Addressing variations in status of a few nutritionally important micronutrients in wheat crop

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Abstract
The micronutrient density of seeds is important not only for human nutrition but also for the nutrition of the next generation seedling. Deficiencies of zinc (Zn), iron (Fe) and manganese (Mn) in soils and crops occur nearly in all countries, particularly in cereals growing areas. The deficiencies adversely affect both food production and human health in a major part of the world. Therefore, variations in micronutrient (Zn, Fe and Mn) accumulation were evaluated among 14 wheat varieties in a field containing DTPA extractable Zn, Fe and Mn 1.60, 17.55 and 3.50 mg/kg soil, respectively at the Research Farm, CCS HAU, Hisar, Haryana, India during 2008-09 The treatments for Zn, Fe and Mn consisted of control, 50% of the recommended dose, recommended dose, 150% of the recommended and recommended foliar spray. There is considerable genetic variation in concentration of Zn, Fe and Mn among all the wheat varieties. The accumulation of Zn, Fe and Mn were more in straw than seed, irrespective of the variety under study.

Key Words
Wheat genotypes, micronutrients levels, grain and straw yields, micronutrients concentration.

Introduction
Crops and varieties within a crop often differ in their yield potential, nutrient requirement and efficiency in nutrient uptake, making it difficult to formulate general fertilizer recommendations. During the last four decades under a global wheat improvement programme, a number of high yielding varieties of wheat have evolved and been introduced in the cropping system which has helped in increasing food production, thereby greatly reducing starvation, and protein malnutrition. However, this has caused greater depletion of micronutrient reserves in soil and thereby accentuated wide spread deficiencies of micronutrients. As much as 48, 12, 5, 4, 33, 13 and 41 percent soil in India are affected with deficiencies of Zn, Fe, Mn, Cu, B, Mo and S, respectively. These deficiencies cause not only hidden hunger but also lead to entire failure of crops and lower content of trace elements in plant parts. Moreover, standard micronutrient concentration values are not available to suggest suboptimal, optimal or excess levels of trace element content in seed in a specific field crop. Similarly, optimal relative micronutrient concentration or critical concentration values are not available for classifying seed into deficient or sufficient categories as an index for their fitness for supporting human health. This necessitated a proper evaluation of influence of genetic variability among the newly released wheat varieties for micronutrient accumulation in seed and straw. Where soils have enough Zn, Fe, Mn and Cu, identifying plant varieties or crop species capable of higher absorption and translocation into the seed is highly desirable. Therefore, in this experiment an attempt has been made to address the micronutrients enrichment of seed and straw by screening the most efficient varieties of wheat.

Methods
The influence of genotypes on Zn, Fe and Mn accumulation in seed and straw in fourteen recently evolved varieties of wheat was evaluated in a field experiment. The characteristics of the experimental field were pH-7.2, E.C.-0.37 dS/m, O.C.-0.69%, $CaCO_3$-Nil and DTPA-extractable Zn, Fe and Mn contents were 1.60, 17.55 and 3.50 mg/kg soil, respectively (Lindsay and Norvell, 1978). Three rows of each variety were sown in a plot size of 12.3m X 12.3m for each element and received a basal application of N, P and K @ 120, 60 and 60 kg/ha, respectively as urea, DAP and muriate of potash.

The details of the experimental treatments are:
Soil type: One
Genotypes**:** Fourteen (WH-1025, PBW- 502, WH-542, PBW- 550, HD- 2851, PBW- 343, WH-711, WH-896, WH- 147, C- 306, RAJ- 3765, PBW- 373 WH-1021, WH-1022)

Micronutrients Levels:
Zn = 0, 12.5, 25.0, 37.5 kg $ZnSO_4$/ha and 0.5% $ZnSO_4$ foliar application.
Fe = 0, 25.0, 50.0, 75.0 kg $FeSO_4$/ha and 1.0% $FeSO_4$ foliar application.
Mn = 0, 25.0, 50.0, 75.0 kg $MnSO_4$/ha and 0.5% $MnSO_4$ foliar application.

In the case of Zn and Fe foliar application, all the sprays were done after first irrigation at an interval of 10-12 days. . In the case of Mn first spray was done four weeks after of seeding and the next two sprays after irrigation at 7-10 day intervals. The crop was harvested at maturity and the grain and straw yields was recorded. The plant samples were ground in a stainless steel grinder and digested with diacid mixture (nitric and percholoric acid, 3:1). The Zn, Fe and Mn concentrations in plant digests were determined by atomic absorption spectrophotometer. Total uptake of Mn, Fe and Zn in different wheat varieties was computed. In order to correlate the nutrient content in plants, to biological parameters the number of tillers, ear length, number of grains/tiller and 1000 grain weight were also recorded.

Results

The increments in content of critical micronutrients can materially increase the vigour, ear length, number of grains/tiller and grain yield of the subsequent crop grown in the soil deficient in the treatment nutrient. Plant breeders can select seeds for higher micronutrient content but greater enhancement in most cases can be achieved through fertilization, both by soil applied or sprayed on the flowers, seed pods, or ears 1 to 3 times during seed development. In this study all the varieties responded both to soil and foliar applied Zn, Fe and Mn which significantly increased the tillering, ear length, number of grains/tiller, thousand grain weights, yield of grain and straw as well as their concentration in seed and straw (Grunes and Alloway 1985; Alloway 1986). In the case of Zn, the maximum increase in grain yield was found when the recommended doses of Zn (25 kg $ZnSO_4$/ha) was applied as a soil application and 0.5 % solution of $ZnSO_4$ as foliar spray (Table-1). However, the increase in biomass production with Zn application was much lower than the increase in grain indicating that Zn is of critical importance for seed setting than for vegetative growth.

Table 1. Effect of Zinc, Iron and Manganese application methods on grain yield of wheat.

Treatments	Grain Yield (q/ha)		
	Zn	Fe	Mn
Control	33.66-48.73 (40.98)	31.93-52.75 (43.30)	32.94-48.36 (43.11)
Soil Application	34.35-50.90 (42.51)	36.55-57.38 (49.06)	34.42-52.60 (48.62)
Foliar Application	33.82-48.20 (42.22)	34.24-57.84 (47.85)	33.49-60.32 (47.93)

As Zn applied to soil has a significant effect for at least a couple of years, the soil application method has been considered as the most effective and economical for wheat in the long run. Both methods of Zn application clearly enhanced grain Zn concentration over control but the most effective method for increasing Zn in shoot and seed was foliar application that resulted in 1.0 to 5.5 and 1.0 to 2.1 fold increases in the concentration (Table 2). There was either no change or a slight increase in magnitude of Zn, Fe and Mn response when their levels were raised 50% higher than the recommended dose.

Table-2 Effect of Zinc, Iron and Manganese fertilization methods on metal concentrations in wheat grain.

Treatments	Micronutrients Content (mg/kg)		
	Zn	Fe	Mn
Control	26.5-39.5 (32.2)*	29.7-42.5 (34.4)	22.9- 31.5 (27.6)
Soil Application	26.5- 46.5 (37.9)	32.4- 77.0 (49.2)	25.4- 36.2 (31.06)
Foliar Application	32.5- 60.0 (47.2)	39.1- 98.4 (63.9)	25.4- 38.1 (32.7)

*Figures in parenthesis are mean values

Soil application of Fe and Mn usually has no or only limited residual effects as Fe^{2+} and Mn^{2+} are rapidly converted to Fe^{3+} and Mn^{4+}. Foliar application of Fe^{2+} was more effective than soil application increasing concentrations from 1.0 to 2.3 and 1.0 to 3.54 mg/kg, respectively in seed and straw of wheat (Tables 2 and 3). However, because of its rapid oxidation in soil and low mobility in phloem, soluble Fe^{2+} fertilizer is ineffective in increasing the Fe concentration in plants especially in the grain that develops months after germination. In contrast to Zn content in seed, which is easily enhanced, foliar application of $FeSO_4$ was not much better for increasing Fe content in wheat. The Mn content in seed and straw can be increased significantly by applying 0.5% $MnSO_4$ solution to the generative tissues (Asher 1994). However, in the present study the corresponding increase in Mn concentration of seed and straw of wheat varieties varied from 1.0 to 1.3 and 1.0 to 2.54 fold (Tables 2 and 3). This might be due to the variations in uptake and use efficiency of Mn between genotypes (Marschner 1995).

Table 3. Effect of recommended doses of Zinc, Iron and Manganese fertilization methods on metal concentrations in straw of wheat

Treatments	Micronutrients Content (mg/kg)		
	Zn	Fe	Mn
Control	8.0- 17.0 (11.1)*	61.9- 169.1 (110.3)	11.3- 16.0 (13.6)
Soil Application	10.0- 23.5 (14.6)	85.2-241.6 (168.4)	13.2- 23.7 (17.4)
Foliar Application	20.5- 45.5 (32.4)	131.3- 306.1 (204.5)	16.8- 35.6 (22.8)

*Figures in parenthesis are mean values

Conclusion
The response to Zn, Fe and Mn fertilization of the enrichment of these metals in seed and straw may varies from variety to variety. When an increase in grain Zn, Fe or Mn concentration in grain is required, in addition to soil fertilization, foliar application should also be recommended.

References

Alloway BJ (2008) 'Micronutrient Deficiencies in Global Crop production'. (Department of Soil Science, White Knights Reading RG 66DW: UK).

Alloway WH (1986) 'Soil, Plant-animal and Human Relationship in trace elements nutrition. Trace elements in Human and Animal Nutrition'. 5th edition. (Academic, Orlando, C.A.: Newyork, Sydney, Tokyo, Toranto).

Ascher JS (1994) Phosphorus and Mn seed coating for Crop growth and Yield. PhD. thesis, University of New England, Armidale.

Gruner DL, Alloway WH (1985) Nutritional quality of plants in relation to fertilizer use. In 'Fertilizer Technology and Use'. 3rd edition. (Ed OP Engelsstas) pp. 589-619. (Soil Science Society of America: Madison, WI).

Lindsay WI, Norvell WA (1978) Development of DTPA soil test for Zinc, Iron, Manganese and Copper. *Soil Sci. Soc. Am. J.* **42**, 421- 428.

Marschner H (1995) 'Mineral Nutrition of Higher Plants'. 2nd edition. (Academic: San Diego, CA).