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IMPACT OF ZINC APPLICATION ON ITS TRANSLOCATION INTO VARIOUS PLANT PARTS OF WHEAT IN A VERTISOL

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ABSTRACT

The present investigation were conducted for two *rabi* season 2010-11 and 2011-12 in the field of Department of Soil Science and Agricultural Chemistry, J.N. Krishi Vishwa Vidyalaya, Jabalpur (M.P.) to study the influence of Zn application on its translocation into various plant parts of wheat in a Vertisol. The results revealed that the application of increasing levels of Zn @ 5, 10 and 20 kg ha^{-1} significantly increased the Zn concentration in root, stem, leaves and earhead of wheat over NPK fertilization alone at different growth stages of wheat. Further, the grain and straw yields as well as harvest index increased with the increasing levels of Zn as compared to NPK alone. The maximum pooled grain yield 4.66 t ha^{-1} was observed in the treatment 20 kg Zn ha^{-1}, while the minimum pooled grain 3.88 t ha^{-1} in the control plot (100 % NPK). Thus, the findings of present investigation indicated that the application of Zn eradicates its deficiency in different plant parts of wheat with enhancing the crop yields.

INTRODUCTION

Wheat (*Triticum aestivum L.)* is an important cereal crop, source of staple food and thus the most important crop in food security prospective. India occupies second position next to China in the world with regard to area (29.9 million hectares) and production (93.9 million tonnes) of wheat (Anonymous, 2012). Nutrient deficiency is one of the important yield limiting factors includes delayed sowing, high weeds infestations, water shortage at critical growth stages, intensive cultivation and imbalance and non-judicious application of fertilizers. The universal deficiency of nitrogen and phosphorus is followed by Zn deficiency. Almost 50 per cent of the world soils used for cereal production is Zn deficient (Gibbson, 2006). Zn deficiency is the most widespread micronutrient disorder among different crops. The deficiency of this micronutrient frequently occurs in wheat which is very sensitive to low Zn supply (Zhao, 2011).

Nutrient content in various parts of plant can assist in evaluating the nutrient status of crops. The higher the capacity for a plant to accumulate a nutrient, the greater would be the difference in its nutrient concentration in response to varying rates of fertilizer application. Often, the concentration of micronutrients cations does not vary greatly within plants parts, however, application of nutrient(s) in question may alter the concentration of other micronutrients to some extent which may influence their critical level in the plant parts. The knowledge of translocation of Zn into various plant parts of wheat at various growth stages may be useful criterion in delineating the deficiency levels of nutrients from sufficiency and toxicity levels (Sharma, 2000). Knowledge of Zn transport in plant is inadequate. Little is known about transport of Zn from roots to shoots and from shoots to other plant parts. Zn absorption by plants involves a number of steps (Lasat *et al.*, 1998). First, adequate Zn bioavailability was necessary in the rhizoshpere. There are two pathways for Zn to move from the soil solution to the rhizosphere, mass flow and diffusion. Zn transport in plants takes place through both the xylem and the phloem. Following absorption by the root, Zn is rapidly transported via the xylem to the shoot (Riceman and Jones, 1958). It has been claimed that the Zn was transported from phloem does not occur in wheat, leaving roots straved of Zn if not supplied in root environment. However, more recent studies with wheat showed good transport of Zn from stem and leaves to developing grain, as well as from one root to another, indicating involvement of phloem transport.

Keeping this in view, the present investigation was conducted to evaluate the effect of Zn application on its translocation into various plant parts of wheat and crop productivity.

MATERIALS AND METHODS

Soils and its characteristics

The present investigation was conducted under an ongoing All India Co-ordinated Research Project on "Micro, secondary nutrients and pollutant elements in soils and plants", with fallow-wheat cropping sequence during the two consecutive years 2010-11 and 2011-12, at two different Zn deficient sites of the Research Farm of Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa

Vidyalaya, Jabalpur, Madhya Pradesh, India. Both the experimental sites (23°10'' N latitude and 79°57'' E longitude) have a semi-arid and sub-tropical climate with a characteristic feature of dry summer and cold winter. In winter season *i.e.* from November to February months, the temperature ranges from 4 to 33°C and the relative humidity varies from 70 to 90 per cent. Dry and warm weather usually prevails during the months of March to June. The temperature in the month of May attains a value as high as 46°C. Monsoon season extends from mid-June to mid-September. The temperature during this period varies from 25 to 35°C and the relative humidity ranges from 70 to 80 per cent. The total annual rainfall varies from 1000 to 1500 mm with the mean value of around 1350 mm. The length of growing period ranges from 150 to 180 days. The soil of the experimental sites falls under Vertisol and belongs to Kheri"series of fine montmorillonite, Hyperthermic family of *Typic Haplusterts* popularly known as "medium black soil". The textural class of soil is clayey. The key soil properties (0-15 cm soil depth) are presented in Table 1.

Experimental details

The experiment was designed and conducted with different Zn levels (1.25, 2.5, 5, 10 and 20 kg Zn ha^{-1}) having four replications arranged in the randomized block design. Two blocks were separated with a gap of 1.50 m, whereas individual plots (5m × 8 m) were separated with a distance of 1.25 m. The 100 % NPK was commonly applied in all the treatments @ 120 N: 60 P_2O_5: 40 K_2O kg ha^{-1}. A basal dose @ 60:60:40 kg ha^{-1} N, P_2O_5 and K_2O, respectively was applied before sowing of wheat, through urea, super phosphate and muriate of potash fertilizers. Remaining 60 kg N ha^{-1} was applied to wheat crop in two splits first half at 21–25 days (after the first irrigation) and the rest at 51-55 days after sowing. The doses of Zn @ 1.25, 2.5, 5, 10 and 20 kg ha^{-1} were given through zinc sulphate fertilizer before sowing. Wheat (GW-273) was sown during 2-3rd week of Dec. 2010-11 and 2011-12 of *rabi* season with hand drill using seed rate 120 kg ha^{-1}. It is irrigated at critical phases of crop growth and as when needed. All crop management and protection measures were followed. Weed control practices were included hoeing along with appropriate weedicides spray. Insects and diseases were kept under check by following suitable control measures. Wheat crop were harvested at maturity (120 days after sowing) and yield data were recorded after threshing.

Table 1: Physico-chemical properties of soil of two experimental sites

Properties	Values	
	Site-I (2010-11)	Site-II (2011-12)
Sand (%)	25.3	25.1
Silt (%)	17.9	17.9
Clay (%)	56.7	56.8
Soil pH (1:2.5)	7.2	7.0
Electrical conductivity (dS m^{-1})	0.30	0.24
Organic carbon (%)	0.63	0.68
Calcium carbonate (%)	2.40	3.00
Available Nitrogen (kg ha^{-1})	219.0	216.6
Available Phosphorus (kg ha^{-1})	18.9	18.2
Available Potassium (kg ha^{-1})	330.3	329.7
DTPA extractable-Zn (mg kg^{-1})	0.53	0.56

Chemical analysis of soil and plant

In present investigations, composite surface (0-20 cm) soil samples were collected from two different Zn deficient sites were analyzed for different basic soil properties by adopting standard laboratory procedure. The samples of various plant parts like root, stem, leaves and earhead were collected at different successive growth stages of wheat and washed thoroughly with 0.01 N HCl and then with demineralized water and dried in an oven at 60^{0}C for analyzing Zn concentration. The chemical analysis of the plant sample was carried out by digesting with HNO_3:$HClO_4$ (4:1) di-acid mixture as per the procedure outlined by Jackson, 1973. The Zn content in various plant parts was analyzed by atomic absorption spectrophotometer as described by Lindsay and Norvell, 1978.

Statistical analysis

The data generated from the present study were analyzed statistically and to draw suitable inference as per standard ANOVA technique described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The results obtained from the present investigations as well as relevant discussion are given in following heads

Translocation and distribution of Zn into various plant parts of wheat at tillering stage

The data presented in Table 2 indicates that the Zn accumulation by root, stem and leaves of wheat were found to be increase by the increasing levels of Zn at tillering stage. The application of 5, 10 and 20 kg Zn ha^{-1} resulted in significant increase in Zn concentration in root by 7.98, 15.96 and 20.18 per cent, in stem by 12.88, 17.89 and 20.09 per cent and leaves by 9.28, 17.10 and 19.52 per cent, respectively, as compared to the application of NPK alone. However, the application of 10 and 20 kg Zn ha^{-1} were statistically at par with each other. The magnitude of Zn concentration in different plant parts was assorted as: root > stem > leaves. Zinc is taken up by root cells as Zn^{+2} and, in some plant species, also as Zn-phytosiderophore complexes. The distribution of Zn within shoots and leaves varies between plant species. Plant tissues accumulate Zn in both soluble and insoluble forms. In crop plants, much of the soluble Zn is complexed with organic compounds (White, 2012). Zn concentrations in roots, leaves and stems can be increased readily by applying Zn-fertilizers to the soil in plants growing on most, but not all, soils and by foliar application of Zn-fertilizers. Thus, Zn concentrations in these tissues will be limited solely by Zn toxicity (Bouis and Welch, 2010). When Zn-fertilizers are added to the soil, root tissues often exhibit higher Zn concentrations than shoot tissues, and it is likely that plant Zn accumulation and yield is limited by Zn toxicity to root cells under these conditions. Critical leaf Zn concentrations for most crop plants lie between 100 and 700 mg kg^{-1} dry matter when Zn-fertilizers are applied to the soil (Fageria, 2009). Enhanced translocation of Zn from root to shoot meristems and its retranslation from senescing to growing organ under Zn supply might also contribute towards Zn efficiency in wheat. Zn is unevenly distributed within the

Table 2: Influence of Zn application on its translocation into various plant parts of wheat at tillering stage

Treatment	Zn concentration (mg kg^{-1})								
	Root			Stem			Leaves		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
T_1-NPK (Control)	26.75	29.00	27.88	23.33	26.14	24.73	17.63	19.51	18.57
T_2-1.25 kg Zn ha^{-1}	27.18	29.18	28.18	23.95	26.84	25.39	17.75	19.64	18.69
T_3-2.50 kg Zn ha^{-1}	27.55	30.13	28.84	24.58	27.61	26.09	18.30	20.08	19.19
T_4-5.00 kg Zn ha^{-1}	29.08	31.13	30.10	26.45	29.39	27.92	18.90	21.68	20.29
T_5-10.00 kg Zn ha^{-1}	31.23	33.43	32.33	27.60	30.71	29.16	20.65	22.84	21.74
T_6-20.00 kg Zn ha^{-1}	32.38	34.63	33.50	28.28	31.12	29.70	20.98	23.41	22.19
SEm (±)	1.08	1.15	0.74	0.91	1.03	0.64	0.72	0.78	0.50
C.D. (5 %)	3.34	3.55	2.14	2.81	3.18	1.86	2.23	2.40	1.45

Table 3: Influence of Zn application on its translocation into various plant parts of wheat at flowering and maturity stages

Treatment	Zn concentration (mg kg^{-1})											
	Root			Stem			Leaves			Earhead		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
T_1-NPK (Control)	23.88	24.65	24.26	22.63	22.43	22.53	14.83	17.78	16.30	28.35	28.43	28.39
T_2-1.25 kg Zn ha^{-1}	24.18	24.85	24.51	22.93	23.30	23.11	14.95	17.88	16.41	29.03	28.70	28.86
T_3-2.50 kg Zn ha^{-1}	25.78	26.70	26.24	24.33	24.53	24.43	15.75	18.33	17.04	29.33	29.65	29.49
T_4-5.00 kg Zn ha^{-1}	27.03	28.68	27.85	25.20	25.13	25.16	16.48	19.40	17.94	30.93	31.69	31.31
T_5-10.00 kg Zn ha^{-1}	27.88	29.00	28.44	26.55	26.18	26.36	17.48	20.73	19.10	32.13	33.54	32.83
T_6-20.00 kg Zn ha^{-1}	28.45	29.53	28.99	26.99	27.13	27.06	18.00	21.25	19.63	33.25	33.89	33.57
SEm (±)	0.97	1.00	0.66	0.89	0.87	0.59	0.57	0.67	0.42	1.04	1.12	0.73
C.D. (5 %)	2.98	3.10	1.90	2.76	2.68	1.69	1.77	2.08	1.21	3.21	3.47	2.10
Treatment	Zn concentration (mg kg^{-1})											
T_1-NPK (Control)	19.63	22.78	21.20	17.68	19.50	18.59	15.63	16.35	15.99	29.48	30.00	29.74
T_2-1.25 kg Zn ha^{-1}	19.73	22.88	21.30	17.85	19.60	18.73	16.25	16.50	16.38	30.15	30.23	30.19
T_3-2.50 kg Zn ha^{-1}	20.13	23.33	21.73	18.35	20.45	19.40	16.78	16.90	16.84	31.13	30.75	30.94
T_4-5.00 kg Zn ha^{-1}	21.13	24.40	22.76	19.19	21.05	20.12	17.78	17.75	17.76	33.70	32.90	33.30
T_5-10.00 kg Zn ha^{-1}	22.95	26.23	24.59	20.38	22.25	21.31	18.38	18.85	18.61	34.73	34.98	34.85
T_6-20.00 kg Zn ha^{-1}	23.18	26.83	25.00	21.18	23.10	22.14	18.50	19.61	19.06	35.33	35.88	35.60
SEm (±)	0.77	0.86	0.54	0.62	0.79	0.47	0.66	0.77	0.45	1.15	1.17	0.77
C.D. (5 %)	2.36	2.64	1.56	1.90	2.45	1.36	2.04	2.37	1.31	3.55	3.61	2.24

plant. Within each organ, Zn is preferentially accumulated by specific cell types. Similar findings are enunciated by the other workers like Kumar and Qureshi (2012).

Translocation and distribution of Zn into various plant parts of wheat at flowering stage

The data pertaining on Zn accumulation by different plant parts of wheat at flowering stage are presented in table 3 showed that the Zn concentration increased in various plant parts *viz.,* root, stem, leaves and earhead of wheat with the increasing levels of Zn fertilization. The application of 2.5, 5, 10 and 20 kg Zn ha^{-1} significantly increased the Zn concentration in root by 8.12, 14.79, 17.21 and 19.47 per cent and in stem by 8.44, 11.70, 17.04 and 20.12 per cent, respectively, as compared to control (100 % NPK alone). However, the application of 5, 10 and 20 kg Zn ha^{-1} increased Zn concentration in leaves by 10.05, 17.18 and 20.40 per cent and in earhead by 10.29, 15.65 and 18.25 per cent, respectively, over NPK fertilization alone. The application of 5, 10 and 20 kg Zn ha^{-1} were statistically at par with each other in increasing the Zn concentration in root and earhead while, 10 and 20 kg Zn ha^{-1} were at par in enhancing Zn accumulation in stem and leaves over control. The maximum concentration of Zn was found in earhead and lowest in leaves. The above findings suggested that during flowering stage Zn is translocated to reproductive part of the plant indicating earhead as the metabolically active region and site of maximum accumulation for Zn during flowering stage. Almost equal amount of Zn was observed in stem and root of wheat at flowering stage. This may be due to fact that Zn enters plants from the soil solution and is transported either symplastically, following uptake by root cells, or apoplastically, in regions of the root lacking a casparian band, to the stele where it enters the xylem. Xylem to phloem transfer may occur in the crown (where root meet the stem) as shown by Zn transport from one to another. Within the shoot, uptake of Zn^{+2} and Zn-complexes was by specific cell. Shoot Zn concentrations are often an order of magnitude greater than root Zn concentrations in plants that hyperaccumulated Zn, although the exact ratio depends on soil Zn phytoavailability (Broadley *et al.,* 2007). Higher accumulation of Zn was also noted in meristematic region at base of leaves and the root tips probably because of a large Zn requirement in there rapid growing tissues. However, transport of Zn from roots could have occurred in the xylem all the way to stem or leaves, with the subsequent transfer to the phloem from downward transport to roots representing a somewhat less directly route from one part of split-root system to the other. In addition, due to the relative long periods, some of Zn transported from leaves to roots via phloem could have been re-translocate back to the stem and leaves in the xylem. The above results are in agreement with the results of White and Broadley (2011).

Table 4: Effect of Zn application on grain and straw yields and harvest index

Treatment	Yield								
	Grain (t ha^{-1})			Straw (t ha^{-1})			Harvest index (%)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
T_1-NPK (Control)	3.75	4.00	3.88	4.60	4.93	4.76	45.01	44.92	44.97
T_2-1.25 kg Zn ha^{-1}	3.80	4.06	3.93	4.66	4.96	4.81	45.01	44.95	44.98
T_3-2.50 kg Zn ha^{-1}	3.89	4.19	4.04	4.73	5.04	4.88	45.06	45.24	45.15
T_4-5.00 kg Zn ha^{-1}	3.98	4.49	4.24	4.80	5.37	5.09	45.36	45.37	45.37
T_5-10.00 kg Zn ha^{-1}	4.48	4.77	4.62	5.28	5.56	5.42	45.97	46.41	46.19
T_6-20.00 kg Zn ha^{-1}	4.52	4.79	4.66	5.29	5.59	5.44	46.02	46.12	46.07
SEm (±)	0.23	0.24	0.16	0.29	0.29	0.19	0.84	0.93	0.59
C.D. (5 %)	0.70	0.74	0.45	NS	NS	0.56	NS	NS	NS

Translocation and distribution of Zn into various plant parts of wheat at maturity stage

The Zn concentration in root increased significantly by 7.37, 15.98 and 17.92 per cent, in stem by 8.24, 14.66 and 19.10 per cent, in leaves by 11.10, 16.42 and 19.19 per cent and in earhead by 11.98, 17.19 and 19.71 per cent with the application of 5, 10 and 20 kg Zn ha^{-1}, respectively, at maturity stage (Table 3). However, the application of 10 and 20 kg Zn ha^{-1} were statistically at par with each other. Further, Zn accumulation in grain was controlled by homostatic mechanism in plant that regulates Zn absorption, translocation and loading and unloading rates of phloem sap (Hao *et al.,* 2007). The grain Zn originated from two sources: first directly from soil and second, from the remobilization of stored Zn from leaves. In wheat, retranslocation from leaves is important for Zn allocation to the grain. The redistribution of Zn may depend on age of the plant as well as on Zn content of the source organs (Page and Feller, 2005). For example, senescence or limited Zn supply may limit redistribution, especially during grain filling (Palmgren *et al.,* 2008). Remobilization of Zn from old leaves to younger tissues and generative organs is much greater under adequate supply of Zn. However, increasing Zn concentrations in grain, seeds and fruits requires adequate Zn mobility in the phloem and, unless Zn-fertilizers are applied directly or they have functional xylem continuity, the mobility of Zn in the phloem will limit their Zn accumulation. Moreover, the decrease in concentration of Zn at maturity stage as compared to early growth stages might be due to dilution effect on account of increased vegetative growth and consequent dry matter accumulation. Similar spool of thought was advocated by Zhao *et al.,* (2011).

Yield and harvest index

The grain and straw yields as well as harvest index increased with the increasing levels of Zn as compared to NPK alone (Table 4). Zn fertilization @ 10 kg ha^{-1} enhanced both grain and straw yields significantly by 19.19 and 14.26 per cent, respectively, as compared to control. Further, the application of 20 kg Zn ha^{-1} was also significant increased grain and straw yields by 20.15 and 14.26 per cent, respectively, over control but statistically at par with 10 kg Zn ha^{-1}. However, the harvest index was also increased, though non-significantly with the increasing levels of Zn as compare to control. This was perhaps due to abundant supply of Zn nutrition and balanced NPK, which increased the protoplasmic constituents, accelerates the process of cell division and elongation, photosynthesis processes, respiration, nitrogen metabolism-protein synthesis, other biochemical and physiological activates. This in turn increased the values of all growth and yield attributing parameters, which finally reflected in increased both grain and straw yields as well as harvest index. Our results are in line with Mukherjee (2012) and Ram *et al.* (2012) which showed that the soil application of Zn had economical and long-term effects on enhanced crop production on Zn deficient soils.

REFERENCES

Anonymous 2012. Agriculture Statistics At a Glance. Agricultural Statistics Division. *Directorate of Economics and Statistics. Department of Agriculture and Co-operation, Ministary of Agriculture, Govt, of India, New Delhi.*

Bouis, H. E. and Welch, R. M. 2010. Biofortification-a sustainable agricultural strategy for reducing micronutrient malnutrition in the global South. *Crop Science.* **50:** 20-32.

Broadley, M. R., White, P. J., Hammond, J. P., Zelko, I. and Lux, A. 2007. Zinc in plants. *New Phytology.* **173**: 677-702.

Fageria, N. K. 2009. The Use of Nutrients in Crop Plants. *Boca Raton, FL:CRC Press.*

Gibbson, R. S. 2006. Zinc: the missing link in combating micronutrient malnutrition in developing countries. *Proceedings of the Nutrition Society, University of East Anglia, Norwich,* June 28 - July 1, 2005.

Gomez, K. A. and Gomez, A. A. 1984. Statistical Procedures for Agricultural Research. *J. Wiely and Sons,* New York, p. 680.

Hao, H. L., Wei, Y. Z., Yang, X. E., Feng, Y. and Wu, C. Y. 2007. Effects of different nitrogen fertilizer levels on Fe, Mn, Cu and Zn concentrations in shoot and grain quality in rice (*Oryza sativa*). *Rice Science.* **14**: 289-294.

Jackson, M. L. 1973. Soil chemical analysis Prentice Hall of India Ltd. New Delhi. pp. 219-221.

Kumar, M. and Qureshi, F. M. 2012. Dynamics of zinc fractions, availability to wheat and residual effect on succeeding maize in Inceptisols. *J. Agricultural Science.* **4**: 236-245.

Lasat, M. M., Baker, A. J. M. and Kochian, L. V. 1998. Altered zinc compartmentation in the root symplasm and stimulated zinc absorption into the leaf as mechanisms involved in zinc hyperaccumulation in *Thlaspi caerulescens*. *Plant Physiology.* **118**: 875-883.

Lindsay, W. L. and Norvell, W. A. 1978. Development of a DTPA-Soil test for zinc, iron, manganese and copper. *Soil Science Society of America J.* **42:** 421-428.

Mukherjee, D. 2012. Effect of different sowing dates on growth and yield of wheat cultivars under mid hill situation of West Bengal.

Indian J. Agronomy. **57**: 152-156.

Page, V. and Feller, U. 2005. Selective transport of zinc, manganese, nickel, cobalt and cadmium in the root system and transfer to the leaves in young wheat plants. *Annals of Botany*. **96**: 425-434.

Palmgren, M. G., Clemens, S., Williams, L. E., Kramer, U., Borg, S., Schjorring, J. K. and Sanders, D. 2008. Zinc biofortification of cereals: problems and solutions. *Trends in Plant Science*. **13**: 464-473.

Ram, A., Pannu, R. K. and Prasad, D. 2012. Effect of management practices on growth, yield and quality of late sown wheat. *Indian J. Agronomy*. **57**: 92-95.

Riceman, D. S. and Jones, G. B. 1958. Distribution of zinc in subterranean clover (*Trifolium subterraneum* L.) grown to maturity in a culture solution containing zinc labeled with the radioactive isotope 65Zn. *Australian J. Agricultural Research*. **9**: 730-744.

Sharma, B. L. and Bapat, P. N. 2000. Levels of micronutrient cation in various plant parts of wheat influenced by Zn and P application. *J. the Indian Society of Soil Science*. **48**: 130-134.

White P. J. and Broadley, Martin R. 2011. Physiological limits to zinc biofortification of edible crops. *Frontiers in Plant Science*. **2**: 1-11.

White, P. J. 2012. Heavy metal toxicity in plants, in Plant Stress Physiology, ed. S. Shabala (Wallingford:CABI), (in press).

Zhao, A., Lu, X. Chen, Z., Tian, X. and Yang, X. 2011. Zinc fertilization methods on zinc absorption and translocation in wheat. *J. Agricultural Science* **3**: 28-35.