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Enrichment of Cereal Grains with Manganese through Ferti-Fortification

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SUMMARY

Micronutrients are among major group of nutrients which our body needs. Lack of one or two can cause serious deficiency disease in humans. Plants also show micronutrient deficiency which occurs when a micronutrient is deficient in the soil in which the plants grow. Some of the best known micronutrient deficiencies include: zinc deficiency, boron deficiency, iron deficiency and manganese deficiency. manganese activates some important enzymes involved in chlorophyll formation. Mg deficient plants will develop chlorosis between the veins of its leaves. Breeding new plant genotypes for high grain concentrations of Zn, Fe and Mn (genetic bio-fortification) is the most cost-effective strategy to address the problem; but, this strategy is a long-term process. In this regard, agronomic bio-fortification or fertilizer strategy (ferti-fortification) represents an effective way and rapid process for combating human Zn, Fe and Mn malnutrition in developing countries. Ferti-fortification which means fertilising crops with micronutrients such as Fe, Mn, Zn, Cu, B and Mo can largely improve the malnutrition in human beings.

INTRODUCTION

Together with NPK, Calcium (Ca), Magnesium (Mg), and Sulphur (S) are essential macronutrients. The eight other essential nutrients constitute a distinct group of elements required by plants in very small amounts, described conventionally as micronutrients namely Copper (Cu), iron (Fe), manganese (Mn), molydednum (Mo), Nickel (Ni), Zinc (Zn), boron (B) and Chlorine (Cl). Still, other elements like selenium (Se), Silicon (Si) and Sodium (Na) are regarded as non essential, although they have been found to enhance growth and confer other benefits to plants (Datnoff et al, 2007; Marschner 2012). In countries or regions where staple foods consist mainly of cereals, root and tubers grown in nutrient poor soils, human micronutrient deficiency is widespread. Micronutrient deficiency can lower IQ level, cause stunting and blindness in children, lower resistance to disease in both children and adults and increase risks for both mothers and infants during child birth. (Gowthami and Ananda 2017). Manganese serves as an activator for enzymes in growth processes, assist iron in chlorophyll formation. About 5 per cent of Indian soils are deficient in manganese (Mn). Symptoms of manganese deficiency include interveinal chlorosis (dark-green veins), the most sensitive species being bean, lettuce, onions, peas, potato, sorghum, soybean, wheat (Humphries et al. 2007). Mn deficiency is also a serious problem to humans and can lead to asthma and severe birth defects and subjects that adopted a manganese deficient diet developed fine, scaly skin and presented increases of serum calcium, phosphorus and alkaline phosphatase levels (Enzo et al. 2011), However, it is relatively less prevalent compared to Fe and Zn deficiency. Sources of manganese fertilizer are shown in Table 1.

Table 1: Sources of manganese fertilizer

Manganese fertilizer	Chemical formula	Mn content, %
Manganese Carbonate	$MnCO_3$	31
Manganese Chelate	Mn-EDTA	12
Manganese Chloride	$MnCl_2$	17
Manganese Dioxide	MnO_2	63
Manganese Oxide	MnO	41-68
Manganese Sulphate	$MnSO_4 \cdot 3H_2O$	26-28

(Ozbahce *et al*. 2010., Mousavi *et al*. 2011)

Main Body

The process of increasing the micronutrient content of a food crop through selective breeding, genetic modification or the use of enriched fertilizers is called biofortification. This is a growing global concern regarding malnutrition for evolving crop cultivars having denser grains. Ferti-fortification which means fertilising crops with micronutrients such as Fe, Mn, Zn, Cu, B and Mo can largely improve the malnutrition in human beings. Let us discuss some work carried on fertifortification of micronutrient Mn. Zeidan (2010) reported that foliar application of micro elements significantly increased Fe, Mn and Zn contents in grains of wheat compared to control treatments (Table 2). Bansal & Nayyar (2000) observed that Mn chelate was four times more efficient than $MnSO_4 \cdot H_2O$ when applied to the foliage for correcting Mn deficiency in wheat at PAU, Ludhiana (Table 3). A field experiment was conducted in Ludhiana Punjab by Khurana *et al.* (2009) to study the response of wheat to 0.5% foliar spray of $MnSo_4$ and reported that root length (cm/plant), Dry matter yield (mg/plant) as well as Mn conc. (mg/kg DW) increased with the increase in number of Mn sprays (Table 4). Salem *et al* (2012) revealed that micronutrient fertilization using Zn + Mn + Fe treatment was the most effective treatment in increasing the concentrations of both Fe and Zn over the other treatments (Table 5).

Various field tests in China with peanut/maize and chickpea/wheat intercropping systems showed that gramineaceous species are highly beneficial in bio-fortifying dicots with micronutrients. In many wheat-cultivated countries, continuous wheat cropping is a widely used cropping system. Inclusion of legumes in the crop rotation system may contribute to grain concentrations of wheat plants. A field experiment was conducted by Yassen *et al*. (2011) in Egypt, comparing between the rates of FYM (10 and 20 m^3 fed^{-1}) and humic acid (1% and 2%), data showed that high rates of FYM and humic acid in combination with zinc increased Fe, Mn and Zn in grain of wheat plants as compared with the control treatment (Table 6). It might be due to beneficial effect of application of FYM and humic acid containing a considerable amount of organic matter and nutritional elements for plant growth. Optimised methods and rates of micronutrient application are shown in (Table 7)

Table 2: Macro and micronutrients concentration in grains as affected by micronutrients fertilization

S.No.	Items	Treatments		
		Control	Mn	L.S.D
1	Grain protein content (%)	9.70	10.80	0.5**
2	Grain P (%)	0.37	0.41	NS
3	Grain K (%)	1.27	2.35	NS
4	Grain Fe(mg/kg) Revise	33.10	48.10	11.5**
5	Mn (mg/kg)	42.50	54.60	15.9**
6	Zn (mg/kg)	22.00	25.90	17.0**
7	Cu (mg/kg)	6.30	9.50	0.3**

Table 3: Effect of mode, source and rate of Mn application on yield, Mn concentration and Mn uptake by wheat.

Source	Rate	Grain yield (t/ha)	Mn conc. (mg/kg)		Mn uptake (g/ha)
			Grain	Straw	
Soil application					
$MnSO_4.H_2O$	20 kg Mn ha^{-1} 40 kg Mn ha^{-1}	2.58 2.70	13.0 14.5	7.0 7.5	65 74
Seed treatment					
$MnSO_4.H_2O$ Teprosyn-Mn	75 g/kg 5 mL/kg	2.90 2.50	14.8 17.3	13.5 14.0	114 102
Foliar spray					

$MnSO_4.H_2O$	0.50% 1.00%	3.85 4.00	16.5 17.8	12.3 14.0	150 173
Mn-EDTA	0.10% 0.25%	3.73 4.05	16.0 18.0	11.3 13.0	137 166
Control yield (t/ha)		2.25	11.8	6.3	52
LSD (P=0.05)		0.69	4.2	3.1	32

Table 4: Dry matter yield, Mn concentration and Mn uptake as influenced by Mn sprays of wheat crop at 60 days of growth

No. of 0.5% Mn sprays	Root Length (cm/plant)	Dry matter yield (mg/plant)	Mn conc. (mg/kg DW)
0	3123	565	12.3
3	6678	987	21.1
CD (5%)	190	49	1.7

Foliar spray was done at weekly intervals
Var. – PBW 343
Design- RBD
Soil- Mn deficient (Loamy sand)

Table 5: Main effects of Zn, Mn and Fe addition and its application methods on Mn, concentrations in maize leaves at silking stage.

Treatments	**Mn concentration (mg/kg DW)**	
	2007	**2008**
Micronutrient fertilization (M)		
Non-fertilized treatment Zn Mn Fe Zn+Mn+Fe	32.7b 33.1b 35.8a 33.1b 35.2a	31.8b 32.3b 33.5b 32.3b 35.5a
Application method (A)		
Foliar spray Soaking Coating	34.6a 33.7a 33.6a	33.8a 33.3a 32.2a
F test Prob.		
M A M*A CV(%)	** NS NS 4.2	** NS NS 5.7

Means with different alphabets indicate significant difference between treatments by Duncan's multiple range test at p=0.05.*, ** significantly different at 0.05 and 0.01 probability levels, respectively.

Design – Split plot
Soil- Clay textured with 19mg/kg OM
Foliar spray applied at 40 days after seeding

Table 6: Effect of FYM, humic acid and zinc application on micronutrient uptake (g/kg) in wheat

Treatments	Mn grains (g/kg)
Control	41.4
FYM1 (10t/ha)	80.0
FYM2 (20 t/ha)	75.4
HA1 (1%)	71.8
HA2 (2%)	65.0
FYM1 + 0.5% Zn	90.0
FYM2 + 0.5% Zn	108.4
HA1 + 0.5% Zn	87.0
HA2+ 0.5% Zn	92.7
LSD (0.05)	16.9

FYM= Farmyard manure., HA= Humic acid., Foliar spray at tillering and boot stage

Table 7: Optimised methods and rates of micronutrient application

Manganese	3-4 sprays of 0.5-1.0% manganese sulphate is better than its soil application @ 40-50 kg/ha

Constraints in Ferti-fortification

- Fertilizers are expensive and have to be applied regularly
- Involves recurrent costs
- Resource-poor farmers cannot afford application of mineral fertilizers, especially micronutrient fertilizers.

CONCLUSION

All of the approaches of fortification in general and fert-fortification in particular are complementary to each other and should go hand in hand to alleviate the major concern of undernutrition. Ferti-fortification can be a rapid solution to enrich the cereals. Seed ferti-fortification by foliar feeding is more excellent to increase the grain yield and micronutrient concentration in grain part and has low cost as compared to other chemical methods. However, foliar sprays should be done at proper stages of crop growth.

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