The Current Scenario and Efficient Management of Zinc, Iron, and Manganese Deficiencies

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Of the micronutrients, zinc (Zn) deficiency is the most widespread problem in Punjab State. Soil application of zinc sulphate ($ZnSO_4$) is the most commonly used method to correct Zn deficiency in different crops. Severe iron (Fe) and manganese (Mn) deficiency is difficult to manage with soil application due to the oxidation of soil-applied Fe and $MnSO_4$ at high soil pH. Foliar application of Fe and Mn is an immediately effective measure to combat deficiency; however, both have to be applied repeatedly. A separate approach could be sowing of nutrient efficient crops that grow well on soils low in micronutrients. Selection and screening of micronutrient efficient crops should be carried out on a priority basis.

Micronutrient deficiencies have become one of the major constraints in sustaining crop production in the present exploitive agriculture. These deficiencies appeared much faster in the northern states as compared to other parts of the country, which may be attributed primarily to the fast adoption of new agricultural technology, including: cultivation of high yielding crop varieties, increase in cropping intensity, expansion of irrigation facilities, increased use of high analysis fertilisers, and poor quality irrigation water (Nayyar, 1999). Food grain production, no doubt, increased tremendously and made the country self-sufficient in food grains, yet it resulted in the faster depletion of the finite micronutrient reserves of soils. Adoption of the rice-wheat system, particularly in the non-traditional rice growing areas, has resulted in over-exploitation of the natural soil resource base and this trend has been enhanced by the imbalanced use of inputs. The increased use of poor quality irrigation water to meet the water requirement of this cropping system has further aggravated the problems of micronutrient deficiencies.

An early result of such exploitive agriculture practices was the appearance of Zn deficiency in many parts of the country. Field-scale deficiency of Zn was first noticed in rice on Tarai soils (Mollisols) in 1965, then in wheat on sandy soils of Punjab in 1970, and later in most of the intensively cultivated areas, particularly where rice and wheat were grown. Subsequently, deficiencies of Fe and Mn were recorded in particular situations, and their severity depended on soil conditions and the crop grown.

Present Scenario of Micronutrient Deficiencies

The total micronutrient contents of soils are generally of limited value as far as plant growth and responses to their application are concerned. In most cases, total contents are not significantly related to plant content. In order to match the levels of micronutrients in soil with plant requirement, their available contents are determined. Most researchers have used the DTPA soil test method for determining the available content of Zn, Fe, and Mn, particularly in alkaline calcareous soils. Like total contents, the available micronutrient status of soils is also highly variable. Analysis of more than 15,000 soil samples from different districts of Punjab have shown that available Zn, Fe, and Mn content of Punjab soils ranged from 0.02 to 10.4, 0.5 to 176, and 0.8 to 120 mg/kg soil with mean values of 0.95, 10.7, and 11.3 mg/kg soil, respectively (Nayyar et al., 1990).

Abbreviations and notes: ppm = parts per million; FYM = farm yard manure.

Manganese deficiency in wheat.

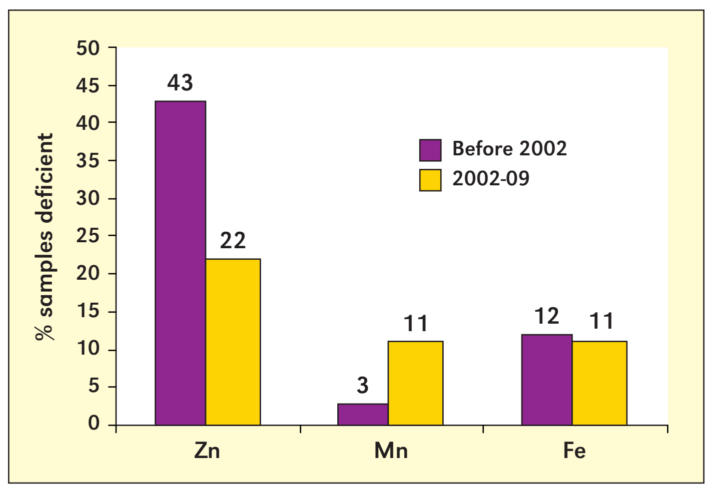

Figure 1. Temporal changes in Zn, Mn, and Fe status of Punjab soils.

Considering 0.6 ppm DTPA-extractable Zn as the critical limit for Zn deficiency, 22% of soils in the State are presently deficient, which has decreased from 43% in 1990 **(Figure 1)**. The soils of the south-western districts of the State are more prone to Zn deficiency compared to central and sub-mountainous districts. Further, soils that are coarse in texture, low in organic matter, and high in pH and $CaCO_3$ are more prone to Zn deficiency. Also, acute Zn deficiency in rice and significant response to Zn application was observed in flood

Zinc deficiency in rice.

Iron deficiency in rice.

plains and sodic soils of the State (Nayyar et al., 1990; Sharma et al., 1982; Sadana and Takkar, 1983).

Iron deficiency is widespread in crops grown on coarse-textured and calcareous soils. In Punjab, Fe is considered to be the second most limiting micronutrient in crop production after Zn. Poor availability of Fe in the soil, insufficient uptake and Fe inactivation within the plants are reported to be the main causes of Fe chlorosis in crops grown on such soils. In view of the high sensitivity of Fe to electro-chemical changes in soils, addition of easily decomposable organic carbon (C) materials is expected to increase the availability of native soil Fe (Sadana and Nayyar 2000). Considering 4.5 ppm DTPA-extractable Fe as the critical limit, about 12% of soils of Punjab are deficient in Fe.

Considering 3.5 ppm DTPA-extractable Mn as the critical limit (Nayyar et al, 1985), Mn deficiency has increased from 2% to 11% over the years. The increase in incidence of Mn deficiency, particularly in wheat and berseem, could be attributed to the previous cultivation of rice on coarse-textured soils, which leads to leaching of Mn to deeper soil layers during the rice season and following wheat or berseem crops show Mn deficiency. Severe Mn deficiency is difficult to manage with soil application due to oxidation of soil-applied Mn at high soil pH. Foliar application of manganese sulphate fertiliser is an immediate effective measure to combat Mn deficiency in wheat and Berseem (Nayyar et al., 1985, 2006; Sadana et al., 1991; Takkar et al, 1986) though it has to be applied every year. Among different crops, raya has been found more Mn efficient than wheat on Mn-deficient soils (Khurana et al., 2008; Sadana et al., 2003; Samal et al., 2003). Durum wheat cultivars are more sensitive to Mn stress and are not recommended on Mn deficient soils (Bansal and Nayyar, 1998; Bansal et al. 1991; Nayyar, 1999; Sadana, 2002, 2005).

Management Practices

Zinc application has increased the average yield by 340 to 950 kg/ha in cereals, 230 to 410 kg/ha in millets, 110 to 330 kg/ha in oilseeds and pulses, and 240 kg/ha in cotton (Nayyar et al. 1990). Response of crops to applied Zn generally increases as soil texture becomes coarser.

By and large, $ZnSO_4$ proves to be the efficient and economical source for correction of Zn deficiency in crops compared to relatively insoluble Zn carriers as well as several multi-micronutrient mixtures. However, organic manures (i.e., 12 t/ha FYM, 5 t/ha poultry manure, and 2.5 t/ha pig manure) were as efficient as 11 kg Zn/ha in meeting the Zn requirements of a maize-wheat rotation (Nayyar et al. 1990). Also half or even smaller quantities of these manures proved equally efficient or better for maize-wheat when amended with half the rate of Zn fertiliser. Among different application methods, soil application of $ZnSO_4$ through broadcast and incorporation proved more efficient compared to placement below or beside the seed, or through top-dressing. Foliar sprays of 0.5 to 1.0% $ZnSO_4$ neutralised solution proved inferior to soil application of Zn to wheat and rice. All other methods such as coating or soaking of seeds in Zn solutions, dipping rice seedling roots in ZnO suspension, and transplanting Zn-enriched nursery stock proved either inferior or just at par with soil application of Zn in combating its deficiency in crops.

The optimum rates of Zn application for different crops have been evaluated and recommendations devised. Soil application of zinc sulphate hepta hydrate (21% Zn) at 62.5 kg/ha or of zinc sulphate mono hydrate (33% Zn) at 40 kg/ha have been found to be equally efficient and economical for correcting Zn deficiency. The best time of Zn application for wheat and rice was found to be at seeding or transplanting of the crops. For the rice-wheat grown on moderately alkali as well as on highly deteriorated sodic soils, both gypsum and Zn proved essential for obtaining the best yields of rice and wheat. In a sandy loam soil, the residual effect of Zn has been found to

Response of wheat (left) to spray application of Mn.

Future Strategies of Research

Screening and/or breeding of micronutrient efficient crops and their cultivars should be done on a priority basis, and more importantly, nutrient efficient crop rotations should be recommended to farmers of the State, particularly those on deficient soils.

Systematic studies to monitor micronutrient deficiencies in different crop rotations and soils should be carried out using GIS. The entire state may be covered once in 2 to 3 years and a repeat survey should be done after 4 to 5 years to monitor the trends. In addition, critical limits for main crops of the State should be refined for different soils.

Limited information is available on emerging deficiencies of B and Cu in the State and on the response of different crops to application of Cu and B in deficient soils. More field experiments should be initiated to generate information on response, critical limits and their efficient management under field conditions.

Table 1. Benefit:cost (B:C) ratio of micronutrient fertiliser application to crops grown on deficient soils.

Crop	Micronutrient	Details	Average response, kg/ha	Benefit: Cost ratio
Wheat	Mn	3 sprays of 0.5% solution	700	14:1
Rice	Zn	62.5 kg zinc sulphate/ha	950	7:1
Wheat	Zn	Residual effect after rice	360	
Rice	Fe	3 sprays of 1% solution	1,880	5.4: 1

persist for 2 years in wheat-rice, gram-bajra, potato-guara, and wheat-maize rotations.

Iron deficiency is acute in rice grown on coarse-textured soils newly brought into cultivation. Rice grown on coarse-textured, alkaline soils can give striking responses to Fe application. Depending upon soil conditions, responses range from 200 to 7,300 kg/ha. Soil application of ferrous sulphate (19% Fe) proved noticeably inferior to three sprays of 1% ferrous sulphate solution in mending Fe deficiency in rice grown on sandy soils. Green manuring in rice markedly decreases the severity of Fe chlorosis in rice.

Significant responses of wheat grown in rotation with rice on alkaline, coarse-textured soils to foliar (0.5 to 1.0 % solution of $MnSO_4{\cdot}H_2O$) and soil (25 to 75 kg Mn/ha) application have been observed. Responses range from 200 to 2,950 kg/ha. For correcting Mn deficiency in wheat, $MnSO_4{\cdot}H_2O$ (30.5% Mn) proved more efficient than Mn-frits, MnO_2, and other multi-micronutrient mixtures. Three to four foliar sprays of 0.5% $MnSO_4{\cdot}H_2O$ solution initiated before the first irrigation proved more effective and economical compared to soil application of Mn. It commonly requires 7.5 to 10 kg $MnSO_4{\cdot}H_2O$/ha to fully ameliorate Mn deficiency.

Economic benefits of application of different micronutrients fertilisers to crops grown on deficient soils is given in **Table 1**.

Summary

For efficient management of Zn deficiency in different crops, soil application of zinc sulphate hepta hydrate (21% Zn) at 62.5 kg/ha or of zinc sulphate mono hydrate (33% Zn) at 40 kg/ha have been found to be equally efficient and economical for correcting Zn deficiency. Iron deficiency is acute in rice grown on coarse-textured soils newly brought under cultivation. Soil application of ferrous sulphate (19% Fe) proves to be inferior to 3 sprays of 1% ferrous sulphate solution in mending Fe deficiency in rice grown on sandy soils. Green manuring in rice can markedly decrease the severity of Fe chlorosis in rice. For correcting Mn deficiency in wheat, 3 to 4 foliar sprays of 0.5% $MnSO_4{\cdot}H_2O$ solution initiated before the first irrigation proves to be more effective and economical as compared to soil application of Mn. BC-SA

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