

Alleviating malnutrition

through agronomic bio-fortification using value-added fertilizers

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In India, a significant portion of the population is suffering due to nutritional deficiency (malnutrition). The common nutritional deficiencies are vitamin A, zinc (Zn), iron (Fe), and protein. Improving the nutritional value of food is considered as the most sustainable and cost-effective approach to alleviate the malnutrition in India. Food fortification classified into 2 groups viz. bio-fortification (involvement of breeding techniques) and agronomic fortification (through the application of fertilisers). Application of value-added fertilizers such as customized, fortified and complex fertiliser is the most effective method to improve soil health through correcting the native soil nutrient deficiency. While the use of speciality fertilizers like water-soluble and liquid fertilizers are more suitable for nutritional enrichment through fertigation and foliar spray, respectively. Thus, the use of both soil and foliar fertilization using value-added fertilizers will be the most effective method for improving the nutritional quality of grain. Agronomic fortification is a short-term solution and complementary method to genetic bio-fortification which is more sustainable.

Keywords: Bio-fortification, Malnutrition, Nutrient management, Value added fertilizers

Soil fertility status and nutrient use efficiency

Increasing the nutrient use efficiency of applied inorganic fertilizers is the sole motto of improved nutrient management practices. Similarly, government policies are also modified time to time to promote balanced nutrition. A lot of effort has been taken for more than three decades to increase the nutrient use efficiency of various nutrients despite that the use efficiency of nitrogen (N), phosphorus (P), potassium (K) and micro-nutrients remains 30-50%, 15-25%, 60-75% and 3-5%, respectively in rice, while in other crops the N use efficiency was slightly higher (50-60%). The present nutrient use efficiency of our country is lower than many developed countries primarily due to imbalanced nutrition of NPK along with an inadequate supply of micronutrients and use of inefficient fertilizers which in turn threatened the sustainability and

nutritional security. Compare to primary nutrients (N, P, K), least importance has given to secondary and micro-nutrients use in Indian agriculture. As a result, the area under micro-nutrient deficit soils is exponentially increasing across the cropping system. There are multiple reasons for the increasing trend of micro-nutrient deficiency in India, including large removal of nutrient due to high yielding varieties, intensive cropping systems, lesser application of organic manures and micronutrient supplements, and use of high analysis fertilizers. It is reported that 48%, 12%, 5%, 3%, 33% and 11% of soils in India are potentially deficient in zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), boron (B) and molybdenum (Mo) respectively.

Problem of imbalanced fertilization

- Poor soil health. The fertility of soil will be lowered if imbalanced fertilization adopted for the long

period.

- Development of multi-nutritional deficiency. For example, in India, addition of K is not matching with its removal by crop plants. As a results K, status in many parts of India is declined from high to medium and medium to low category. Similarly, the number and area of deficiency of many micro-nutrients is increasing over the years.
- Environmental pollution due to low nutrient use efficiency. Excess application of nitrogen leads to leaching loss of N into ground water and surface water bodies, which causes eutrophication and methemoglobinemia in human who drinks nitrate contaminated water.
- Change in soil chemical properties which adversely affect plant growth
- Lower yield. Imbalanced fertilization may cause deficiency of one nutrient and toxicity of another nutrient. Both the condition plant growth is affected adversely and

- yield is reduced.
- Loss of grain quality. Poor soil yields poor quality grain. For example, deficiency of nitrogen leads to lower protein content in many cereals and millets.
- Economic loss to farmer. Low net return and higher cost of cultivation.

Malnutrition in India

The Sustainable Development Goals (SDGs) are the blueprint to achieve, ensure a better and sustainable future for all. They address the major global challenges that we are facing today, including those related to climate change, poverty and hunger. Malnutrition emerges as one of the most serious health issues worldwide and part of the SDG goal- Hunger. Consumption of the imbalanced poor diet in nutritional quality causes malnutrition which is more prevalent in underdeveloped and developing countries. There is a high degree of correlation between micronutrient deficiency in soil and human being. The widespread micro-nutrient deficiencies adversely impact crop yields and cause human nutritional deficiencies through the less nutrient-dense food chain. The chronic lack of micronutrients can cause severe health problems 'hidden hunger', especially among women and young children.

Iron: Iron deficiency in human causes a disease called anaemia (low level of haemoglobin reduces the capacity of blood to carry oxygen) and according to the National Family Health Survey (NFHS), in India 58.6% of children, 53.2% of non-pregnant women and 50.4% of pregnant women were found to be anaemic in 2016. According to World Health Organization (WHO), reported globally (mostly in Asia and Sub-Saharan Africa) around 8 lakh people (including 4.5 lakh children under the age of 5) die every year due to Zn deficiency. Diarrhoea in infants, retardation in growth, loss of appetite, impaired immune function, increased susceptibility to infections such as skin lesion is the most important clinical symptoms of Zn malnutrition.

Protein: About 80% of India's population is deficit in protein. It should be consumed @ 1g/kg of the person's body weight. Protein deficiency in human leads to kwashiorkor and marasmus disease, 60 % of our protein requirement is met through cereals which is relatively low digestibility and quality.

Agronomic bio-fortification/Ferti-fortification

Besides increasing food production, inorganic fertilizers application also helps in nutritional enrichment of food. Genetic bio-fortification approach is the most effective and economically feasible method to address the malnutrition in economically backward countries in long term. Ferti-fortification also known as agronomic bio-fortification is the short term, cost effective contingent approach to address the malnutrition. It involves nutritional enrichment of grain through fertilizer application (either soil or foliage) during the growth and development of the crop. the combination of soil and foliage application is often the most effective method. The combination of soil and foliage application of inorganic fertilizer is often the most effective method. Agronomic bio-fortification is the best approach to address the malnutrition in rural and economically backward population. Many experiments have shown that a balanced supply of nutrients increased the concentration of Fe and Zn in the grain. The supplementation

of Zn through inorganic fertilizers to cereals in Zn deficit soil, increase the grain yield and concentration of Zn in the grain. Basal application of 5 kg Zn/ha through zinc sulfate solution ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$), along with one foliar spray of 0.5% ZnSO_4 at the time of maximum tillering, increased the grain Zn content by 47% (27 mg/kg) over no Zn application.

Customized fertilizers

Customized fertilizer is one type of value-added fertilizer, which supplies the plant-available nutrients in adequate amount and proper proportion, facilitating a balanced application as it contains not only primary nutrients but also secondary and micronutrients. Customized fertilizers are materials containing all needed essential nutrients for a crop and region to meet the need as per Site-Specific Nutrient Management (SSNM). The adoption of SSNM practices and the development of crop and soil specific fertilizers (customized fertilizers) would solve the problem of native soil nutrient mining and also malnutrition in human. The customized fertilizer may include the combination of nutrient-based on soil testing and requirement of crop and the formulation may be of primary, secondary, and micronutrients. The particular workable texture ensures uniform distribution of nutrients and prevents nutrient deficiency and yield losses. The use of customized fertilizers will eliminate the need for separate application secondary and

Table 1. Customized formulations available in India

Formulations	Manufacture	Crop	Region
8:16:24:6:0.5:0.15 N, P, K, S, Zn and B	Tata Chemical Limited (TCL)	Potato	Agra, Aligarh, Farrukhabad districts of Uttar Pradesh
10:13:12:6:2:0 N, P, K, S, Zn and B	TCL	Sweet sorghum	Nanded, Maharashtra
15:15:15:9:0.5:0.2 N, P, K, S, Zn and B	Coromandel Industries Limited	Groundnut	Anantapur, Warangal districts of Andhra Pradesh.
20:0:15:0:0:0.2 N, P, K, S, Zn and B	Coromandel Industries Limited	Maize	Anantapur, Warangal districts of Andhra Pradesh.
10-18-25-3-0.5 N, P, K, S, Zn	TCL	Wheat	Western Uttar Pradesh
'Paras Formula' 10% N, 18% P_2O_5 , 25% K_2O , 3% S and Zn 0.5%	TCL	Sugarcane	Western-central Uttar Pradesh (UP)

micronutrients, save time and cost. It also makes the application of secondary and micronutrients more easy; uniform and overcomes the problem of non-uniformity in the application of a micro nutrients in the field. Because of its 100% solubility in water, it is suitable for fertigation. Thus, customized fertilizers are a potential source of plant nutrients in the high-tech farming system to nourish the crop plants with essential plant nutrients in optimum amount to boost soil health and crop productivity. Need to develop customized fertilizers for different regions and crops. The list of approved formulations of customized fertilizers is given in Table 1.

Water-soluble fertilizers (WSFs)

The water-soluble fertilizers (WSFs) easily dissolve in water and are suitable for application through irrigation water/fertigation/foliar spray. The main advantage of this type of fertilization is that growers can easily adjust the nutrient concentrations according to a crops changing needs during the crop period. The agronomic bio-fortification of Fe through application of Fe-enriched fertilizers in soil is less effective due to the precipitation of Fe (insoluble form) in the soil which cannot be absorbed by plants. The most efficient agronomic practices for Fe enhancement is the foliar application of mineral Fe. Many researchers have reported that increased Fe concentrations in wheat and rice grain through foliar application of mineral Fe. So the development of new water-soluble fertilizers fortified with Fe will greatly help in enriching the grain with Fe.

Table 2. List of water-soluble fertilizer approved by GOI

Fertilizer	Nutrient content
Potassium nitrate	13N:45K
Potassium sulphate	50K:17S
Urea phosphate	17N:44P
Monopotassium phosphate	52P:34K
Mono ammonium phosphate	12N:61P
NPK fertilizer	13N:40P:13K 19N:19P:19K 18N:18P:18K +2MgO

Source: Fertiliser Association of India, 2011

To achieve the full advantage of micro-irrigation, the adoption of fertigation (application of fertilizers through irrigation water) is essential. The list of WSFs approved by the Government and marketed in India are presented in Table 2.

Liquid fertilizers

Use of liquid fertilizers save substantial energy spent on solidifying the fertilizer in the factory, transportation, and its application in the field. Liquid fertilizers require a smaller area to store as compared to solid fertilizers. 'Ankur' a liquid fertilizer developed for wheat by National Fertilisers Ltd (NFL), Nangal, found to be equally effective as that of urea and calcium ammonium nitrate (CAN). In USA, liquid fertilizers are extensively where they have developed the proper storage, transport, and application equipment. The scope for liquid fertilizers in India is very high since the area under micro-irrigation and protected cultivation is increasing over the year.

Improving nitrogen harvest index:

Increasing the N concentration in grain (edible part) in turn increases the protein content. Thus improving N recovery efficiency will indirectly help in alleviating protein malnutrition. Use of nitrification inhibitors increase N use efficiency (NUE) through inhibiting the microbial oxidation of ammonia to nitrite. Similarly, coating of urea with hydrophobic substances reduce the leaching loss of urea and extend the period of urea availability to crop plants, thereby increase the N use efficiency. The leached down nitrate increase the concentration of nitrate in groundwaters and drinking of this water especially in Punjab and causes

health disorders viz. methemoglobinemia (Blue baby syndrome) especially in infants. Thus, low NUE not only leads to financial loss to the farmers, but it also causes environmental problems. As a whole, development of low cost, efficient fertilizer material is, therefore, an urgent need. Urea Super Granules (USG): USG is being used in Bangladesh in rice, and several other countries. The government of India (GOI) may identify the area and crops for its use. Improving N use efficiency, in turn, increase the grain protein content in cereals. Since, N account highest share among the inorganic fertilizer used, there is an immediate need to develop highly effective N fertilizers. Among many options, blending or coating of N fertilizers with nitrification inhibitors might be the best option to increase N use efficiency. There is a need to take into account of the cost: benefit ratio of such fertilizers.

Value-Added/Fortified Fertilizers

Fortification of the presently manufactured N/P/NP/NPK fertilizers to develop value-added/fortified fertilizers and its use in the farmers field will ensure the correction of deficiency of secondary and micronutrients. Evidence is mount up that the yield and nutritional quality of crops is increased by Zn fertilization. Use of Zn-enriched urea on rice could increase yields and grain Zn concentrations three-fold. The list of value-added fertilizers that have been approved by the Government of India is presented in Table 3.

Bioavailability mechanism of micro nutrients

The absorption and bioavailability of micro nutrient is largely influenced

Table 3. List of value-added fertilizers approved by GOI

Fertilizer	Nutrient concentration (P as P_2O_5 , K as K_2O)
NPK fertilizer fortified with Zn	12N:32P:16K:0.5Zn
DAP fortified with B	18N:46P:0.3B
NPK fertilizer fortified with Zn	10N:26P:26K:0.5Zn
Zinc coated phosphate (suspension)	12.9P:19.4Zn
Zinc coated urea	43N:2Zn
NPK fertilizer fortified with B	10N:26P:26K:0.3B
NPK fertilizer fortified with B	12N:32P:16K:0.3B
Calcium nitrate with B	14.6N:0.25B

by interaction between the micro-nutrients. Several absorption studies demonstrated the negative effect of iron supplementation on zinc and copper status and vice-versa. Similarly, Ascorbic acid supplementation strongly enhances iron absorption potential and improve iron status in iron deficit population. Thus, effect of one micro nutrient on another micro nutrient absorption and utilisation should also be considered while developing strategies to increase micronutrient status in a population.

SUMMARY

The nutrient-based subsidy (NBS)

scheme is promoting the development, manufacturing, and marketing of value-added fertilizers (Liquid/foliar/fortified/customized fertilizers). For Fe fortification, soil application of value-added fertilizer material was found less effective compared to foliar/fertigation using water and liquid soluble fertilizers. While for Zn enrichment both soil and foliar application using value-added fertilizers found equally effective. Improving the nitrogen harvest index through improving N recovery efficiency will be an effective method to overcome protein malnutrition. To tap the full potential of value-added fertilizers,

government and private institutions should develop more efficient fertilizer material and appropriate government policy will promote the development of new fertilizer material and its use in the field. The real impact of value-added fertilizers can be realized only if the urea fertilizer is brought under NBS.

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