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Application of graded doses of zinc in rice soil and its uptake, translocation and grain zinc loading to rice plant

Sapna Kiolu Mara, RK Panda, RK Nayak and V Dinesh Rahul

Abstract
A Field experiment was conducted since last five years at Central Farm, OUAT, Bhubaneswar, under AICRP on micronutrient during Rabi 2015-16 to study the Effect of graded doses of Zinc in rice (Lalit variety) soil and its uptake, translocation and grain Zinc loading to rice plant. The experiment was carried out in factorial randomized block design with 13 treatments i.e. T_1-2.5 kg/ha $ZnSO_4$, T_2-5 kg/ha $ZnSO_4$, T_3-7.5 kg/ha $ZnSO_4$ and T_4-10 kg/ha $ZnSO_4$ at once in 6 years, T_5-2.5 kg/ha $ZnSO_4$, T_6-5 kg/ha $ZnSO_4$, T_7-7.5 kg/ha $ZnSO_4$ and T_8-10 kg/ha $ZnSO_4$ at alternate years, T_9-2.5 kg/ha $ZnSO_4$, T_{10}-5 kg/ha $ZnSO_4$, T_{11}-7.5 kg/ha $ZnSO_4$ and T_{12}-10 kg/ha $ZnSO_4$ at every year and T_{13} is control which were replicated 3 times. Experimental results showed that zinc applied at alternate years gave better zinc content in grain T_8 (80.67 mg/kg), husk T_8 (76.83 mg/kg), rachis T_8 (444.5 mg/kg), leaves T_8 (85.67 mg/kg), stems T_8 (534 mg/kg), roots T_8 (906.33 mg/kg).

Keywords: Rice, zinc, translocation, grain, husk, rachis, leaves, stem, roots

Introduction
According to FAO (2009-10) Rice (Oryza sativa L.) is cultivated over an area of 161.8 m ha with production of 678 m tons in the world with the average productivity of 4.3 t/ha. About 45% of the rice area is under rain fed condition which is mainly distributed in south and south-east Asia but contributes only 25% of total rice production. About 90% of the global rice is produced in Asia. It has shaped the culture, diets and economics of thousands of millions of peoples. In Asia alone, more than 2000 million people obtain 60-70% of their calories from rice and its products.

Recognizing the importance of this crop the United Nations General Assembly declared 2004 as the "International Year of Rice (IYR)". The team of IYR – "Rice is Life" reflects the importance of rice as primary food source and is drawn from an understanding that rice-based systems are essential for food, security, poverty, alleviation and improved livelihood.

Rice (Oryza sativa L.) is one of the major staples, feeding more than half of the world population. It is grown in more than 100 countries, predominantly in Asia. India ranks first in the world in terms of area of rice cultivation with 44.6m ha and second in productivity of 2.96 t/ha (Yogendra *et al.*, 2014) [31]. The yield levels in India are low compared to major rice producing countries such as Japan, China and Indonesia. Rice provides 21% of energy and 15% of protein requirements of human populations globally (Maclean *et al.*, 2002; Depar *et al.*, 2011) [18, 7]. To feed ever-rising world population, which is estimated to be 10 billion by the end of this century, an increase in rice production per unit area is direly needed. Although high-yielding input-responsive varieties are available, a large yield gap exists between the farmers' fields and research stations in developing countries. In addition to adequate irrigation water, balanced supply of macro and micronutrients is vital for bridging this yield gap.

Zn deficiency is a global threat that affects both crop production and human nutrition (Quijano-Guerta *et al.*, 2002; Hotz and Brown, 2004) [27, 11]. It is currently listed as a major risk factor for human health and cause of death globally. According to a WHO report on the risk factors responsible for development of illnesses and diseases, Zn deficiency ranks 11th among the 20 most important factors in the world and 5th among the 10 most important factors in developing countries. Zinc deficiency is responsible for many severe health complications, including impairments of physical growth, immune system and learning ability, combined with increased risk of infections, DNA damage and cancer development (Hotz and Brown 2004; Gibson 2006; Prasad 2007) [11, 26].

Distribution of Zn within rice plants largely occurs through transport in the xylem, transfer from the xylem to the phloem, and retranslocation in the phloem (Ishimaru *et al*., 2011) [13]. Xylem transport is simply directed from roots to shoots in the transpiration stream, whereas phloem transport from old to new leaves is more selective, and is largely dependent on the phloem mobility of each element. In relation to their phloem mobility, Zn is considered intermediate or conditionally mobile (Fernández and Brown, 2013) [8].

Remobilization of reserves to supply rice seeds with minerals has been emphasized in previous studies, but the contribution of stored minerals to total seed mineral content is unclear. During rice grain filling, Zn remobilization from leaves is not as important as Zn uptake by roots (Jiang *et al*., 2007) [14]. At the same time, increased root uptake does not necessarily result in enhanced Zn accumulation in rice grains (Jiang *et al*., 2008) [15].

Zinc is involved in a number of physiological processes of plant growth and metabolism including enzyme activation, protein synthesis, metabolism of carbohydrates, lipids, auxins and nucleic acids, gene expression and regulation and reproductive development (pollen formation) (Marschner 1995; Cakmak 2000a, b; Mengel and Kirkby 2001; Chang *et al*., 2005) [19, 3, 4, 20, 5]. Zn solubility and plant availability should be considered before Zn management in rice. Hence, in the present investigation, an attempt will be made to identify suitable graded doses of Zn application to rice soil and its translocation and grain Zn loading to rice plant through morpho-physiological and biochemical approaches.

Materials and Methods

A Field experiment was conducted since last five years at Central Farm, OUAT, Bhubaneswar, under AICRP on micronutrient during Rabi 2015-16 to study the Effect of graded doses of Zn in rice soil and its uptake, translocation and grain Zn loading to rice plant. The central farm, OUAT, Bhubaneswar lies between 20^0 16' and 20^0 17' N latitude and 85^0 48' and 85^0 49' east longitude. It is situated 60 km west to Bay of Bengal with an elevation of 25.9 m above the mean sea level. It receives an average annual rainfall of about 1490mm from south-west monsoon out of which 1325 mm is received between June to October and rest 165 mm between November and May. May is the hottest month. The relative humidity (RH) varies from 86% in August to 65% in December.

Details of Treatment

Once in 6 years	Alternate years	Every year
T_1- 2.5 kg/ha $ZnSO_4$	T_5- 2.5 kg/ha $ZnSO_4$	T_9- 2.5 kg/ha $ZnSO_4$
T_2- 5 kg/ha $ZnSO_4$	T_6- 5 kg/ha $ZnSO_4$	T_{10}- 5 kg/ha $ZnSO_4$
T_3- 7.5 kg/ha $ZnSO_4$	T_7- 7.5 kg/ha $ZnSO_4$	T_{11}- 7.5 kg/ha $ZnSO_4$
T_4- 10 kg/ha $ZnSO_4$	T_8- 10 kg/ha $ZnSO_4$	T_{12}- 10 kg/ha $ZnSO_4$
T_{13}- CONTROL (no zinc applied)		

Results and Discussion

The present investigation was taken up to evaluate the effect of various sources and methods of application of zinc on growth, yield, nutrient uptake and translocation in rice during *Rabi* 2016, in an experiment conducted by AICRP on micronutrient since last five years.

Rice differ greatly in Zn use efficiency and grain Zn content and this aspects investigated in present study revealed that Zn content in grain, husk, rachis, leafs, stem and roots vary significantly. Zn accumulation in roots is highest followed by Zn content in stem, rachis, leaves, grain and husk respectively. It indicates the differential partitioning of Zn regulated by Zn uptake by root and improper translocation to grain resulting differential compartmentalization of Zn in the path. However, Zn uptake was more when applied @ 10 kg/ha of $ZnSO_4$ in alternate years followed by once in 6 years, but Zn accumulation found to be high when applied @ 2.5 kg/ha every year. Decreased rate of accumulation was found in different part of plants when applied @ 10 kg/ha $ZnSO_4$ every year. This indicates that Zn uptake in rice plant slows down at high concentration. Zn uptake and utilization was also reported by (Quijano-Guerta *et al*., 2002; Singh *et al*., 2003) [27, 28]. Application of Zn fertilizers to soil was manifested to cope with Zn deficiency and to increase grain Zn concentration. This necessitates development of permanent and plant based improvement in Zn uptake and utilizations through different sources of Zn fortification, However, it was found that partitioning in rice grain for improve quality was hindered in the path due to differential accumulation of Zn in different plant parts. Relative efficiency of different sources of Zn applied by various methods (once/alternate/every year) in improving soil and plant Zn availability in rice producing systems need agronomic management and breeding options to improve Zn uptake and partitioning. Zinc application increased the % zinc uptake and it was found to be 53.50 to 80.67 mg/kg in Grain, 24.33 to 76.83 mg/kg in Husk, 116.67 to 444.50 mg/kg in Rachis, 57 to 85.67 mg/kg in Leaves, 100.33 to 534 mg/kg in stem and 183.67 to 906.33 mg/kg in Roots. These results were in accordance with (Phattarakul *et al*., 2012) [25], (Khan *et al*., 2002) [17]. The increase in zinc uptake in grain and straw at harvest might be due to the presence of increased amount of zinc in soil solution by the application of zinc that might have facilitated the absorption of zinc through phloem. The higher concentration of zinc in straw as compared to grain was reported by (Naik and Das 2007) [22]. The increase concentration of zinc due to foliar application might be due to zinc absorption by leaf epidermis and remobilization into the rice grain through phloem and several membranes of zinc regulated transporters which might have regulated this process (Bashier *et al*., 2012) [2]. Zinc partitioning into rice grain increased with the elevation of Zn supply (Zhigang *et al*., 2003) [32].

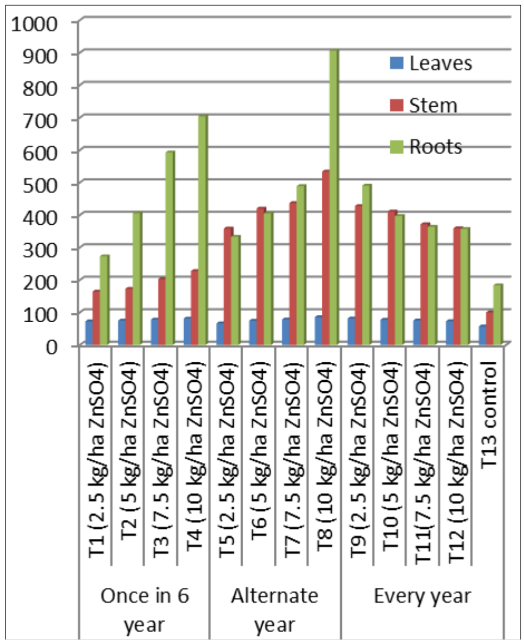

Fig 1: Zn translocation in vegetative parts

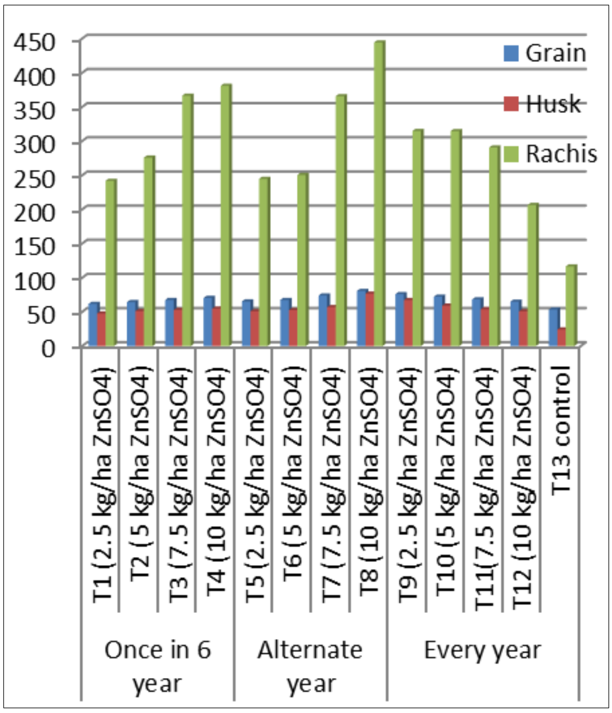

Fig 2: Zn translocation in reproductive parts

Conclusion

Yield of rice crop cv. Lalit increases in all treated plots over control. Rice yields treated with $ZnSO_4$ every year showed descending order to higher dose of $ZnSO_4$ application. However, the plot yield increases with increase application of $ZnSO_4$ when subjected to once in 6 year and alternate year application. In current investigation recorded in 5th year of Zn application showed increased yield in the plots of alternate year application.

The findings in this experiment are in agreement with the results obtained by (Sree Devi *et al*., 2005, Hossain *et al*., 2008, Stalin *et al*., 2011 and Nawaz *et al*., 2004) [29, 12, 30, 23]. Higher grain and straw yield with zinc fertilizer application might be due to the fact that zinc plays an important role in biosynthesis of IAA and initiation of primordial for reproductive part which have favored the metabolic reaction within plant. Muthukumararaja and Sri ramachandrasekharan (2012) [21], Keram *et al*. (2012) [16] and Pedababu *et al*. (2007) [24] also reported that yield increase may be due to enhanced synthesis of carbohydrate and their transport to the site of grain production. Datta and Dhiman (2001) [6] reported that the increase in grain and straw yield may be due to the fact that the zinc exerts a great influence on basic plant life processes such as nitrogen metabolism, uptake of Nitrogen and protein quality, Photosynthesis–chlorophyll synthesis and carbonic anhydrase activity. Hemantaranjan and Gray (1998) [10] and Abdoli *et al*., (2014) [1] were of opinion that chlorophyll and IAA production causes prolonged period of photosynthesis which improves the production of carbohydrate and their transportation to seeds. Also in the treatment receiving doses of zinc every year, yield was found to decrease as the dose of Zn fertilizer increases. These results are due to Zn toxicity found in every year treatment. Silva *et al*., 2014 reported that high available Zn concentrations in the soil caused phytotoxicity symptoms in rice, which ultimately affect the yield of crop by reducing it.

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