The Pharma Innovation Journal 2022; 11(6): 886-894

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(6): 886-894

www.thepharmajournal.com
Received: 03-04-2022
Accepted: 09-05-2022

Rajnish Kumar
M.Sc., Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Dr. Chijina K
Assistant Professor, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Ravu Mohit
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

B Pawan Kumar
Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Dr. Chijina K
Assistant Professor, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

Fortification of micronutrients in chickpea (*Cicer arietinum* L.): Innovative approaches to combat malnutrition

Rajnish Kumar, Dr. Chijina K, Ravu Mohit and B Pawan Kumar

Abstract
Micronutrients are essential for the growth and development of leaving things. Fortification of micronutrients is a cost-effective, social, and economical approach to improve nutritional value either by biofortification or food fortification. WHO estimated that more than two billion people have a deficiency of minerals and vitamins. For low and middle-income countries, agronomic biofortification is an innovative approach to combat malnutrition. Chickpea is a nutritious pulse mainly produced for consumption and has the potential to boost the nutritional status of protein, iron, zinc, folate, carotene, and vitamins that overcome hidden hunger, particularly for children under the age of five years and pregnant women. An agronomic fortification is a sustainable approach to increasing micronutrients whereas food fortification is an industrial approach to supplement micronutrients in food for immediate requirements.

Keywords: Biofortification, chickpea, deficiency, fortification, malnutrition, micronutrient

Introduction

Pulses are a readily available and important source of protein and minerals for vegetarians. Consumption of pulse increases the quality of health and the environment (Curran 2012). Pulses are consumed in various forms such as dal, besan, flour, chole, feed of animals and the health benefit enhances purification of blood and boosts immunity. For national awareness and nutritional security, 2016 is declared the international year of the pulse by United Nations. Indian council of medical research (ICMR) recommends, that the need for pulses be 65 grams per capita per day however due to lack of production and product availability of pulses decreased from 60 grams per capita per day in 1951 to 45 grams per capita per day in 2021. Moreover, 44% of children under the age of 5 are underweight in India.

Chickpea (*Cicer arietinum* L.) is an important pulse crop grown widely in the world after common bean (Phaseolus vulgaris) and pea (Pisum sativum) and India ranked first in production as well as in coverage and contributes 65% world's production (FAOSTAT, 2015) [14]. It contains protein, fiber, and minerals such as phosphorus, iron, calcium, zinc, and magnesium and rich source of β-carotene (Legesse Hidoto *et al*., 2017) [20]. Chickpea contains protein (18-22%), carbohydrate (61-62%), fat (4.5%) and some other minerals such as iron (12.3 mg/100 g), calcium (280 mg/100 g), and phosphorus (301 mg/100 g). It belongs to the Leguminosae family and Papilionaceae as a subfamily having chromosome no. (2n= 14, 16). It is an herbaceous, annual, and rabi season-grown crop.

Major chickpea growing country in all over the world is India, Turkey, Pakistan, Australia, Myanmar, and Ethiopia. In India, it is widely cultivated in Madhya Pradesh, Rajasthan, Uttar Pradesh, Punjab, Haryana, Maharashtra, and Karnataka whereas Madhya Pradesh is a leading state followed by Rajasthan and Uttar Pradesh. India is the largest producer and consumer of chickpea however it does not fulfill the national requirements so it is important to increase the area and production of chickpea. Chickpea is a legume crop it can fix atmospheric nitrogen thus reducing the demand for inorganic nitrogenous fertilizer enhances productivity. In our country, the rice- wheat cropping system is mainly adopted. So there is an approach to increase the area and production by changing rice-wheat crop rotation with chickpea. India is the largest producer of pulse however we need good quality pulses. Biofortification is the best approach to enhance the quality and quantities. It improves the nutrition quality with the addition of essential requirements of micronutrients in our diet. Micronutrients (vitamins and minerals) play a very important role in metabolic activities and also boost our immunity.

Importance of micronutrients
Micronutrients are essential for plants as well as humans for physiological and biological functions. Micronutrients iron (Fe), zinc (Zn), iodine (I), boron (B), copper (Cu), selenium (Se) molybdenum, folates and carotenoids, and folic acid are important nutrients required for human growth and development and as contributes several metabolic functions in human. A major part of the population directly or indirectly depends on plant-based food which is deficient in micronutrients (Waterds and Grusak 2008), that does not intake recommended daily allowance such as malnutrition called "hidden hunger'' (FAO 2013) [15]. The deficiency of micronutrients is a serious problem throughout the world. Human beings required at least twenty-two micronutrients for good health. Deficiency of micronutrients may lead to poor growth, perinatal complications, undernourishment of pregnant mother may lead to low birth weight, infection, risk of mortality (Bailey *et al*. 2015) [6], and chronic diseases such as thyroid deficiency, cardiovascular diseases, cancer, etc. thus influence the quality of life (Tulchinsky 2010) [46]. Micronutrient is important for pulses and oilseeds crop for the symbiotic nitrogen fixation that improves the yield as well as enriches the nutrient deficient soil. Under nutrient deficient soil micronutrients mainly iron, zinc, boron, molybdenum, and copper respond well in pulse crops. The application of micronutrients in pulses increases the concentration of micronutrients in grain (Mohammad *et al*., 2011; Pathak *et al*., 2012) [34, 36].

Role of zinc
Zinc plays various important roles in the various biological and physiological functions of the human body. It is a constituent of nearly 3000 proteins which is 10 percent of total body protein (Krężel and Maret 2016) [29]. It retarded growth, development of the brain, and deficiency susceptibility to diseases (Krebs, Miller, and Hambridge 2014) [28] weak immune system, diarrhea in infants, mental illness retard fertility, and significant in cell division. The deficiency of zinc is a major threat of nutrient deficiency which is responsible for the death of children below the age of 5 years (Black *et al*. 2008). According to world estimation, more than 30 percent of the total population has a deficiency of zinc and 60-80 percent have iron deficiency (Combs 2001). Childhood dwarfism is caused by zinc deficiency (Hotaz and brown 2004). Recommended daily allowance (RDA) for zinc is 8mg per day for adult females and 11 mg per day for an adult. Zinc becomes the fourth essential nutrient after primary nutrients (nitrogen, phosphorus, and Potassium) Singh *et al*. (2011) [44] and it is deficient in the 42% of the Indian soils that are declared by analysis of a soil sample (nearly 250000) and plant (25000) samples were collected from different states of our countries showed that 48% of soil and 44% of plant samples deficient in zinc (Singh 2008) [45]. Zinc is widely involved in several metabolic processes such as carbohydrate, protein, lipid, and nucleic acid synthesis and degradation. Deficiency of zinc accumulation the concentration of boron in young leaves and the tip of branches thus decreasing the growth of the plant, delays in crop maturity, and also reduces nitrogen fixation (Ahalawat *et al*., 2007) resulting in the reduction of yield and also reduce water use and water use efficiency (Khan *et al*. 2004) [27].
In the chickpea growing region deficiency of zinc is widespread in the world (Roy *et al*., 2006; Ahlawat *et al*., 2007) [40] and this is the most common among micronutrients. Zinc fortification is necessary for the chickpea growing region, 38 grams of zinc, 35 grams of boron, and 1.5 grams of molybdenum are removed from the soil by each tone of chickpea (Ahlawat *et al*., 2007) thus it is more sensitive to zinc. The concentration of zinc in the soil varies on the type of soil and the common range of zinc in the soil is 0.48 mg/kg to 2.5 mg/kg (Ahlawat *et al*., 2007). Foliar spray of zinc increase the grain yield and protein content (Sarkar *et al*., 2007) [41]. In a developed country contribution of zinc in food is much more than in developing countries (Wessells and Brown 2012) [48]. However, in developing countries, most people are vegetarian either by choice or because low economic conditions for pulses are an important source of protein (Prasad 2009) [39]. In recent years, biofortification of zinc in wheat and rice have great attention to enhance nutritional quality but Pulses has not received such effective attention.

Role of iron
Iron plays a very crucial role in living organisms and is essential for several metabolic processes such as the synthesis of deoxyribonucleic acid (DNA) and electron transport and it acts as a cofactor of several enzymes. Recommended daily allowance of iron is 18mg per day for females and 8 mg per day for adult males (Food and nutrition board of the institute of medicines). Iron is essential for the synthesis of oxygen transport proteins (myoglobin and hemoglobin) and enzymes involved in electron transfer. Deficiency of iron causes anemia, diarrhea, pneumonia in children dizziness, disability, loss of energy, lower mental growth, low weight in newborn babies, lower cognitive skill, and poor growth and development in infants so iron fortification is a good and most desirable and cost-effective approach to reduce the malnutrition or hidden hunger of iron.

Role of boron
Response of boron in chickpea is higher than in other crops. It involves the metabolic process of plants. Foliar application of boron is beneficial in increasing plant growth and yield when soil deficit in boron is less than 0.3 mg per kg (Ahalawat *et al*., 2007). The deficiency of boron causes flower drop thus a poor set of pods and lower yield. 100% loss of yield in boron deficient soil (Ahlawat *et al*., 2007). Availability of boron decreases at higher soil pH or pH exceeds 6.5-7.0 (Sims, 2000).

Methodology for improvement of nutritional status
Several approaches are used for the enhancement of the nutritional status of crops to minimize the micronutrient deficiencies such are food supplements, dietary diversification, food fortification, and food fortification.

Food Supplements
Food supplements are consumed when intake foods are unable to meet an adequate amount of nutrients. Micronutrients consumed in the form of powder, solution, tablets, and pills which are used to improve nutritional health in a short period not useful for a sustainable approach. This is used in some particular conditions when highly essential nutrients such as pregnant women, children, and health problems however, this approach is not cost-effective for a low-income family. This method needs medical care,

education, knowledge of supply and storage, etc., therefore becoming unmanageable for low-income consumers or rural populations.

Dietary diversification

It involves a food-based approach to improving nutritional status by consuming g wide range of foods. It promotes the consumption of different plant-based food *viz*. fruits, vegetable, and grain mainly used at the household level to enhance bioavailable micronutrient nutrients such as cooking food that involved soaking, germination, and fermentation. It is rich in promoter substance and enhanced mineral absorption and reduces intake of antinutrients which inhibit mineral absorption.

Food fortification

Food fortification is the addition of minerals and vitamins to consuming food either by agronomic practices or by food processing to the enhanced nutritional quality of food. Several world food programs assist to fortified pre-cooked pulses and cereals to reduce micronutrient deficiencies. It is the best, safe, and cost-effective approach to improving nutritional diet and minimizing malnutrition, and controlling micronutrient deficiency. Food fortified components are used as ferrous sulfate, ferric pyrophosphate, electric iron powder, folic acid, and iodized salt to improve nutritional status. In this era, mainly produced and consumed starchy food crops like wheat, maize, and rice which have low micronutrient content. These foods are unable to deliver nutrition to the diet and the production of the crop depends on the green revolution; a huge amount of inorganic fertilizers used in this crop certainly give high returns but have a bad effect on human and soil health as well as on the environment. In the last few decades, food fortification becomes popular in low and middle-income countries. Food fortification reduces the deficiency of micronutrients including deficiency of vitamin A, iron and anemia deficiency, and iodine deficiency among the children and women is evidenced by a systematic review and meta-analysis of large-scale food fortification programs that reduce the neural tube defect and goiter among children and enhanced serum folate of reproductive stage among women.

Types of food fortification

Types of fortification depend on various factors such as available infrastructure, the prevalence of deficiency of micronutrients in the population, dietary composition, the capacity of food production and processing system, and national and governmental regulation. Types of fortification vehicles are-

i. Industrial or Large scale food fortification
ii. Home or point of use fortification
iii. Biofortification.

Large scale food fortification

Large-scale food fortification is the industrial addition of micronutrients during the processing of food like sugar, salt, oil, condiments, flours, etc. Large-scale food fortification programs are either mandatory or voluntary but regulated by a regulatory limit government. Mandatory fortification is commonly used such as fortified flour, iodized salt, oil, and milk. In 1942, the first time introduction of wheat flour fortification since time used as mandate fortification. South and North America mandate the use of folic acid in wheat flour to reduce the risk of birth defects. Many countries used fortified milk with vitamin A and D, oil fortified with Vitamin A, whereas rice is fortified with iron and folic acid. In 1970 Latin America fortified sugar with vitamin A and implemented it in Guatemala 1975 become a model for other countries because it decrease the deficiency of vitamin A only in one year from 22 to 5%. In the voluntary fortification, manufacturers add or choose micronutrients to processed food under the guidance of government standards. In Ghana, long grain rice was fortified with zinc, iron, and vitamin (B-complex) which provides more than 15% of the minimum recommended dietary allowance.

Home or point of use fortification

Home fortification is the addition of minerals and vitamins to cooked food that is ready to be eaten thus known as “point-of-use fortification” in 2012 world health organization adopted the term “point-of-use” whereas, in 2016, the point-of-use fortification was recommended as complementary foods with micronutrient powders. It is a key method to improve the intake of micronutrients, for example, and reduce anemia and improving iron status in children aged 6–24 months. Single-dose micronutrient packets containing several minerals and vitamins in powdered form which is sprinkled on cooked food without affecting color and taste. At this time most the countries used fifteen micronutrient formulation in one micronutrient packet which provides a dose as per recommended dose for children under five years which reduce child infectious diseases like anemia, diarrhea, malaria, and worms.

It was reviewed that micronutrient packets are very effective in the reduction of iron deficiencies and anemia under the age of children 6-24 months. Iron deficiencies were reduced by 51% in young children and infants and anemia deficiencies were reduced by 31% with home fortification as compared to others who were not taken. Home fortification reduces the malnutrition of children as well as pregnant women. Generally, Women have deficiencies in minerals and vitamins like zinc, iron, iodine, and folic acid due to poor quality of foods. A nutritional diet affects the health of pregnant women as well as their children. Recent estimation revealed that 520 million women are anemic and 154 million women are too weak at reproductive age result 20 million newborn babies being underweight thus supplements of micronutrients are a cost-effective and safe solution to improve the nutritional diet and reduce malnutrition.

Biofortification

Bio-fortification is the best approach to enhance the bioavailability of micronutrients in crops through agronomic practices, breeding methods, and genetic engineering. Biofortification of micronutrients in crops was enhanced by the help of agronomic practices such as soil and foliar application. It is the easiest, simplest, and most effective way to accumulate the concentration of particular micronutrients (iron and zinc) in food grain thus called agronomic bio-fortification however conventional breeding takes a longer period (Cakmak 2009 or de Valenca *et al*. 2017) [10, 13]. Agronomic bio-fortification is the best way to improve nutritional quality by increasing productivity and it also plays a major role in metabolic actives and boosts immunity, (Pathak *et al*.,2012; Márquez-Quiroz *et al*., 2015) [36, 32]. A study reported that foliar application of zinc enhances the concentration of zinc in cereals crops (Cakmak 2008) [9]. Bio-fortified crops increase the intake of micronutrients through consuming pulses in the life cycle (Bouis *et al*., 2011) [8]. Examples of biofortification include zinc biofortification of wheat, beans, rice, corn, and sweet potato; iron biofortification of maize, rice, and sweet potato and vitamin biofortification of corn, sweet potatoes, and cassava. Biofortification has an advantage over the other two approaches of fortification, specifically for poor families or families living in a rural areas having a lack of access to industrial fortified foods. These family or population depends on subsistence cultivation of crop and consumed their fortified produce which is cost effective and more nutritious. For example, orange sweet potato increases the vitamin A intake whereas cereals and tubers crops have multimicronutrient deficiencies thus biofortification improved nutritional value through agronomic biofortification and the traditional breeding approach. Genetic engineering introduces multimicronutrient in a single crop with a higher concentration of micronutrients.

Agronomic strategies for biofortification

Biofortification through an agronomic approach involved the application of minerals fertilizer by soil and foliar fertilization, soil inoculation with microorganisms or soil, and seed inoculation.

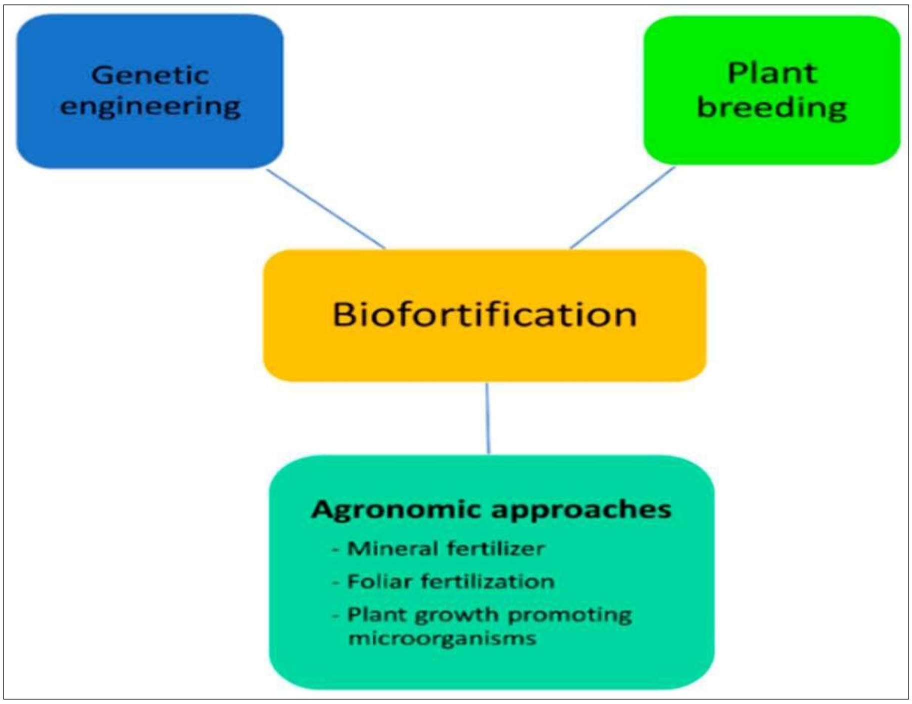

Fig 1: Various approaches to biofortification

Mineral fertilization

Soil and foliar application of mineral fertilizer enhanced the availability of nutrient status in a plant. Soil inoculation increases the mobility and solubility of nutrients in the solution. Through the xylem, it reached all parts of the soil plant. Through this method easily fortified crop with one more nutrient together whereas foliar application of mineral involved direct foliar spray to leaves of the plant. It provides minerals as nutrients very rapidly is and translocated as compared to soil application. Biofortified crops increased the level of micronutrients in grain and straw. The concentration of iron increased in the seed of cowpea up to 29-32% through foliar fertilization recorded by Marquez-Quiroz *et al*. It is reported by Ali *et al*. iron concentration increased by 46% in mungbean similarly zinc, multimicronutrient, and protein content increased in chickpea cowpea, field pea, and common bean. Plant growth promoting microorganisms are beneficial microbes such as Fungi, rhizobia, actinomycetes, and algae which are associated with plant root rhizosphere through symbiotic association. It is naturally available in the soil and its population is increased by agricultural practices which improved the phytoavailability of micronutrients. Microorganisms are mainly used as soil and seed inoculation that excludes plant growth hormones, antibiotics, siderophores, and chitinases. These microbes chelate iron by siderophore and make insoluble nutrients into soluble which increases soil fertility, productivity, ty, and economics of soil. Several studies reported that the concentration of micronutrients is increased by the mycorrhizal association of nitrogen fixation. In chickpea, microbial inoculation increased seed minerals such as ion y 10-38% and zinc by 13-300%compae to uninoculated plants. Khalid *et al*. reported that the concentration of iron increased in the soil by 81% in chickpea by inoculation of iron compounds in the rhizosphere of soil. It is also reported that iron, zinc, and protein content in chickpea through inoculation of arbuscular mycorrhiza.

Methodology for biofortification of chickpea

Agronomic fortification is the introduction of micronutrients to plants by the application of mineral fertilizer. The nutrient was applied as a basal dose and as a foliar spray at the time of flowering and pod formation. Recent research done at Punjab Agriculture University declared that foliar spray of zinc along with iron and nitrogen gives the highest grain yield. Twice or thrice foliar application of zinc, iron and nitrogen produced higher grain yield as compared to a single spray. Combine application of zinc and nitrogen gives es 7-10% higher yield compared to a sole spray of zinc. Similarly, a foliar spray of iron and nitrogen enhanced grain yield by 8–10% over a single spray of iron. Furthermore, the combined application of three nutrients gives a higher grain yield as compared to any two nutrients. However, the application of two or more nutrients either tank mix or individually gives a similar result. Effect of individual and tank mix foliar application of zinc, iron, and urea on grain yield of chickpea.

Table 1: Effect of individual and tank mix application of zinc, iron, and urea on grain yield of chickpea

Foliar spray treatment	Grain yield (kg/ha) 2016–2017
Unsprayed (control)	1511
ZnSO4 (0.5%)	1768
FeSO4 (0.5%)	1764
Urea (2%)	1830
ZnSO4 (0.5%) and urea (2%) (individual application)	1936
FeSO4 (0.5%) and urea (2%) (individual application)	1906
ZnSO4 (0.5%) and FeSO4 (0.5%) (individual application)	1890
ZnSO4 (0.5%), FeSO4 (0.5%) and urea (2%) (individual application)	1947
ZnSO4 (0.5%) and urea (2%) (tank mix application)	1893
FeSO4 (0.5%) and urea (2%) (tank mix application)	1908
ZnSO4 (0.5%) and FeSO4 (0.5%) (tank mix application)	1884
ZnSO4 (0.5%), FeSO4 (0.5%) and urea (2%) (tank mix application)	1925
LSD (P=0.05)	186

***Source*:** Journal of Soil Science and Plant Nutrition https://doi.org/10.1007/s42729-021-00408-0

Biofortification of Zinc and iron in Chickpea Grain with Integrated and individual spray of ZnSO4, FeSO4, and Urea

Nutrients are applied as a combined spray (tank mix or individual application) and sole application of zinc, iron, and nitrogen. All the treatments involving combined and individual applications recorded significantly higher zinc and iron content in grain over control. The highest zinc content in grain was recorded with individual application of iron, zinc, and nitrogen which was statistically at par with tank mix and an individual spray of zinc and nitrogen over sole application. Zinc content in grain was enhanced by 9-11% with Individual foliar spray and 6–8% as tank mix application over sole application of zinc whereas combined application of iron and nitrogen recorded a significant improvement of zinc in grain over sole application of iron. whereas highest iron content in grain was recorded with foliar spray of iron and nitrogen as an individual application which was statistically at par with the tank mix as well as individual application of Zinc along with iron and nitrogen or similar result were obtained with tank mix application of iron along with nitrogen or iron and zinc application of tank mix as well as an individual application.

Table 2: Effect of individual and tank mix application of zinc, iron, and urea on zinc and iron content in grains of chickpea

Foliar spray treatment	Zinc (mg/kg) 2016–2017	Iron (mg/kg) 2016–2017
Unsprayed (control)	25.53	48.66
ZnSO4 (0.5%)	38.40	55.83
FeSO4 (0.5%)	29.01	70.64
Urea (2%)	32.33	58.51
ZnSO4 (0.5%) and urea (2%) (individual application)	42.13	61.25
FeSO4 (0.5%) and urea (2%) (Individual application)	35.93	75.83
ZnSO4 (0.5%) and FeSO4 (0.5%) (individual application)	40.83	71.51
ZnSO4 (0.5%), FeSO4 (0.5%) and urea (2%) (individual application)	45.00	74.16
ZnSO4 (0.5%) and urea (2%) (tank mix application)	39.41	60.91
FeSO4 (0.5%) and urea (2%) (tank mix application)	33.45	73.33
ZnSO4 (0.5%) and FeSO4 (0.5%) (tank mix application)	39.89	71.25
ZnSO4 (0.5%), FeSO4 (0.5%) and urea (2%) (tank mix application)	43.01	73.91
LSD (P=0.05)	3.61	4.90

***Source*:** Journal of Soil Science and Plant Nutrition https://doi.org/10.1007/s42729-021-00408-0)

Protein Content in Grain and Straw of Chickpea

Nitrogen is applied in all the treatments as a sole or combined spray (tank mix or individual application). Individual application of zinc, iron, and nitrogen recorded significantly higher Protein content in grain as well in straw which was statistically at par with the same nutrient of tank mix application and also at par with tank mix and individual application of zinc along with nitrogen or iron along with nitrogen.

Table 3: Effect of individual and tank mix application of zinc, iron, and urea on protein content in grains of chickpea

Foliar spray treatment	Protein content (%) 2016–2017	
	Grain	Straw
Unsprayed (control)	18.62	7.45
ZnSO4 (0.5%)	20.05	8.66
FeSO4 (0.5%)	19.69	8.42
Urea (2%)	22.28	9.09
ZnSO4 (0.5%) and urea (2%) (individual application)	23.00	10.11
FeSO4 (0.5%) and urea (2%) (Individual application)	22.50	9.53
ZnSO4 (0.5%) and FeSO4 (0.5%) (individual application)	20.24	9.35
ZnSO4 (0.5%), FeSO4 (0.5%) and urea (2%) (individual application)	23.37	11.23
ZnSO4 (0.5%) and urea (2%) (tank mix application)	22.78	10.03
FeSO4 (0.5%) and urea (2%) (tank mix application)	22.50	9.53
ZnSO4 (0.5%) and FeSO4 (0.5%) (tank mix application)	20.21	8.93
ZnSO4 (0.5%), FeSO4 (0.5%) and urea (2%) (tank mix application)	23.05	11.13
LSD (P=0.05)	1.82	0.76

***Source*:** Journal of Soil Science and Plant Nutrition https://doi.org/10.1007/s42729-021-00408-0)

Advantages of food fortification

Effect of food fortification on Health

According to mortality data from the world health organization, 1.5% of total death due to deficiency of iron, and similar trend with deficiency of vitamin A. Latest analysis of low and middle-income countries shows that fortification with folic acid, iodine, iron, and vitamin A leads to a drastic reduction in several diseases. Industrial food fortification has a positive impact on nutrition and health of low and middle-income countries including anemia, goiter, and NTD prevalence.

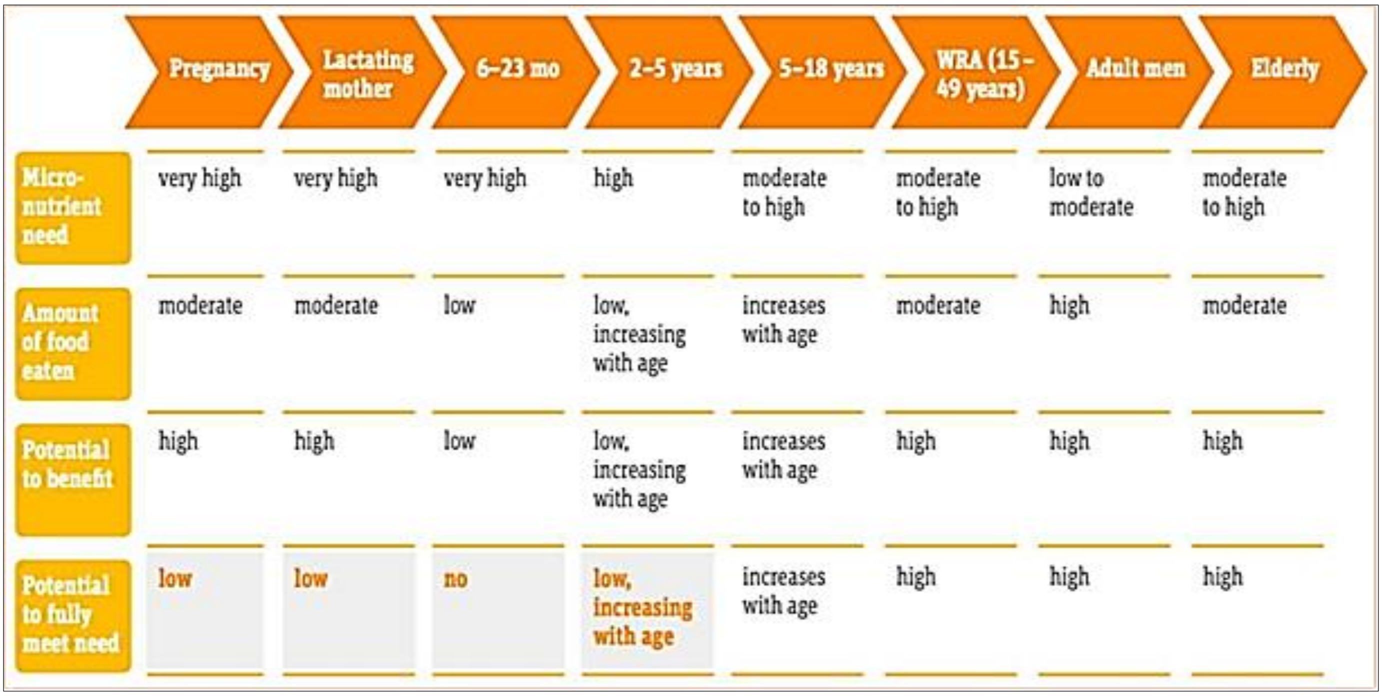

Fig 2: Shows the potential benefits of food fortification across the life cycle.

(Source: Irizarry, L, Prost, MA, Murillo, D, Lopez de Romaña Daniel *et al*. 2017. Scaling Up Rice Fortification in Latin America and the Caribbean. World Food Programme and Sight and Life: 2017. WRA = Women of Reproductive Age).

Effect of food fortification on Economic

Food fortification is a feasible and cost-effective strategy to enhance the nutritional quality of the population and is also associated with high economic benefits. Copenhagen Consensus reviews that the introduction of micronutrients was a cost-effective intervention and gives significant results at a low cost. For example, the investment cost of maize and wheat fortification with folic acid and iron, and iodized salt are low but productivity and health care savings benefit the economy. Similar analysis with the Philippines using fortified milk powdered for addressing iron deficiency amongst children. In the case of biofortification, the health benefit-to-cost ratio was much higher than the investment.

Effect of food fortification on society

World Food Summit 1996 declares that "Everyone to have access to nutritious and safe food and everyone have the fundamental right free from hunger". Unfortunately, still, malnutrition and hunger are a challenge in many low and middle-income countries. During COVID-19 pandemic increases malnutrition and food insecurity due to mandatory lockdowns. Therefore, food fortification plays a crucial role to reduce the risk of nutritious food during and after the pandemic. Sustainable Development (2030 Agenda) and Sustainable Development Goals (SDGs) have aimed to achieve zero hunger and poverty and a world free from hunger and malnutrition. Now, food fortification combined with social safety net programs like school feeding programs, mid-day milk, fortified biscuits in a school program, food for work programs, distributions to the poor or vulnerable groups, and food aid during emergencies become effective tools to deliver fortified food to vulnerable people

Government steps towards fortification

In India, deficiencies of micronutrients are most common among children and women, Prime Minister's officially launched the National Nutrition Mission in early 2018, staple food fortification is a cost-effective approach to control mineral and vitamin deficiencies, Government launched three main food supplementation programs: Mid-day Meal scheme (MDM), Public Distribution System (PDS) and Integrated Child Development Scheme (ICDS). Food Safety and Standards Authority of India (FSSAI) fix specifications for fortified rice after an expert discussion which included proof from leading academic institutions in India. Currently, rice fortification gets momentum to start implementation. These programs get strengthened by Tata Trust in collaboration with Sight and Life and local Government. This is a co-effective implementing approach to fortify rice on a large scale. Since rice, fortification has gained momentum, and currently, fifteen states have drawn up plans to start implementing it through MDM, ICDS, and PDS. To strengthen these programs, Sight and Life, in collaboration with Tata Trust and the local Government, has instituted a promising, cost-effective blending process known as continuous blending. This is the first time that this type of approach has been implemented in India to fortify rice under large-scale government programs.

Conclusion

From this review, I conclude that micronutrient is an important intake of our diet and it is essential for the metabolic activity of human beings. Due to modern cultivation practices, farmers are mainly concerned about macronutrients to get higher production and apply a heavy amount of synthetic macronutrients without soil testing. They do not bother about micronutrients thus the health of the soil, as well as hummus, get deteriorated result of that fertility and productivity of soil decreases and the majority of the population face a major problem due to deficiency of micronutrients like anemia, goiter, low birth weight of infant baby, Childhood dwarfism and chronic disease such as thyroid deficiency, cardiovascular diseases, cancer, etc. Fortification of micronutrients is a cost-effective, economic and social approach to improved nutrients in our diet either by agronomic biofortification or industrial fortification. At the commercial level, industrial food fortification is a good approach to the addition of micronutrients in processed food whereas point use fortification is beneficial for home. Agronomic fortification is a natural as well as commercial biofortification of food with a general adaptation of cultivation practices thus biofortification of chickpea becomes a boon to mitigate malnutrition particularly in children under the age of 5-6 years and pregnant women in low-middle economic countries by providing protein, amino acid, folic acid, vitamin, and mineral. According to my view, agronomic biofortification is more economical, feasible, and beneficial to the farmer because it fetches attractive income by getting more production and higher value of nutrient content in grain under the same cultivation practice..

References

1. Abbaspour N, Hurrell R, Kelishadi R. Review on iron and its importance for human health. J Res. Med. Sci. 2014;19:164-174.
2. Ahalwat IPS, Gangaiah B, Zadid AM. Nutrient management in chickpea. In: Chickpea breeding and management (Yadav, S.S.; Redden, R.; Chen, W. and Sharma, B. eds.) CAB International, Wallingford, Oxon, United Kingdom, 2007, 213-232.
3. Ali B, Ali A, Tahir M, Ali S. Growth, Seed yield and quality of mungbean as influenced by foliar application of iron sulfate. Pak. J Life Soc. Sci. 2014;12:20–25. [Google Scholar]
4. Allen LH. Anemia and iron deficiency: Effects on pregnancy outcome. Am. J Clin. Nutr., 71, THE 1280S–1284S. [Cross Ref] [PubMed], 2000.
5. Ankerman D, Large R. Soil and plant analysis. A&L Agricultural Laboratories, Inc, New York, Unit Abbaspour, N.; Hurrell, R.; Kelishadi, R. Review on iron and its importance for human health. J Res. Med. Sci. 2014;19:164-174.
6. Bailey RL, West KP Jr, Black RE. The epidemiology of global micronutrient deficiencies. Ann. Nutr. Metab. 2015;66:2233. [Cross Ref] [PubMed]
7. Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, *et al*. Maternal and child under nutrition: Global and regional exposures and health consequences. The Lancet 2008;371:243-60. Doi:10.1016/S0140-6736(07)61690-0. [Crossref], [PubMed], [Web of Science ®], [Google Scholar]
8. Bouis HE, Hotz C, McClafferty B, Meenakshi JV, Pfeiffer WH. Biofortification: A new tool to reduce micronutrient malnutrition. Food Nutrition Bulletin. 2011;32(Supplement 1):31S-40S.
9. Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? Plant and Soil 2008;302:1-17. Doi:10.1007/s11104-007-9466-[Crossref], [Web of Science ®], [Google Scholar]
10. Cakmak I. Enrichment of fertilizers with zinc: An excellent investment for humanity and crop production in India. Journal of Trace Elements in Medicine and Biology. 2009;23:281-89. Doi:10.1016/j.jtemb.2009.05.002. [Crossref], [PubMed], [Web of Science ®], [Google Scholar]
11. Combs GF. Selenium in global food systems. British Journal of Nutrition. 2001;85:517-47. Doi:10.1079/BJN2000280. [Crossref], [PubMed], [Web of Science ®], [Google Scholar]
12. Curran J. The nutritional value and health benefits of pulses in relation to obesity, diabetes, heart disease and cancer. Br. J. Nutr. 2012;108:1-2. [CrossRef]
13. de Valenca AW, Bake A, Brouwer ID, Giller KE. Agronomic biofortification of crops to fight hidden hunger in sub-Saharan Africa. Global Food Security. 2017;12:8-14. Doi:10.1016/j.gfs.2016.12.001. [Crossref], [Google Scholar]
14. FAO (Food and Agriculture Organization of the United Nations). Agricultural production year book/ or 2015. http://faostat.fao.org.

15. FAO. The State of Food and Agriculture; Food and Agriculture Organization: Rome, Italy, 2013.
16. FAO. The Plant Production and Protection Division (AGP)-Soil Biological Management with Beneficial Microorganisms; FAO: Rome, Italy, 2019. [Google Scholar]
17. Gibson RS, Hotz C. Dietary diversification/modification strategies to enhance micronutrient content and bioavailability of diets in developing countries. Br. J. Nutr. 2001;85:S159-S166. [Google Scholar] [CrossRef] [PubMed]
18. Gopalakrishnan S, Vadlamudi S, Samineni S, Sameer Kumar CV. Plant growth- promotion and biofortification of chickpea and pigeonpea through inoculation of biocontrol potential bacteria, isolated from organic soils. Springerplus 2016;5:1882. [Google Scholar] [CrossRef] [PubMed]
19. Harvest Plus. Biofortification: The Evidence: A Summary of Research Informing Scaling up of Biofortification to Improve Nutrition and Health Globally. Harvest Plus; Washington, DC, USA: 2019. [Google Scholar]
20. Hidoto Legesse, Worku Walelign, Mohammed Husein, Tar'an Bunyamin. Effects of zinc application strategy on zinc content and productivity of chickpea grown under zinc deficient soils. Journal of Soil Science and Plant Nutrition. 2017;17(1):112-126.
21. Hoddinott J, Rosegrant M, Torero M. Investments to Reduce Hunger and Undernutrition. Copenhagen Consensus Center; Copenhagen, Denmark: 2012. Copenhagen Consensus Center Working Paper March. [Google Scholar]
22. Home Fortification Technical Advisory Group Programmatic Guidance Brief on Use of Micronutrient Powders (MNP) for Home Fortification. [(accessed on 8 September 2020)]; Available online: https://sites.unicef.org/nutrition/files/HFTAG_Micronutrient_Powder_Program_ Guidance_Brief.pdf.
23. Horton S, Mannar V, Wesley A. Best Practice Paper Food Fortification with Iron and Iodine. Copenhagen Consensus Center; Copenhagen, Denmark: 2008. Copenhagen Consensus Center Working Paper October. [Google Scholar]
24. Hotz C, Brown KH. Assessment of the risk of zinc deficiency in populations and options for its control. Food Nutr Bull. 2004;25:194-204.
25. Hurrell RF. Bioavailability of iron. Eur. J. Clin. Nutr. 1997;51:S4-S8.
26. Khalid S, Asghar HN, Akhtar MJ, Aslam A, Zahir ZA. Biofortification of iron in chickpea by plant growth promoting rhizobacteria. Pak. J Bot. 2015;47:1191-1194. [Google Scholar]
27. Khan HR, McDonald GK, Rengel Z. Zinc fertilization and water stress affects plant water relations, stomatal conductance and osmotic adjustment in chickpea (*Cicer arietinum*). Plant and Soil. 2004;267(12):271284.
28. Krebs NF, Miller LV, Hambridge KM. Zinc deficiency in infants and children: A review of its complex and synergistic interactions. Paediatrics and International Child Health. 2014;34:279-88. Doi:10.1179/2046905514Y.0000000151. [Taylor & Francis Online], [Web of Science ®], [Google Scholar]
29. Kręẓel A, Maret W. The biological inorganic chemistry of zinc ions. Archives of Biochemistry and Biophysics. 2016;611:3-19. Doi:10.1016/j.abb.2016.04.010. [Crossref], [PubMed], [Web of Science ®], [Google Scholar]
30. Mahaffee WF, Kloepper JW. Applications of plant growth-promoting rhizobacteria in sustainable agriculture. In Soil Biota: Management in Sustainable Farming Systems.
31. Pankhurst CE, Doube BM, Gupta VVSR, Grace PR, Eds.; CSIRO: Melbourne, Australia. 1994, 23-31. [Google Scholar]
32. Márquez-Quiroz C, De-la-Cruz-Lázaro E, Osorio Osorio R, Sánchez-Chávez E. Biofortification of cowpea beans with iron: iron´s influence on mineral content and yield. J. Soil Sci. Plant Nutr. 2015;15(4):839-847.
33. McDowell LR. Minerals in Animal and Human Nutrition, 2nd ed.; Elsevier Science: Amsterdam, The Netherlands, 2003, 660.
34. Mohammad N, Mansoureh K, Hossein A. Zn-foliar application influence on quality and quantity features in Phaseolous vulgaris under different levels of N and K fertilizers. Adv. Environ. Biol. 2011;5(5):839-846.
35. Pal V, Singh G, Dhaliwal SS. A new approach in agronomic biofortification for improving zinc and iron content in chickpea (*Cicer arietinum* L.) grain with simultaneous foliar application of zinc sulphate, ferrous sulphate and urea. Journal of Soil Science and Plant Nutrition. 2021;21(2):883-896.
36. Pathak GC, Gupta B, Pandey N. Improving reproductive efficiency of chickpea by foliar application of zinc. Braz. J. Plant Physiol. 2012;24(3):173-180.
37. Pellegrino E, Bedini S. Enhancing ecosystem services in sustainable agriculture: Biofertilization and biofortification of chickpea (*Cicer arietinum* L.) by arbuscular mycorrhizal fungi. Soil Biol. Biochem. 2014;68:429-439. [Google Scholar] [CrossRef]
38. Poblaciones MJ, Rengel Z. Soil and foliar zinc biofortification in field pea (*Pisum sativum* L.). Grain accumulation and bioavailability in raw and cooked grains. Food Chem. 2016;212:427-433. [Google Scholar] [CrossRef] [PubMed]
39. Prasad R. Zinc malnutrition and its alleviation through zinc fortified cereal grains. Proceedings of the Indian National Science Academy. 2009;75:89–91. [Google Scholar]
40. Roy RN, Finck A, Blair GJ, Tandon HLS. Plant nutrition for food security. A guide for integrated nutrient management. FAO Fertilizer and Plant Nutrition Bulletin 16. Food and Agriculture Organization of the United Nations, Rome, Italy, 2006, 368.
41. Sarkar D, Mandal B, Kundu MC. Increasing use efficiency of boron fertilisers by rescheduling the time and methods of application for crops in India. Plant Soil. 2007;301:77-85.
42. Sathya A, Vijayabharati R, Srinivas V, Gopalakrishnan S. Plant growth-promoting action-bacteria on chickpea seed mineral density: An upcoming complementary tool for sustainable biofortification strategy. 3 Biotech 2013;6:138. [Google Scholar] [CrossRef]
43. Sims TT. Soil fertility evaluation. In: Summer ME Handbook of soil science. Boca Raton, Florida, USA, CRC Press, 2000, 11315421.
44. Singh KK, Praharaj CS, Choudhary AK, Kumar N,

Venkatesh MS. Zinc response in pulses. Indian Journal of Fertilisers. 2011;7:118-26. [Google Scholar]
45. Singh MV. Micronutrient deficiencies in crops and soils in India. In Micronutrient deficiencies in global crop production, ed. B. J. Alloway, 2008, 93-125. Berlin: Springer. [Crossref], [Google Scholar]
46. Tulchinsky TH. Micronutrient deficiency conditions: Global health issues. Public Health Rev. 2010;32:243. [Cross Ref]
47. Waters BM, Grusak MA. Quantitative trait locus mapping for seed mineral concentrations in two Arabidopsis thaliana recombinant inbred populations. New Phytol. 2008;179:1033-1047. [Cross Ref] [PubMed]
48. Wessells KR, Brown KH. Estimating the global prevalence of zinc deficiency: Results based on zinc availability in national food supplies and the prevalence of stunting. PLoS One. 2012;7:e50568. Doi:10.1371/journal.pone.0050568. [Crossref], [PubMed], [Web of Science ®], [Google Scholar]
49. White PJ, Broadley MR. Biofortification of crops with seven mineral elements often lacking in human diets- iron, zinc, copper, calcium, magnesium, selenium and iodine. New Phytol. 2009; 182:49-84. [Google Scholar] [CrossRef] [PubMed]
50. WHO. Guideline: Use of Multiple Micronutrient Powders for Point-of-Use Fortification of Foods Consumed by Infants and Young Children Aged 6–23 Months and Children Aged 2–12 Years. WHO; Geneva, Switzerland: 2016. [Google Scholar]
51. Wiltgren AR, Booth AO, Kaur G, Cicerale S, Lacy KE, Thorpe MG, *et al*. Micronutrient supplement use and diet quality in university students. Nutrients. 2015;7:1094–1107. [Google Scholar] [Cross Ref]
52. World Health Organization. Iron Deficiency Anaemia: Assessment, Prevention and Control, a Guide for Programme Managers; WHO: Geneva, Switzerland, 2001.
53. World Health Organization. Worldwide Prevalence of Anaemia 1993–2005: WHO Global Database on Anaemia; de Benoist, B., McLean, E., Egli, I., Cogswell, M., Eds.; WHO: Geneva, Switzerland, 2008.