Introduction

Micronutrient deficiencies have been widely noticed in rice, wheat and other crops which causes low yield and increases malnutrition (Alloway 2004, Singh 2009). In India, the crop response ratio of fertilizers has gone down from 10.5 of 1960 to 5.3 of 1990 and growth process is not sustainable. Total factor productivity growth rate during the years 1980-90 in West Bengal, Haryana, Bihar, Uttar Pradesh and Punjab states was 5.13, 3.22, 1.47, 1.40 and 1.20 % yr^{-1} but this has come down to 1.25, 0.10, 0.24,-0.54 and 1.20 % yr^{-1} respectively which needs attention. Such change in factor productivity might be due to depletion of micronutrient reserve of soil. In view of this, present study is planned to assess the changing scenario of micronutrient deficiencies in soils during four decades and their influence on mineral nutrition of plants.

Materials and Methods

To delineate micronutrient deficient areas 262,476 surface soil samples were collected during past four decades and analyzed for available Zn, Cu, Fe and Mn status (Lindsay and Norvell, 1978). Changes in micronutrient deficiency was assessed phase wise with periodic increase or decrease in deficiencies in soils using critical level of 0.6, 0.2, 4.5 and 2 mg kg^{-1} soil for Zn, Cu, Fe & Mn, respectively (Singh 2001).Zinc deficiency in soil was confirmed through biological response based on 5823 field trials conducted by applying 5 kg Zn ha^{-1} prior to sowing of crops. Response data was grouped into percent trials responding to <0.2, 0.2-0.5, 0.5-1 and >1 t ha^{-1} representing <5, 5-10, 10-20 and .20% response over Zn control yield (Singh 2006).

To assess the impact of soil zinc fertility on mineral content in seed and nutritional health of animal and human subjects, studies were planned to collect 200 soil, grain and straw samples from wheat, maize and paddy fields. Samples were washed, dried, ground and digested in di-acid ($3HNO_3$:$1HClO_4$) mixture for micronutrient analysis. Also 20-60 farming families in Ranga reddy and east Godavary in Andhra Pradesh (AP), Panchmahal and Vadodara in Gujarat and Karnal and Sirsa in Haryana were selected with care that the subjects are generally consuming their farm produce and animals are not given concentrates. Intravenous blood samples were collected in clean tube and kept in ice box for 4 hrs for clotting. Samples were centrifuged at 2000 rpm for 10 min, decanted and serum plasma was stored in deep freezer. 5ml of clear aliquot was digested in di-acid for the estimation of micronutrient by atomic absorption spectro-photometer. In A.P., sampling was done for adult subjects kept on-fast before sampling but in Haryana, nonfasting subject samples were taken. Grain and fodder samples were washed, dried, and processed for mineral analysis after di-acid digestion in clear solution using standard methods.

Results and Discussion

Periodic Changes in scenario of Micronutrients Deficiencies

Scenario of micronutrient deficiency in north India in early eighties was different than now after four decades. Zinc deficiency remained a major problem all over country. Zinc deficiency has increased from 44% to 48% and expected to further increase up to 63% by 2025 as most of the marginal soils are showing higher response to added zinc (Singh, 2006). Data of

5823 trials indicated a shift in crop response from <0.2 t ha^{-1} in 44-46% trials during 1980's to response of 0.2-0.5 t ha^{-1} recorded in 40-65% trials in after nineties. This suggests that overall soil zinc status is declining and zinc deficiency is increasing with an exception in north India.

Scenario of zinc deficiency in soils of north zone showed a negative change. Though zinc deficiency before 1980 was a dominant problem in 77, 69 and 53% soils in Haryana, Punjab and Uttar Pradesh respectively but now this has declined to 19, 22.6 and 39% (Table-1). In these areas government promoted regular use of 15-25 kg zinc sulphate ha^{-1} to paddy, wheat and other crops instead of multi micronutrient mixtures. Consumption of zinc sulphate has increased during the years 1988 to 2008 from 16292 to 48,000 t yr^{-1} in Punjab, 1692 to 11470 t yr^{-1} in Haryana and 1752 to 22600 t yr^{-1} in Uttar Pradesh, which in turn improved the zinc fertility of soils, crop yields and its content in seeds. Thus in north India, decline in total factor productivity growth rate is neither attributed to zinc deficiency nor its toxicity is seen. Manganese (Mn) deficiency has emerged as a serious problem in wheat and other winter crops in coarse textured alkaline soils. In rice-wheat cropping, submergence of rice solubilizes more soil Mn which gets leached down to lower layers so next wheat crop badly suffered with severe Mn deficiency as wheat seedling roots are not able to absorb Mn from lower soil horizons (Singh 2006). Deficiency of Mn did not appear in maize-wheat system in similar soils so diversification of crops or cultivars is very much helpful in reducing Mn deficiency in wheat grown in these soils. Deficiencies of Cu, Fe and B in north India zone are not widely observed.

In middle India prevalence of Zn deficiency was higher 63 and 54% in Madhya Pradesh (M.P.) and Bihar compared to 26-36% in Gujarat, and West Bengal. Zinc deficiency remained similar over the four decades despite micronutrient fertilization. Even after four decades, little change in zinc deficiency 63.7, 57 and 36.5 % for M.P, Bihar and Gujarat soils is mainly attributed to the inherent low organic matter, high $CaCO_3$, and cultivation of soybean-gram, wheat crops. In calcareous soils of Bihar, management of multi nutrient deficiencies (Zn,B,S) is of utmost important for sustaining higher crop yields. These soils have marginal status of Fe, Cu, Mn.

Table 1 : Changes in percent zinc deficiency (PSD) in various states during four decades

Year	**1968-83**		**1983-89**		**1988-97**		**1997-2008**	
State	No. of Sample	PSD	No. of Sample	PSD	State	No. of sample	PSD	No. of Sample
Punjab	13341	53	6641	37	3142	27	3790	22.6
Haryana	14472	77	13350	52	7376	28	1702	19.4
Uttar Pradesh	6093	69	5570	62	20033	39	1259	35.5
Mean north India	**33906**	**66**	**25561**	**50**	**30551**	**35**	**6751**	**24.2**
Bihar	10779	54	6746	49	8435	66	721	57.0
Madhya Pradesh	7643	63	8069	66	25224	38	1804	63.8
Gujarat	21994	26	18944	22	8158	18	943	36.5
Mean middle India	**40416**	**41**	**33759**	**38**	**41817**	**55**	**3468**	**55.0**
Andhra Pradesh	4405	51	3304	52	3753	47	685	45.0
Tamil Nadu	7540	36	19433	48	2547	67	4581	73.9
Mean south India	**11945**	**42**	**22737**	**49**	**6300**	**55**	**5266**	**70.1**
Overall	**86267**	**51**	**82057**	**42**	**78668**	**47**	**15485**	**46.7**

In southern India, zinc deficiency is a predominant problem in. 58.4, 72.8,and 83 % soils of Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra due to low organic matter, high clay and $CaCO_3$. Zinc deficiency is frequently observed in swell-shrink soils in these states. In some part of Tamil Nadu, zinc deficiency has increased from 36% in 1980 to 73.8% in 2008 during four decades because of extensive use of multi micronutrient mixtures, mainly through foliar sprays which left little residual effect in soils compared to states using zinc sulphate.

Improvement in zinc content in grain and straw and nutritional health

In north India improvement in zinc fertility in four decades has helped in enriching seed with higher concentration of Zn in paddy, wheat & maize from 12 to 29, 14 to 72, 28 to 47 mg kg^{-1} seed. Zinc content was 3 to 4 time lower in seeds obtained from zinc deficient plants. Rice had low zinc than maize and wheat. Concentration of Fe, Mn, B, S also increased in seeds and stover with micronutrient and S fertilization. Study to assess impact of zinc deficiency on nutritional health of fasting adult men and women in Rangareddy and East Godavary district indicated that soils having low zinc status (0.37-0.45 mg kg^{-1}) produced low zinc grain (14-18 mg Zn kg^{-1}) and plants with (25-26 mg kg^{-1}). In similar studies in Gujarat and Haryana, soil zinc fertility influences the Zn enrichment in seeds and thereby, variations in blood plasma in non-fasting human and animals in Haryana. Thus, zinc fertilization to soil and thereby to seeds and feeds is very much desired to reduce malnutrition in animals and humans. Fodders in Haryana showed Cu deficiency instead of Zn and that of Mn deficiency in soils of Bihar and Punjab (Singh 2009).

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