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Micronutrients for Food and Nutrition Security

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Abstract

Micronutrient fertilizers play significant role in Indian agriculture as deficiencies of these nutrients exist in different soil-crop situations across India. On average, 36.5, 23.2, 12.8, 7.1 and 4.2% soils of the country are deficient in Zn, B, Fe, Mn and Cu, respectively. Along with single micronutrient deficiency, multi-micronutrient deficiencies prevail in different states. Every fertilizer granule carrying the right amount of micronutrient and delivering it efficiently to the plant will help to reduce the micronutrient deficiency very quickly. The responses of different crops to micronutrient applications vary with soil types and soil-crop management practices and micronutrients play significant role in enhancing use efficiency of macronutrients. Experiments carried out with rice, wheat and maize crops with soil and foliar applications revealed that soil Zn and Fe applications at the time of sowing had little or nil effect on the concentration of Zn and Fe in the grain under field conditions, whereas both soil and foliar application of Zn and Fe were very effective in improving the grain Zn and Fe concentration. Identification of high yielding Zn and Fe efficient cultivars is a better alternative to reduce and/or meet fertilizer Zn and Fe need of crops for high level of productivity. It is important to go for innovative solution which will allow proactive management of micronutrient nutrition which will ensure better and quality yield. The need-based micronutrient applications help in enhancing crop production of quality agricultural produce and maintaining animal and human health.

Key words: Micronutrient deficiencies, soil micronutrients, crop yield, crop quality, micronutrient fertilizer, malnutrition, food security, nutrition security

Introduction

Agriculture and its allied sectors are indisputably the largest livelihood provider in India, more so in the rural areas. It also contributes significantly towards the Gross Domestic Product (GDP) of the country. Agriculture is the main source of food and nutrition for animals and humans. Fertilizers have played a key role in the success of India's green revolution and subsequent self-reliance in foodgrain production. The demand of fertilizers has witnessed double digit growth rates over the past several years in India. However, factor productivity has declined over the years due to emergence of micronutrient deficiencies in soils. Micronutrient are essential elements which are required in very small quantities for overall growth of the plants. The essential micronutrients for plants are zinc (Zn), boron (B), iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo), chlorine (Cl) and nickel (Ni); for animals are Zn, Fe, Mn, Cu, selenium (Se), iodine (I) and cobalt (Co) and for humans are Zn, Cu, Fe, Mn, Mo, Co, I, Se, fluoride (F), chromium (Cr). Boron is considered as beneficial trace element for animals and humans because it prevents losses of Ca and Mg from the body. Every micronutrient performs specific roles in plant, animal and human metabolism and deficiency of a particular nutrient cannot be mitigated by replacing with other elements.

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Minerals applied to crops for their nourishment improve the nutrition content of the crops. Inadequate supply of these nutrients in micronutrient deficient soils can lead to loss of yield as well as quality of produce, and thereby animal and human health and their productivity (Shukla et al., 2018). The intensification of agriculture resulted in a further whooping of nutrient mining from the finite micronutrient soil resources leading to wide spread micronutrient deficiencies. The continuous shipping away of micronutrients by crops has depleted the soil reserve and rendered the soils deficient in these nutrients across the country. On an average, 188 thousand tonnes micronutrients are removed annually by agricultural crops. Research evidences suggested that need-based inclusion of micronutrients in the fertilizer schedules would not only eliminate their deficiencies in soil but also enhance the efficiency of macronutrient fertilizers (Shukla and Behera, 2019). Stagnation in crop productivity can also be minimized by proper micronutrient management with balanced fertilization schedule, leading to reduction in cost of cultivation.

The health and wellbeing of human population is influenced by nutrients and other biological active compounds obtained from food. Agricultural produce is the primary source of

food and in turn the nutrients for human. Vitamins and essential trace elements are called micronutrients which are required in small quantities for human health. Micronutrient malnutrition develops when food intake could not provide the desired amounts of these nutrients to meet the requirement. This prevails widely in low-income population who mainly depend upon cereals and tubers, for energy requirement, which are low in micronutrients density (Bouis et al., 2011). They consume very little of micronutrients dense foods like fruits, vegetable and animal products. Among the important micronutrient malnutrition in world population, Zn and Fe deficiencies are the most prevalent ones. At a global scale, about three billion people have been inadequate in Zn and Fe nutrition and 500,000 children lose their lives due to this. In recent years, the interest in adopting healthy diets drew increased attention to mineral nutrients, including Zn and Fe. Deficiencies of Zn, Fe and other micronutrients in human population (often referred as "hidden hunger") especially in developing countries adversely affect gross national product and causes higher economic losses.

Micronutrient Deficiencies in Crops and Soils

In spite of the relatively high total concentrations of micronutrients reported in soils of India, micronutrient deficiencies have been frequently reported in many crops grown on various soils of the country due to low levels of available micronutrients in soils. The extent of deficiencies varies with soil type, crop genotype, management and agro-ecological situations. With the intensive cropping of high yielding varieties of rice and wheat, deficiency of Zn initially, and subsequently deficiencies of Fe in rice, and Mn in wheat, emerged as threats to sustaining high levels of crop production. Micronutrient deficiencies are now frequently observed in intensively grown cereals, oilseeds, pulses and vegetable crops. Availability can be defined as the quantity of a soil nutrient that is accessible to plant roots during the period of growing season. Since plant roots accumulate micronutrients directly from the soil solution, total pool of soil micronutrients is not directly available.

Based on the critical limits followed in different states of India, status of micronutrient deficiencies has been assessed in different soils. The analysis of more than 2.40 lakhs soil samples, under the aegis of All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, revealed widespread micronutrient deficiencies in soils. On average, 36.5, 12.8, 4.2, 7.1 and 23.2% soils are deficient (acute deficient + deficient) in Zn, Fe, Cu, Mn and B, respectively **(Figure 1)**. Based on the newly devised critical limits, 7.9, 28.6 and 14.7% area are acute deficient, deficient and latent deficient in Zn, respectively (Shukla et al., 2021a). While 4.0, 19.2 and 21.5% area are acute deficient, deficient and latent deficient in B. Areas under Mn, Cu and Fe deficiencies in different categories are coming up in different states of the country.

Micronutrient Fertilizers in India

The fertilizers containing micronutrients with specifications are included under Schedule-I, Part-A, 1(g) (Micronutrients), 1(h) (Fortified fertilizers) and 1(k) (Liquid fertilizers) of the Fertilizer (Inorganic, Organic or Mixed) (Control) Order (FCO), 1985. Straight micronutrient fertilizers cover Zn, B, Fe, Mn, Mo, Cu, Cl and Ni is a mined, refined or manufactured product containing one or more essential plant nutrients in available or potentially available forms and in commercially valuable amounts without

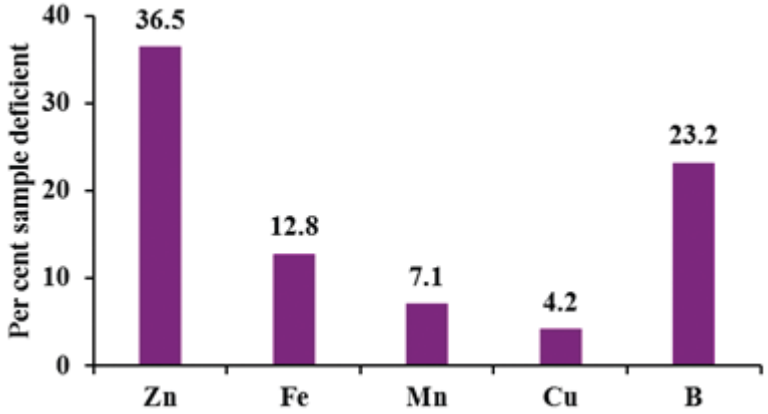

Figure 1. Status of micronutrient deficiencies in soils of India (Source : Shukla and Behera, 2019)

carrying any harmful substances especially those have adverse environmental impact. Government of India included a new category of fertilizers called Customized Fertilizers (CFs) under clause 20B of FCO basically to address the problem of increasing multi-nutrient deficiencies. In addition, a number of multi-micronutrient mixture formulations have been notified by different state governments. While single-micronutrient fertilizers are common for all states based on FCO declaration, micronutrient mixtures viz., mixture of two or more micronutrients are notified by different states based on respective crops and soils.

Consumption and Requirement of Micronutrients Fertilizers and Production of Foodgrains

There is an increasing trend in consumption of micronutrient fertilizers and foodgrain production of the country over the years. **Figure 2** shows the importance of micronutrients in sustainable food production. According to an estimate, contribution of Zn and B fertilizers to present food crop production comes around 29 Mt rice equivalent yields (Shukla and Behera, 2012). Contribution from other micronutrients should not be underestimated as their use has been increasing consistently to enhance crop productivity. As per recent estimate of micronutrients' consumption, use of zinc sulphate was the highest (2,03,794 tonnes) followed by ferrous sulphate (43,425 tonnes), boric acid / borax (27,929 tonnes), manganese sulphate (18,698 tonnes) and copper sulphate (4,760 tonnes) during 2021-22 (FAI, 2022). Analysis of state-wise data revealed that five states, viz; Punjab, Haryana, Uttar Pradesh, Karnataka, Maharashtra, Madhya Pradesh and West Bengal together accounted for 80% of zinc sulphate consumption of the country's total consumption. The whole array of product range (including Zn-EDTA, Zn coated fertilizer, Zn fortified fertilizer, Zn containing liquid fertilizer, etc.) is available for addressing the issue of Zn nutrition. Since, Zn-EDTA is quite costly, it is expected that zinc sulphate will continue to be the principal Zn containing fertilizer, so long as cost of efficient fertilizer (like Zn-EDTA) does not becomes affordable for the farmers.

The new category of fertilizers included in the FCO, like Zn-fortified fertilizers, Zn-containing liquid fertilizers, etc. are promising micronutrient fertilizer grades. Of the total Zn used, 70% goes to the field crops and remaining 30% to vegetable and fruit crops, while the reverse is true for Mn, Fe and Cu. Of the total B application, about 60% is applied to vegetable and fruit crops and 40% to food and oilseed crops. Present requirement of different micronutrients is 285,000 tonnes of zinc sulphate 177,000 tonnes of ferrous sulphate 118,000 tonnes of manganese sulphate 29, 000 tonnes of copper sulphate and 129, 000 tonnes of boric acid/borax, as estimated based on current level of deficiencies, nutrient mining from the soil and micronutrient recommendations for different crops **(Table 1)**. However, the corresponding requirements of those fertilizers may be 347,000 tonnes, 193,000 tonnes, 127,000 tonnes, 31,000 tonnes and 147,000 tonnes by 2035 and to 402,000 tonnes, 216,000 tonnes, 138,000 tonnes, 34,000 tonnes and 167,000 tonnes by 2050 as estimated based on area likely to be deficient and enhanced

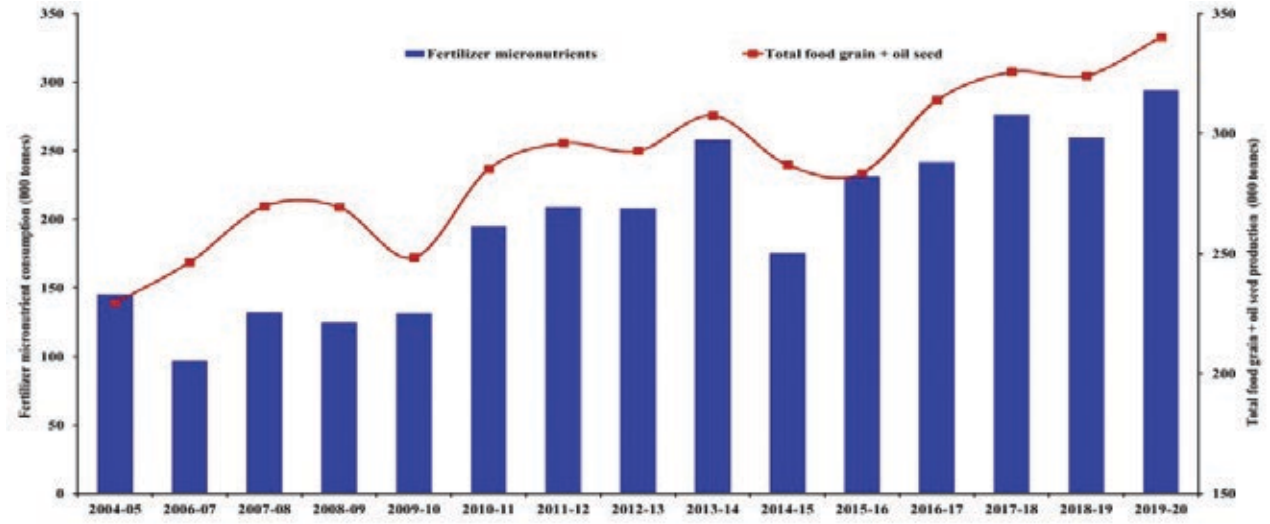

Figure 2. Foodgrain and oilseed production vis-a-vis micronutrients fertilizers consumption in India

Table 1. Micronutrients requirement for agricultural and horticultural crops (Source: Shukla et al., 2021b)

Micronutrient products	Requirements ('000 tonnes)		
	2020	2035	2050
Zinc sulphate	285	347	402
Ferrous sulphate	177	193	216
Manganese sulphate	118	127	138
Copper sulphate	29	31	34
Boric acid/borax	129	147	167

crop requirement due to intensification of agriculture.

Strategies to Combat Malnutrition

Ensuring consumption of a micronutrient enriched balanced diet is the most effective way of preventing and even eliminating micronutrient malnutrition in India. The supplementation through pills, food fortification with Zn and Fe, homestead food production, and crops enrichment through genetic and agronomic manipulation, *i.e.*, biofortification are common approaches to address malnutrition of micronutrients. Fortification of food is the most practical way of preventing widespread deficiencies of elements by delivering nutrients to large segments of the population without requiring radical changes in food consumption patterns among population. For example, salt fortification with iodine and fluoride is mandatory in 134 countries. The mandatory fortification in India was inaugurated in 1953 through fortification of hydrogenated vegetable oil with vitamin A and D. Later on, in 1998, salt fortification through iodization came into existence to control Goiter. Currently, around 83 countries are exploring fortification legislations for micronutrient enrichment of the staple food. In civilized societies and cities, micronutrient deficiencies are addressed through supplementation and fortification.

However, in developing countries widespread implementation of dietary diversification and food fortification /supplementation programmes are constrained by low income coupled with the poor access of the target population to market. The success of supplementation and fortification approaches is depending only if most of the people purchase processed foods as diets supplement. Unfortunately, in country like India, majority of the poor, especially, farming community are dependent on their own produce for food, consumption of industrially processed foods is beyond their reach. The fortification interventions can be quite limited, especially in rural areas of developing countries where most of the poor people live. To combat the drawbacks of supplementation / fortification, bio-fortification of staple food is a promising, viable and effective route for delivering nutrient rich food to take care of hidden hunger particularly in rural population. This strategy can complement other approaches through providing a sustainable and cheaper means of reducing under-nourished mass which depends on supplementation and commercial fortification for nutrition. Therefore, to address the occurrence of micronutrient deficiencies in human populations, agricultural scientists are concentrating to formulate methods to apply fertilizers and/or use plant breeding strategies to increase the concentrations and/or bioavailability of mineral elements in edible portion of crop plants (Cakmak and Kutman, 2018; Behera et al, 2020, Shukla et al, 2014), looking to the problems of malnutrition.

ICAR institutes/State agricultural universities have been engaged in developing varieties of crops, more so rice, wheat and millets enriched in Zn and Fe. Even during Covid-19, doctors advised the patients for Zn tables for helping them to develop immunity against this viral disease.

Conclusions

Indian soils are generally poor in fertility especially in micronutrients as these have consistently been mined away from the finite soil resources due to continuous cultivation for a very long-time without addition of micronutrient fertilizers resulting in emerging their deficiencies. Identification of site-specific micronutrient-deficient and/or sufficient areas under major soil types for different cropping systems and preparation of the detailed geo-referenced digitized maps is helpful in precise micronutrients applications to achieve higher sustainable agricultural productivity, nutritional quality, and better soil and human health. Biofortification could be efficient, useful and cost-effective strategy for eliminating Zn and Fe malnutrition in Indian population. The progress made on different aspects of biofortification needs to be intensified for developing genetically and agronomically efficient cultivars of different crops for Zn and Fe enrichment and their bioavailability to human. Genetically biofortified varieties/hybrids need to be evaluated with different agronomic biofortification strategies for their performance. Agronomic biofortification strategies for different crops grown in various

parts of the country need to be standardized for adoption by the farmers. Agronomic biofortification approaches such as soil and foliar application of fertilizers, physiological manipulation and use of microorganisms need to be tried separately or in combination for better result. Detailed foliar feeding schemes for different crops with appropriate fertilizer rate with right fertilizer products for improving load of Zn and Fe in edible plant produce need to be developed. Furthermore, Zn in soil-plant-animal-human continuum study needs to be scaled up for generating site-specific information. And finally, micronutrient fertilizer use efficiency is abysmally low and doesn't exceed 5%. Development of new and innovative micronutrient fertilizer products for higher use efficiency is the need of the hour.

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