (T_4) and RDF + Zn EDTA @ 0.25% spray at 50% flowering stage (T_6). The lowest seed yield of paddy (11.96 g pot^{-1}) was recorded in absolute control treatment (T_1). Hussain (2017) observed the effect of zinc application in increasing the grain yield of paddy [7], whereas Saha (2015) reported that grain yield of paddy increased when zinc was applied through both soil and foliar application [12]. Shivay (2015) reported that zinc application in rice had positive effect on yield and yield attributing characters [14]. He also reported that application of zinc through soil application was significantly superior over foliar application and the application of 5 kg Zn ha^{-1} recorded significantly higher yield over foliar application but soil + foliar treatment was significantly highest over others.

The significantly higher paddy straw yield (38.10 g pot^{-1}) was also observed with soil application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) and it was found to be on par with RDF + two foliar application of $ZnSO_4$ @ 0.5% at 50% flowering and dough stage (T_5), RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage (T_7), RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage (T_4) and RDF + Zn EDTA @ 0.25% spray at 50% flowering stage (T_6). The lowest seed yield of paddy (23.87 g pot^{-1}) was recorded in absolute control treatment (T_1).Shivay (2015) reported that the application of zinc through soil application increased the straw yield over foliar application [14]. In this experiment it was seen that soil application of zinc through $ZnSO_4$ @ 25 kg ha^{-1} increased the yield about 44.81% over RDF (T_2) and foliar application of zinc through $ZnSO_4$ with one foliar spray @ 0.5% at 50% flowering stage and two foliar spray @ 0.5% at 50% flowering and dough stage increased the yield up to 44.20% and 41.77% respectively and that of zinc through Zn EDTA with one foliar spray @ 0.25% at 50% flowering stage and two foliar spray @ 0.25% at 50% flowering and dough stage increased the yield up to 42.68% and 35.23% respectively.

Table 1: Growth characters and yield of paddy as influenced by different treatments of zinc

Treatments		Plant height (cm)	Dry matter accumulation (g $plant^{-1}$)	Number of tillers $plant^{-1}$	Dry matter accumulation (g pot^{-1})	Number of seeds $plant^{-1}$	Yield (g pot^{-1})	
							Grain	Straw
T_1	Absolute control	42.70	7.16	5.53	35.83	128.33	11.96	23.87
T_2	Recommended dose fertilizer (RDF) 100:50:50 kg ha^{-1}	46.29	8.54	5.90	42.73	147.33	16.42	26.31
T_3	RDF + $ZnSO_4$ @ 25 kg ha^{-1}	54.26	12.28	7.33	61.40	195.66	23.30	38.10
T_4	RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage	52.80	11.79	7.00	58.97	183.00	21.66	37.30
T_5	RDF + $ZnSO_4$ two foliar spray @ 0.5% at 50% flowering and dough stage	53.58	12.09	7.26	60.45	188.66	22.50	37.94
T_6	RDF + Zn EDTA @ 0.25% spray at 50% flowering stage	51.60	11.33	7.00	56.67	180.66	21.08	35.58
T_7	RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage	53.10	11.96	7.23	59.84	187.33	22.30	37.54
	SE (m)±	1.70	0.38	0.75	1.93	1.88	1.36	1.46
	CD at 5%	5.16	1.17	NS	5.88	5.73	4.15	4.43

Nitrogen uptake

The significantly highest total N uptake (0.54 g pot^{-1})) by paddy was recorded in treatment of soil application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) which was found to be on par with the treatments such as RDF + $ZnSO_4$ two foliar spray @ 0.5% at 50% flowering and dough stage (T_5), RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage (T_7), RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage (T_4), RDF + Zn EDTA @ 0.25% spray at 50% flowering stage (T_6). The lowest total N uptake (0.28 g pot^{-1}) by paddy was observed in Absolute control (T_1) treatment. The soil application of zinc showed highest grain, straw and total uptake than other treatments, which was 44, 58 and 54 per cent respectively higher than RDF (T_2) treatment. The results are in conformity with findings reported by Keram *et al.* (2012) [9].

Phosphorous uptake

The significantly higher total P uptake (0.12 g pot^{-1}) by paddy was observed in treatment of soil application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) and it was about 33% higher than RDF (T_2) treatment. The lowest total P uptake (0.05 g pot^{-1}) was observed in Absolute control (T_1) treatment.

Potassium uptake

The significantly highest total K uptake (0.93 g pot^{-1}) by paddy was observed in treatment of soil application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) and it was on par with RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage (T_4), RDF + $ZnSO_4$ two foliar spray @ 0.5% at 50% flowering and dough stage (T_5), RDF + Zn EDTA @ 0.25% spray at 50% flowering stage (T_6) and RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage (T_7). The lowest total K uptake (0.47 g pot^{-1}) by paddy was observed in Absolute control (T_1) treatment.

Zinc uptake

The highest total zinc uptake (23.38 µg pot^{-1}) in paddy was observed in treatment of soil application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} (T_3) which was statistically on par with RDF + $ZnSO_4$ two foliar spray @ 0.5% at 50% flowering and dough stage (T_5), RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage (T_7), RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage (T_4) and RDF + Zn EDTA @ 0.25% spray at 50% flowering stage (T_6). The lowest total uptake of zinc (9.77 µg pot^{-1}) was found in Absolute control (T_1) treatment. The highest total uptake of zinc in treatment (T_5) was found to be 67% higher than RDF (T_2) treatment.

Table 2: Total nutrient uptake by paddy influenced by different treatments of zinc

Treatments		Nitrogen uptake (g pot^{-1})	Phosphorous uptake (g pot^{-1})	Potassium uptake (g pot^{-1})	Zinc uptake (µg pot^{-1})
T_1	Absolute control	0.28	0.05	0.47	9.77
T_2	Recommended dose fertilizer (RDF) 100:50:50 kg ha^{-1}	0.35	0.09	0.56	14.00
T_3	RDF + $ZnSO_4$ @ 25 kg ha^{-1}	0.54	0.12	0.93	23.38
T_4	RDF + $ZnSO_4$ foliar spray @ 0.5% at 50% flowering stage	0.50	0.11	0.88	21.48
T_5	RDF + $ZnSO_4$ two foliar spray @ 0.5% at 50% flowering and dough stage	0.52	0.11	0.92	22.74
T_6	RDF + Zn EDTA @ 0.25% spray at 50% flowering stage	0.48	0.11	0.84	19.76
T_7	RDF + Zn EDTA two foliar spray @ 0.25% at 50% flowering and dough stage	0.51	0.11	0.90	22.18
	SE (m)±	0.02	0.004	0.05	0.71
	CD at 5%	0.07	0.01	0.16	2.15

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