

Best micronutrient management practices

for ameliorating micronutrient deficiency and enhance crop productivity

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Adoption of intensive cropping with modern agronomic practices, use of high-analysis NPK fertilizers devoid of micronutrients and less/no use of organic manures has resulted in emerging micronutrient deficiency in soils and crops of different states of India. Extent of micronutrient deficiency and the response of crops to micronutrient application varied with different soil-crop situations. There is need for adoption of best micronutrient management practices for ameliorating micronutrient deficiency in soils and crops and enhancing crop productivity and producing micronutrient rich agricultural produce.

Key words: Crop, Deficiency, Fertilizer, Intensive cropping, Micronutrient

MICRONUTRIENTS are required in lesser quantities by the plants compared to macronutrients although they are as important as macronutrients. Micronutrients are also known as trace or minor elements because of their lesser concentration in plant tissue compared to macronutrients. These are zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), nickel (Ni) and chlorine (Cl). Micronutrients are required for sustainable crop productivity, producing quality food materials and maintaining better animal and human health.

Inadequate supply of micronutrients leads to poor crop productivity as well as low quality of agricultural produce. At the same time, poor supply of micronutrients results in animal and human health impairment due disturbance in metabolic activities. Prevailing wide-spread nutrient deficiencies especially micronutrient deficiencies in crop plants are predominantly due to increased demand of micronutrients by the high yielding crop cultivars as well as adoption of intensive

cropping practices, use of high-analysis fertilizers with low micronutrient content, decreased use of organic manures and crop residues, growing of crops in soils with low micronutrient reserves, and other natural and anthropogenic factors affecting phyto-availability of micronutrients. Therefore, management of micronutrient deficiency in soil-plant system is utmost important for enhancing crop productivity, producing micronutrient rich agricultural produce and maintaining animal/human health.

Status of micronutrient deficiencies in India

Information on status of micronutrients in different soil types, districts, regions as well as for the country is highly essential to determine the nature and extent of their deficiencies/ toxicities to formulate strategies for their correction as well as industries. To study the changes in micronutrients status of soils and crops through its cooperating centres, All India Coordinated Research Project on Micro and Secondary Nutrients and

Pollutant Elements in Soils and Plants (AICRP-MSPE) initiated the work on delineation of soils in various agro-climatic zones since its inception in 1967. Through the intensive effort of delineation programme, AICRP-MSPE has been continuously reporting the status of micronutrients in soil-plant system. Based on the critical limits followed in different states of India, the micronutrients deficiency status has been assessed in different soils during 2011-2017. The analysis of more than 2.0 lakhs soil samples collected from 508 districts during 2011-2017 revealed wide spread micronutrients deficiency in soils. On average, 36.5, 12.8, 7.1, 4.2 and 23.2% soils are deficient in Zn, Fe, Mn, Cu and B, respectively.

Zinc deficiency mostly prevail in intensely cultivated soils and soils with coarse in texture, high in pH, low in organic carbon and high in CaCO₃ content. Among the different states of India, Zn deficiency (% sample deficiency) varies with a minimum of 9.6% in Uttarakhand to as high as 75.3% in Rajasthan. In general, higher Zn deficiency is observed in Rajasthan, Madhya

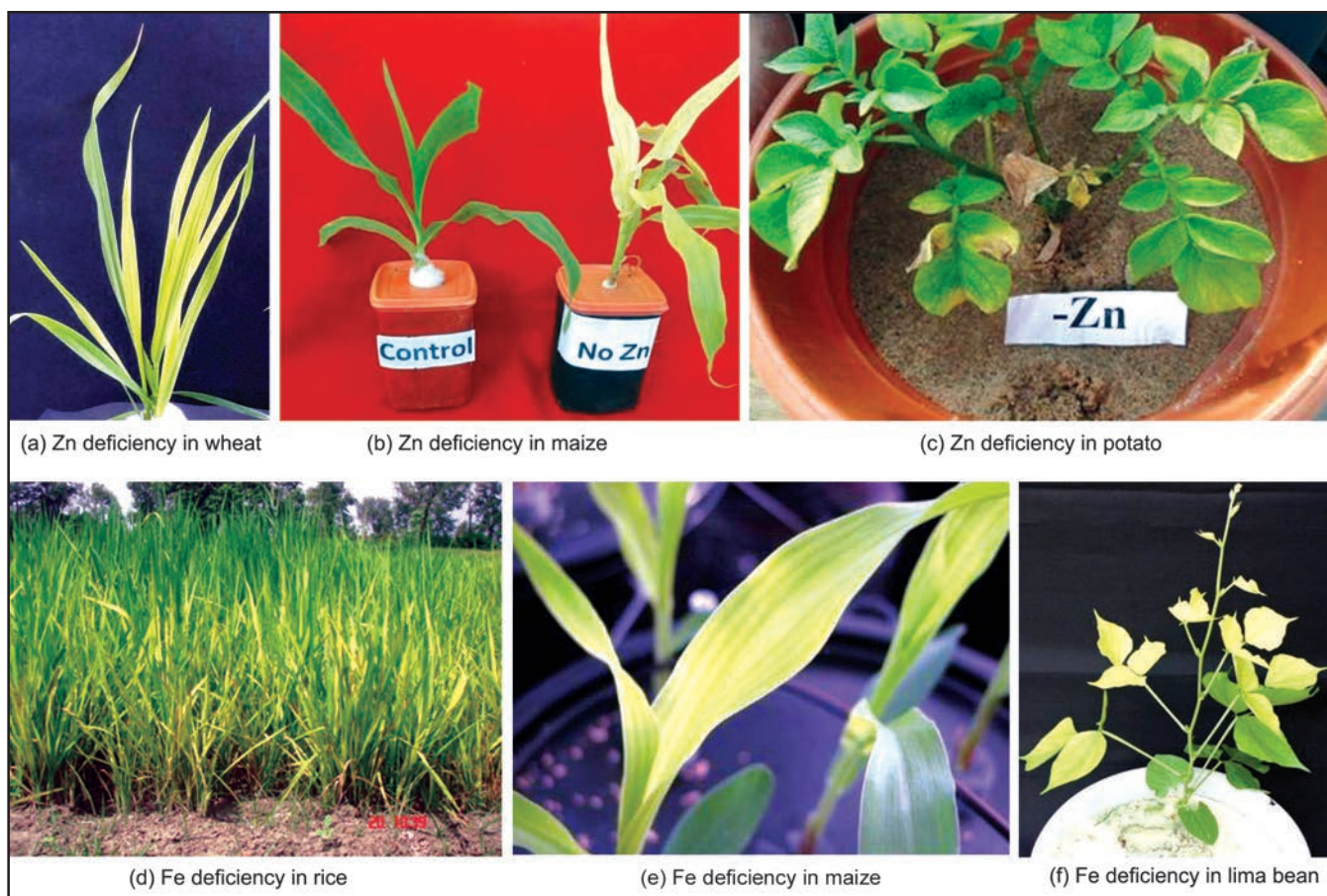


Fig. 1. Micronutrient deficiency in crop

Pradesh (66.9%), Tamil Nadu (65.5%), Maharashtra (54.0%), Bihar (44.0 %), and Uttar Pradesh (33.1%). Out of 508 districts delineated, 117, 100, 80, 63, 38 and 110 districts had deficiency in the range of 0-10, 10-20, 20-30, 30-40, 40-50 and > 50%, respectively. Zn deficiency has declined from 46% in 1967-1987 to 36.5% in 2011-2017 in soils of the country. It is due to regular and more use of Zn fertilizer in some parts of the country. Severe Fe deficiency prevails in the western states Rajasthan, Gujarat and Maharashtra. Iron deficiency is also emerging in Telangana, Karnataka, Uttar Pradesh and Bihar. In India, the problem of iron deficiency is mainly in calcareous and other alkaline soils having pH > 7.5. The availability of Fe gets reduced under draught or moisture stress condition due to conversion of Fe^{2+} iron to less available Fe^{3+} iron. On the other hand, the soils of north-eastern states, Odisha and Kerala are reported to have Fe toxicity problem in rice paddies. In general, manganese deficiency problems occur on soils

with low total contents of Mn (heavily weathered tropical and sandy soils), on peaty soils, or organic-rich soils with a pH above 6, and on mineral soils with pH values of 6.5 or above, such as calcareous soils, or acid soils which have been heavily limed. The incidence of Mn deficiency is increasing very fast particularly in rice-wheat cropping systems under sandy or loamy sand soils of Punjab and Haryana. In India, B deficiency has been recognised next to Zn. Availability B to plants is governed by soil pH, CaCO_3 and organic matter contents, beside total B content in soil, interactions with other nutrients, plant type or variety and environmental factors. Boron deficiency is more common in highly calcareous soils of Bihar and Gujarat and acid soils of West Bengal, Odisha and Jharkhand. Out of 508 districts, 193, 87, 64, 60, 41 and 63 districts exhibited B deficiency by <10, 10-20, 20-30, 30-40 40-50 and >50%, respectively. Most of the soils are adequate in Mo but its deficiency is noticed in some acidic, sandy and

leached soils. The deficiency is rarely reported in calcareous alkaline soils of arid and semi-arid regions as these soils have high available Mo contents. Mo deficiency is very scarce and localized in some parts of Maharashtra and acidic soils of Odisha and West Bengal, Kerala and Himachal Pradesh.

Micronutrient deficiency in crops

Soil micronutrient deficiency results in micronutrient deficiency in plants. Deprivation of particular micronutrient in plant leads to impairment of biological and physiological functions. Metabolic disruptions resulting from micronutrient deficiencies provide links between the function of an element and the appearance of a specific visible abnormality. Different crops show varied micronutrient deficiency symptoms (Plate 1). Micronutrient deficiency in soils and plants result in micronutrient deficiency in animal/human, because soil is the major source of micronutrients entering the food chain. It has been observed that cereals

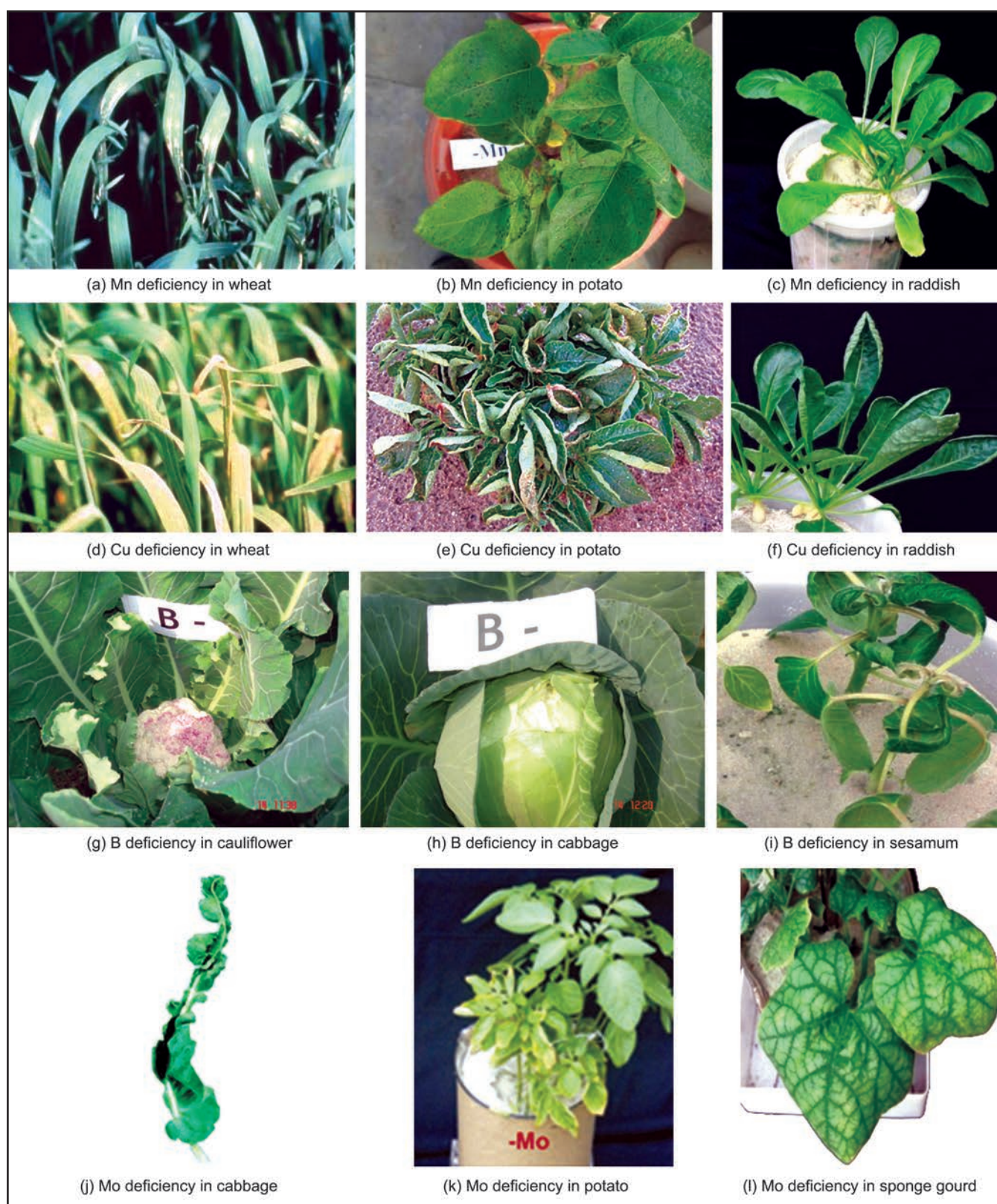


Fig. 2. Visual micronutrient deficiency symptoms of different crops

such as rice and wheat grown in Zn and Fe deficient soils have low Zn and Fe content in their food grains. Consequently, the cereal based food/diet, that contributes 70% of the daily calorie intake of the poor population of India, is also low in Zn and Fe concentration. Hence, production of

micronutrient-rich staple food grains, especially of rice and wheat, right at the farmers' field through innovative agricultural interventions such as biofortification techniques are required for managing the problem of Zn and Fe deficiency on a long-lasting and sustainable basis.

Crop responses to micronutrient application

Crop responses to micronutrient application was recorded in the study in micronutrient deficient soils and it varies widely depending upon soil and crop type. Crop responses to Zn application in large number of crops

was reported across the country based on more than 15,000 trials conducted at cultivator's field from 1967 to 2016. Depending upon the level of increase in relative economic yield (REY) of different crops, a soil is classified as marginal or non-responsive, responsive, very responsive, and highly responsive to Zn when incremental REY was <200, 200-500, 500-1000, > 1000 kg ha⁻¹, respectively. The number of responsive trials increased over the years from 58% during 1967-1984 to 63% during 1985-2000, 72% during 2000-2010 and 80% during 2011-2016. This indicates that either new cultivars are more responsive to Zn application or its deficiency has magnified due to greater mining of Zn from soil without its replenishment. On an average, crop responses to soil and foliar application of Fe ranges from 0.45 to 0.89 t/ha for cereals, 0.3 to 0.68 t/ha for millet, 0.34 to 0.58 t/ha for pulses, 0.16 to 0.55 t/ha for oil seeds, 0.20 to 1.53 t/ha for vegetables and 0.39 to 9.68 t/ha for cash and other crops. Soil and foliage application of Mn resulted in marked response of crops on Mn-deficient soils. The responses ranged from trace to 3.78 t/ha for wheat, trace to 1.78 t/ha for rice, 0.03 to 1.02 t/ha for soybean, 0.40 to 0.70 t/ha for sunflower, 3.63 to 4.30 t/ha for onion, 0.30 to 0.80 t/ha for tomato. Crop responses to Cu application ranged from trace to 1.78 t/ha of cereals, 0.20 to 0.30 t/ha of millets, trace to 0.80 t/ha of oil seeds, 4.43 to 6.18 t/ha of onion and 0.30 to 0.50 t/ha of sugarcane. Soil application of 0.5 to 2.5 kg B/ha gave a response of 108 to 684 kg grain/kg of B or 10 to 44% over NPK and helped in sustaining the high productivity of cereal, pulses, oilseeds and cash crops in B- deficient soils of Bihar, Orissa, West Bengal, Asom and Punjab. Response of crops to Mo application ranged from 0.24 to 1.01 t/ha for rice, 0 to 0.47 t/ha for wheat, 0.08 to 0.19 t/ha for soybean, and 0.10 to 0.40 t/ha for green gram.

Best micronutrient management practices

Best micronutrient management practices comprise demand and

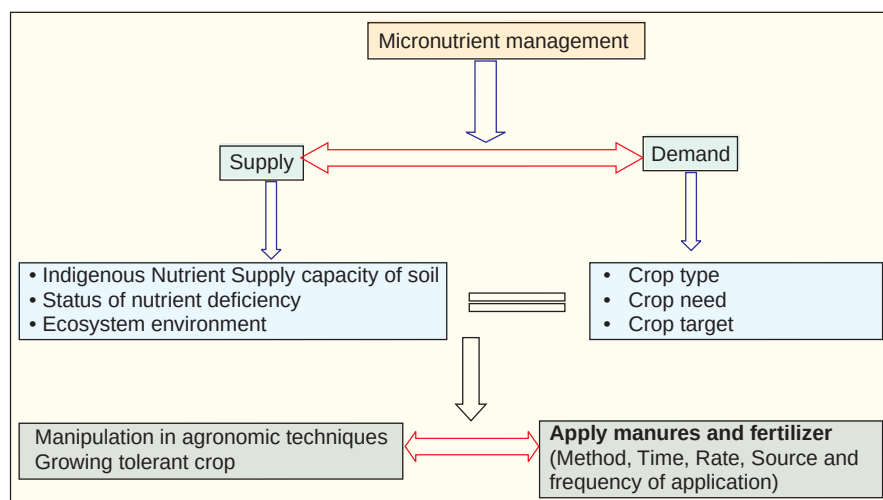


Fig 3. Schematic diagram of steps in management of micronutrients in soil-plant system

supply of micronutrient in soil-plant system (Fig. 3) is needed for ameliorating micronutrient deficiency in soil-plant system. It varies with crops, soil types, severity of deficiency, source, method, time, rates and frequency of application. Different micronutrient carriers available in the market need to be applied at required doses in appropriate way at appropriate time, depending upon the soil and crop types. Over the years, the consumption of micronutrient fertilizer has increased in India. The increasing trend in consumption of micronutrients fertilizer and food grain production of the country reveals the importance of micronutrients in sustainable food production (Fig. 4). The consumption of micronutrient fertilizer followed the order: zinc

sulphate > iron sulphate > boric acid/borax > manganese sulphate > copper sulphate. 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% are applied to vegetables and fruit crops and 40 % to food and oilseed crops. Based on the thousands experiments conducted at farmers' field, best micronutrient management practices have been developed for efficient management of nutrients to enhance system productivity.

Important micronutrient management practices are summarized for management of micronutrients under field condition.

Best management practices for Zn

- Among various inorganic sources, zinc sulphate hepta hydrate

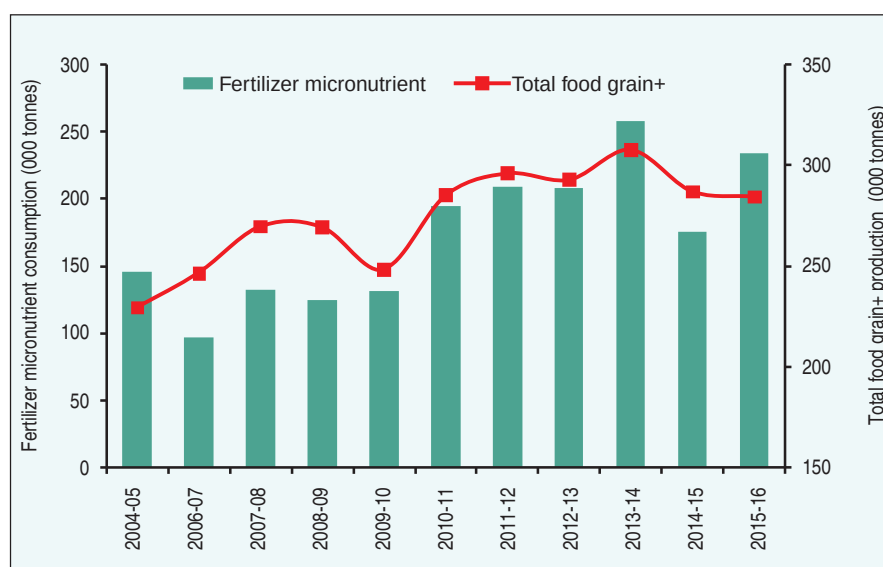


Fig. 4. Micronutrient fertilizer consumption vis-a-vis food grain production in the country during last decade

($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) containing 21-22% Zn is found to be the most efficient, commonly available, economically cheapest zinc source for correcting Zn deficiency in most of the crops and diverse soils as compared to sparingly soluble Zn sources, chelates and mixtures. Mono hydrated zinc sulphate (33%) and hepta hydrated zinc sulphate containing (21% Zn) were found equally efficient for correcting zinc deficiency either through soil and foliar application.

- Regular application of farm yard manure (FYM) at 10-15 t/ha if applied, it helps in mitigating deficiencies of all the micronutrients in long run. However, if farm yard manure is not applied annually, one should apply on alternate year to prevent emerging micronutrient deficiencies. When adequate FYM is not available, and 4-5 t/ha is added then one may reduce 50% of the recommended dose of FYM.
- If biogas slurry is applied, then application of 2.5 kg Zn/ha is adequate to get good yield in highly deficient soils. Green manuring is found helpful in enhancing availability of native micronutrients of soil and enhances yield. However, green manuring is not feasible in intensive cropping systems.
- The efficiency of synthetic Zn-EDTA was comparable with zinc sulphate. However, high cost of Zn-EDTA make this fertilizer most uneconomical and less effective for common use.
- The efficiency of sparingly soluble Zn sources such as ZnO , ZnCO_3 , Zn frits and highly soluble $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ source was at par in fine textured high Zn fixing soils. However, in coarse textured soils, soluble zinc sources proved better.
- Micronutrient blended macronutrients sources such as zincated urea, zincated super and boronated super were found inferior to zinc sulphate or chelates in highly Zn or B deficient soils.
- For root dipping and seed coating before transplanting, Zinc oxide and Zinc phosphate were better sources than zinc sulphate.
- Amount of zinc required for alleviating zinc deficiency varied

with severity of deficiency, location/soil types, nature of crops and cultivars. In case of the cereals application of 5.0 kg Zn/ha was sufficient to meet the Zn requirement of 2-3 crop cycles as Zn leaves marked residual effect for succeeding crops. In Calcareous soils, Zinc deficiency can be best alleviated with the use of 11 kg Zn/ha to wheat in rice-wheat system for two crop cycles.

- The dose may be reduced or increased as per severity of deficiency. Alkali soils are generally deficient in Zn and Ca. So higher yields of rice, wheat, berseem and other crops in such soils can not be achieved unless the toxicity of Na/deficiency Ca and Zn are corrected simultaneously. Zinc requirement of crops in alkali soils is reduced substantially by 25-75% depending upon the levels of amendments added (25-100%GR) or reducing level of sodicity.
- Fertilizer Zn requirement of crops was found to be double in coarse textured loamy sand soil than in fine textured loam or clayey soil for wheat and rice.
- Under brackish water irrigation in a highly sodic soil (pH 10.4) amended with gypsum @ 50% of the gypsum requirement (GR) the residual effect of 22 kg Zn ha^{-1} could last for four crops of rice-wheat sequence and the fifth crop required repeat application of Zn.
- The beneficial effect of FYM in combination with zinc was higher compared to Zn application alone.
- Application of 5 kg Zn/ha, or 4 t FYM + 2.5 kg Zn/ha were equally efficient in enhancing soybean-wheat productivity for 2-3 cropping cycles in medium to deep Vertisols.
- Time of zinc application mainly depends upon seed Zn content or severity of its deficiency in soil. Normally, basal application of Zn to soil through broadcast and band placement below the seed proved superior to top dressing, side dressing, foliar sprays and soaking or coating of seeds/seedling in Zn solution/slurry as zinc absorption by plants takes place up to tillering or pre-flowering stages.
- However, if basal application is

missed, zinc deficiency can be corrected by top dressing of zinc up to 45 days after sowing or transplanting. Seed coating with ZnO , Teprosyn zinc and zinc phosphate slurry can successfully correct Zn deficiency in marginally deficient soils.

- Foliar spray of 0.5 to 2.0% $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ solution to crops works as supplement to soil application of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ but not as a substitute. In field crops foliar spray was found to be inferior to soil application. However, it was reverse in horticultural and plantation crops.
- Foliar sprays of 0.5% zinc sulphate two to three times at 7-10 days interval just after appearance of its deficiency can control zinc deficiency more efficiently and effectively. If deficiency persists then more sprays may be applied.
- Fertilizer use efficiency of Zn applied to soil seldom exceeds 5%. However, application of organic manures was found to increase the efficiency of soil applied Zn.
- Relative efficiency of organic wastes (on the basis of equal quantity of Zn supply) was in the order of: poultry manure > FYM > compost > biogas slurry > sewage sludge > municipal waste > presumed. Residual effect of Zn applied through organic wastes was much higher than alone zinc sulphate application.

Best management practices for Fe

- Iron deficiency is a serious constraint to crop production in many upland, alkaline, calcareous and coarse textured soils with low in organic matter.
- Foliar sprays of 1-2% un-neutralized ferrous sulphate solution three to four times efficiently correct the iron chlorosis. Soil application of Fe is inferior and less profitable than foliar sprays.
- Iron chelates are more efficient than inorganic sources in combating Fe deficiency but farmers do not prefer to use chelates due to high cost except in cash crops.
- Iron deficiency in rice seedlings can be effectively controlled by raising them under puddled nursery beds

supplemented with requisite dose of FYM or compost. Ponding of water in nursery beds during dry spell is essential to mitigate Fe chlorosis.

- Iron deficiency in rice is encountered in upland soils or highly permeable coarse textured soils because of less mobilization of Fe^{2+} as the desired degree of reduction does not occur. So puddling markedly reduces the extent of Fe deficiency in rice.
- Green manuring, use of FYM and compost helped in mobilization of native soil iron during its decomposition. Combination of green manure (GM) or organic manures with foliar spray of un-neutralized 1% $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ solution is more effective in increasing crop yield than either GM or spray of iron sulphate solution alone.

Best management practices for Mn

- Sporadic deficiency of manganese was reported. Mn deficiency was reported in rice-wheat systems of Punjab especially in highly permeable coarse textured alkaline soils having low organic matter.
- Three to four foliar spray of 0.5-1.0% MnSO_4 solution is more efficient and economical than basal application for enhancing wheat yield in sandy soils.
- Foliar spray of MnSO_4 solution one before and two after first irrigation gave maximum wheat yield response in alkaline sandy soils.

- Durum wheat genotypes are more susceptible to Mn deficiency than aestivum wheat.

Best management practices for Cu

- Sporadic deficiency of Cu was reported and response of Cu fertilization is assessed only at few locations.
- Copper sulphate is widely used fertilizer material for soil application as well as foliar spray in order to ameliorate Cu deficiency.

Best management practices for B

- Borax, Granubor & boric acid proved equally efficient in combating B deficiency in crops.
- Basal application of B proved superior than foliar sprays. Sprays controlled B deficiency in standing crops but less effectively.
- Boron helps in pollination and seed formation, so foliar sprays are helpful in better pollination, seed setting and yield even in few soils tested adequate in soil available B. In case of hidden deficiency sprays of 0.2% boric acid or borax at pre flowering or flower head formation stages enhanced the crop yields.
- The optimum dose of B in lateritic soils ranged between 1.0-1.5 kg B/ha for cereals and 1.5-2.0 kg B/ha for pulses and oilseeds for 3-4 crops as boron leaves residual effect to the succeeding crops.

Best management practices for Mo

- Ammonium molybdate and sodium

molybdate are common sources of Mo to rectify Mo deficiency in soils and crops.

- Vegetables, pulses and oilseeds are more responsive to Mo application than cereals in Mo deficient soils.
- Application of 0.4-0.5 kg Mo/ha is sufficient to meet the Mo requirement of the crops in Mo deficient red acid soils. Mixing of ammonium or sodium molybdate with phosphatic fertilizers proved very effective to increase Mo use efficiency.

SUMMARY

Adoption of intensive cropping with modern agronomic practices, use of high-analysis NPK fertilizers devoid of micronutrients and less/no use of organic manures has resulted in emerging micronutrient deficiency in soils and crops in India. Extent of micronutrient deficiency and the response of crops to micronutrient application varied with different soil-crop situations. There is need for adoption of best micronutrient management practices for ameliorating micronutrient deficiency in soils and crops and enhance crop productivity and produce micronutrient rich agricultural produce.

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Cropping Season and Fertilizer Requirement

To ensure adequate availability of fertilizers, Department of Agriculture and Cooperation (DAC) assesses requirement of major fertilizers before each cropping seasons. The assessment is made based on requirements projected by State Governments/UTs, past consumption, weather conditions, targeted area, cropping pattern, area under irrigation etc.

Most ideally, fertilizer requirements should be assessed on the basis of nutrient needs of the crops and cropping systems in a particular area (block, district, and state) commensurable with existing nutrient deficiencies. This will ensure balanced fertilization and also ensure availability of needed fertilizers, in particular, secondary and micronutrients which very often farmers do not get at right time and right place. IFFCO has made soil testing service robust and performing to ensure adoption of site specific nutrient management. The Government has rightly initiated the scheme of soil health cards which will help farmers to know about soil health.

— Editor