Research Biotica 2021, 3(2):139-144 DOI: 10.54083/ResBio/3.2.2021.139-144

Review Article **Article ID:** RB0092

A Review on Agronomic Biofortification for Improving Food and Nutritional Security

Sumit Sow* and Shivani Ranjan

Dept. of Agronomy, Bihar Agricultural University, Sabour, Bhagalpur, Bihar (813 210), India

Open Access

Corresponding Author

Sumit Sow

e-mail: sumitsow19@gmail.com

Keywords

Agronomic biofortification, Foliar fertilization, Malnutrition, Micronutrient deficiencies, Nutritional quality

How to cite this article?

Sow and Ranjan, 2021. A Review on Agronomic Biofortification for Improving Food and Nutritional Security. *Research Biotica* 3(2), 139-144.

Abstract

Micronutrients are important not only for better productivity of crops, but also essential for sustaining human and animal health. There is a widespread deficiency of micronutrients especially zinc in the Indian soils. Micronutrient malnutrition is known to affect more than half of the world's population and considered to be among the most serious global challenges to mankind. Malnutrition is of great public health significance in various developing and underdeveloped countries. Deficiency of iron and zinc can cause various severe health issues. Modern plant breeding has been historically focused towards achieving high agronomic yield rather than nutritional quality, and other efforts related to solve the problem have been mainly through industrial fortification or pharmaceutical supplementation. In humans, problems caused due to micronutrient deficiencies can be solved through biofortification. Biofortification is a promising and sustainable agriculture-based strategy to reduce micronutrient deficiency in dietary food substances. Effective biofortification techniques need to be recognized and applied in an effort to enrich the micronutrient content in the staple crops. Foliar fertilization with micronutrients often increases nutrient uptake and efficient allocation in the edible plant parts than soil fertilization, especially in the case of cereals. Agronomic biofortification can be a way to enrich the food crops leading to decreased micronutrient malnutrition in humans. Moreover, it is the most cost effective and sustainable solution for tackling the micronutrient deficiencies as the intake of micronutrients is on a continuing basis with no additional costs to the consumer in the arid-tropics and sub-tropics of developing countries

1. Introduction

Malnutrition accounts for more than 20 million individuals annually. It leads to deficiencies, excess or imbalances in a person's intake of energy and nutrients. The term malnutrition covers 2 broad group of conditions that are 'undernutrition' which includes stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and another is overweight, obesity and diet-related non-communicable disease such as heart disease, stroke, diabetes. Many factors responsible for malnutrition are poor diet or severe and repeated infections, particularly in under privileged populations. It is also a projective feature of rising infection, incapacity, and immature psychological and physical development. An adequate self-possessed diet of fruits, vegetables, and animal foods is mandatory to meet the needs for micronutrients and energy. Biofortification can be a relatively new approach towards development of human nutrition worldwide, with more focus on poor and developing countries. Its basic objective is to eliminate the micronutrient malnutrition related fatality rates and to improve the food security in developing nations. Increased micronutrient quality and quantity in staple crops have significantly enhanced the nutrient levels in humans. Biofortification of staple food crops can help to tackle malnutrition to reduce the gap in human and animal micronutrient digestion. Micronutrients deficiency is rising because of increasing world population. Deficiency of minerals such as Fe and Zn causes various severe health issues. Malnutrition results in various diseases, but also worsens welfare and economic performance globally.

Currently, the emergence of malnutrition with Fe and Zinc deficiency is now distressing 3 billion people worldwide and has severe health consequences. The World Health Organization (WHO) estimated that 25% of the world population is suffering from anaemia. Globally, there are 17.3% of people at risk of zinc deficiency. Two billion people across the world suffering from another type of hunger known as "hidden hunger" which is caused by insufficient intake of essential micronutrients in the daily diet. In India, more than

Article History

RECEIVED on 07th April 2021 RECEIVED in revised form 25th June 2021 ACCEPTED in final form 27th June 2021

50% of women, 46% of children below 3 years are underweight and 38% are stunted, 44% of children under the age of 5 are underweight, while 72% of infants are suffering from anaemia. Malnutrition caused 69% of deaths of children below the age of five in India (India State Hunger Index, 2009). About 20% of death in children under five can be attributed to vitamin A, zinc, iron and iodine deficiency (Christian and Smith, 2018). Over 60% of the world's population are iron deficient, over 30% are zinc deficient.

2. Approaches to Reduce Malnutrition

a) Dietary Diversification: It is related to the changes in food consumption at the household level, such as increasing the consumption of animal-source foods. Fortification is the addition of the desired minerals to food stuffs like iodine in salts, iron in flour, fluorine in toothpaste and zinc in flours (White and Broadley, 2009).

b) Supplementation: It refers to the oral delivery of micronutrients in the forms of tablets and syrups, and this strategy has been used in chronic deficiencies.

c) Biofortification: Biofortification is the process of increasing nutritional level of crop either through plant breeding or agronomic approaches. It focuses on the consistent daily intake of food staples, thus indirectly emphasizes on low income household who cannot avail more diverse diet.

3. Need of Biofortification

Micronutrient deficiency, also known as hidden hunger, is one of the most important challenges faced by the world. It is caused due to lack of essential vitamins and minerals primarily vitamin A, iron, and zinc in the diet and currently affecting more than two billion people worldwide. "Biofortification" or "biological fortification" refers to nutritionally enhanced food crops with increased bioavailability to the human population that are developed using modern biotechnological techniques, conventional plant breeding and agronomic practices. Biofortification provides a comparatively cost effective, sustainable, and long-term means of delivering more micronutrients is one of the solutions to malnutrition or hidden hunger mitigation. It focuses on improving mineral concentration and their bioavailability in economicpart of crops. It is different from ordinary biofortification (Figure 1) as it emphasises on making plant foods more nutritious as the plants are growing, rather than adding nutrients to the foods when they are being processed. This approach not only will lower the number of severely malnourished people who complementary interventions require treatment by but also will help them maintain improved nutritional status. Some crop varieties whose quality has been enhanced through biofortification are given in Table 1.

Table 1: Varieties with Improved Quality Released in Some Crop Plants in India (Yadav *et al*., 2017)

Crop	Variety	Quality Character	Developed by
Wheat	WB 02	High Zinc (42 ppm), Iron (40 ppm)	IIWBR, Karnal
	HPBW 01	High Zinc (40.6 ppm), Iron (40 ppm)	PAU, Ludhiana
Maize	Pusa Vivek QPM 9	Pro vitamin-A (8.15 ppm), Lysine (2.67%), Tryptophan (0.74%)	IARI, New Delhi
	Pusa HM 4	High Lysine (3.62%), Tryptophan (0.91%)	IARI, New Delhi
Mustard	Pusa Mustard 30	Erucic acid < 2%	IARI, New Delhi
	Pusa Double Zero Mustard 31	Glucosinate < 30 ppm	IARI, New Delhi
Sorghum	Pusa Shakti	High Iron (45 ppm), Zinc (32 ppm)	VNMKV, Parbhani with ICRISAT
Pearl Millet	HHB 299	High Iron (73 ppm), Zinc (41 ppm)	HAU, Haryana with ICRISAT
Rice	CR Dhan 310	High Protein (10.3%)	NRRI, Cuttack
	CR Dhan 311	High Protein (10.1%), Iron (20 ppm)	NRRI, Cuttack
Lentil	Pusa Ageti Masoor	High Iron (63 ppm)	IARI, New Delhi

4. Agronomic Biofortification

Agronomic biofortification can be defined as the application of micronutrient containing mineral fertilizer to the soil or plant leaves (foliar) in order to increase micronutrient contents of the edible part of food crops. It increases micronutrient concentration by soil application, foliar application, soil in combination with foliar application, seed treatment, organic matter, soil amendments. Agronomic approaches to enhance the content of mineral nutrient in edible parts normally rely upon by the use of mineral fertilizers and enhancing the solubilization and mobilization of mineral elements in the soil (White and Broadley, 2009).

4.1 Agronomic Biofortification on Rice

Wei *et al*. (2012) conducted an experiment to evaluate the effect of foliar $FeSO_4$ containing applications on concentration of Fe, Zn and Fe bioavailability in polished rice. The results showed that foliar application of $FeSO_4$, $FeSO_4$ with nicotianamine (NA), and $FeSO_4$ with NA with $ZnSO_4$ increased the grain Fe concentration by 16.97%, 29.9%, and 27.08%, respectively. The grain Fe bioavailability also increased by

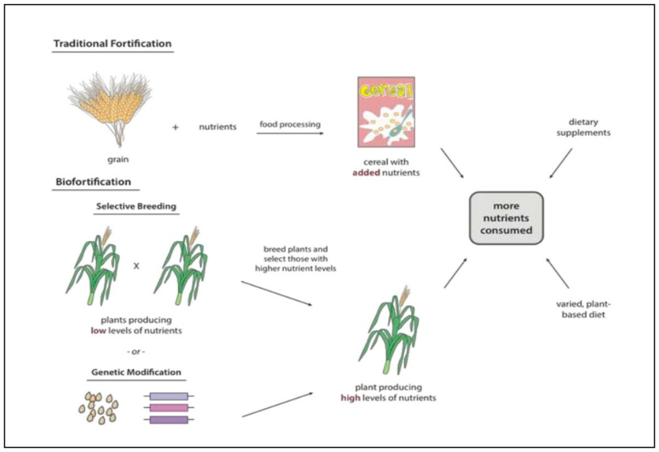

Figure 1: Difference between Ordinary Fortification and Bio-fortification

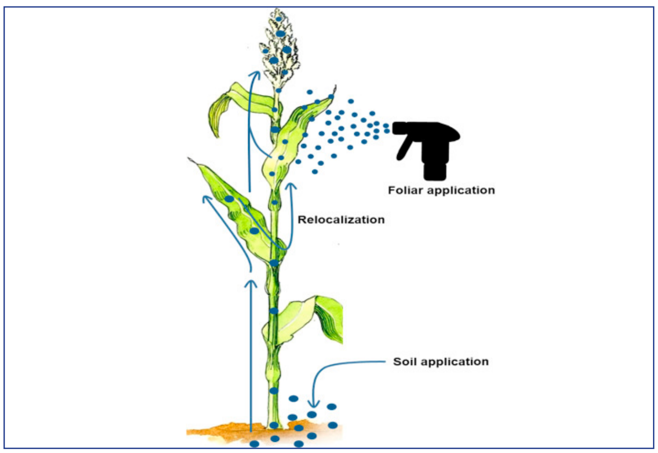

Figure 2: Methods of Agronomic Biofortification

foliar application of $FeSO_4$, $FeSO_4$ plus NA, and $FeSO_4$ plus NA with $ZnSO_4$; these represent increases of 12.63%, 20.86%, and 18.75%, respectively. Foliar $FeSO_4$ containing applications improved the Fe-bioavailability and might be attributed to the reduction of phytic acid and the increase of Fe-concentration in polished rice. Addition of $ZnSO_4$ to foliar Fe-application increased both Fe and Zn content without altering Fe content and bioavailability.

Barua and Saikia (2018) showed that Zn-content in grain, straw and kernel of rice varied significantly under different zinc fertilization. The highest zinc content in grain, straw and kernel was found in the treatment where zinc sulphate was applied @ 25 kg ha^{-1} as basal + 0.5% foliar application at three stages (tillering, panicle initiation and milk stage).

4.2 Agronomic Biofortification on Maize

Chaudhary *et al.* (2012) studied the interrelationship among various nutritional components of maize kernel. The results showed that the protein content exhibited a significant negative correlation with two important essential amino acids such as tryptophan and lysine. An inverse correlation was found between starch and oil showing that breeding for high oil maize may lead to lower grain yield. A significant positive correlation was observed between oil content and 100-kernel weight showing that although increase in oil down-regulate the starch content, the total grain yield, however, would remain unaffected. Protein content showed a non-significant negative correlation with 100-kernel weight. Imran and Rehim (2016) studied the zinc fertilization approaches for agronomic biofortification and estimated human bioavailability of Zn in maize grain and observed that the plant height was significantly ($P \leq 0.05$) increased in all Zn treatments as compared to control (without Zn), maximum increase of 13% was by banding + foliar followed by 10% with broadcasting + foliar Zn fertilization, respectively. Shoot fresh weight was maximum (322 g pot^{-1}) with banding + foliar followed by broadcasting + foliar (313 g pot^{-1}) and banding (302 g pot^{-1}), respectively. Apart from these treatments, broadcasting and foliar spray significantly influence shoot fresh weight compared to control. Grain yield (g pot^{-1}) was significantly different for each Zn application methods. Foliar spray combined with banding and broadcasting has maximum grain yield of 442 g and 427 g pot^{-1}, respectively.

Table 2: Effect of Zn Fertilizer Schedule on Zn Content in Grain, Straw and Brown Rice (Barua and Saikia, 2018)

Treatments	Zn Content (mg/kg)		
	Grain	Straw	Brown Rice (kernel)
$ZnSO_4$ @ 25 kg ha^{-1} as basal	27.89	52.14	20.85
$ZnSO_4$ @ 25 kg ha^{-1} as basal + seed priming with 2% $ZnSO_4$	32.24	57.24	26.57
$ZnSO_4$ @ 25 kg ha^{-1} as basal + foliar spray @ 0.5% $ZnSO_4$ at three stages	35.09	59.86	28.31
Seed priming with 2% $ZnSO_4$ + foliar spray @ 0.5% $ZnSO_4$ at three stages	29.01	53.99	23.12

Saleem *et al.* (2016) showed that Zn and Fe contents were significantly influenced by the application of these nutrients to the maize crop. It is clearly observed from the data that grain nutrients content increased with the application of each treatment comparing with the treatment where NPK was applied alone. The highest Zn (31.8 mg kg^{-1}) and Fe (153.6 mg kg^{-1}) content were calculated in treatments where foliar application of 0.1% was applied to the maize crop. This increase is 122.4% in case of Zn and 107.3% in case of Fe. The minimum contents were obtained in case of control *i.e.*, 14.3 and 74.1 mg kg^{-1} of Zn and Fe, respectively (Table 3).

4.3 Agronomic Biofortification on Chickpea

Habib *et al*. (2018) noticed that the application of Zn up to 2.50 kg ha^{-1} showed positive effect on the plant height (52.28 cm), number of pods plant^{-1} (48.99), number of branches

Table 3: Effect of Zn and Fe Application on the Zinc and Iron Contents of Maize Grain (Saleem *et al.*, 2016)

Treatments	Fe Content (mg/kg)	% Increase	Zn Content (mg/kg)	% Increase
NPK	74.1	-	14.3	-
NPK + 10 Kg ha^{-1} Zn and Fe	91.6	23.6	18.3	28.0
NPK + 20 Kg ha^{-1} Zn and Fe	107.6	45.2	23.2	62.2
NPK + 30 Kg ha^{-1} Zn and Fe	122.7	65.6	25.1	75.5
NPK + 0.1% foliar spray of Zn and Fe	153.6	107.3	31.8	122.4

$plant^{-1}$ (5.71), pod length (5.06 cm), number of seeds pod^{-1} (6.98), seed yield (1.54 t ha^{-1}) and stover yield (3.59 t ha^{-1}) in chickpea. Harris *et al*. (2008) reported that 29% increase in seed zinc content in seed priming with $ZnSO_4$. Seeds priming with $ZnSO_4$ was very cost-effective. Seed priming enhanced the seed Zn content 49 to 780 mg kg^{-1} in chickpea. Singh *et al*. (2015) found that the foliar fertilization with combination of Urea + Zn + Fe had highest influence on nutrient concentration (N, Protein, Zn, and Fe) enrichment of chickpea seed, and significantly higher plants height, higher pods, grains, were observed due to application of one irrigation over no irrigation. Hence,e one irrigation combined with foliar spray (Fe + Zn + Urea) of fertilizer give potential strategy for obtain higher yield and nutrition security.

In chickpea, Deshlahare (2019) found that maximum protein content (24.32%) was observed in treatment RDF + $ZnSO_4$ and $FeSO_4$ through foliar application at pre-flowering and pod formation stage compared to all other treatment and minimum protein content (20.65%) was observed in treatment RDF (Standard control). It was also observed that the treatment RDF + soil application of $ZnSO_4$ @ 25 kg ha^{-1} at basal was at par with treatment RDF + $ZnSO_4$ and $FeSO_4$ through foliar application at pre flowering and pod formation stage.

4.4 Agronomic Biofortification on Sorghum

Kumar *et al.* (2017) revealed that soil application of RDF + Enriched FYM 1 (*i.e*., 50 kg FYM ha^{-1} + 3.75 kg $ZnSO_4$ ha^{-1} and $FeSO_4$ ha^{-1}) recorded significantly higher grain yield (4287 kg ha^{-1}), fodder yield (7.51 t ha^{-1}), and test weight (37.77 g) as compared to control and recommended dose of fertilizer and recommended package of practices in sorghum.

Eknath (2018) observed that Fe and Zn content in sorghum grain and stover was influenced significantly influenced due to different treatments under consideration. The Mn and Cu content in grain and stover were numerically differed from each other but, statistically it was not significant. Significantly the higher Fe and Zn content in grain was recorded under T_{11} (T_2 + Enriched vermicompost4) and it was on par with T_7 (T_2 + Enriched FYM 4). In case of sorghum stover, the Fe and Zn content was significantly influenced by T_{11} and the treatments T_{10} and T_7 were remain second in order. The soil micro-organisms *i.e*., arbuscular mycorrhizal (AM) fungi are known to assist the plant in uptake of all the nutrients and to improve plant growth (Douds *et al*., 2005) in soils of scarcity areas where the soils are low in P. Cavender *et al*. (2003) has shown that vermicompost increased mycorrhizal colonization in sorghum roots. Hence, numerical deviation in concentration was noticed due to differential activities of soil micronutrients regarding to uptake of native soil micronutrient content.

Table 4: Micronutrients Concentration in Sorghum Grain and Stover at Harvest as Influenced by Different Treatments (Eknath, 2018)

Treatments	Fe (ppm)		Zn (ppm)		Mn (ppm)		Cu (ppm)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T_1: Absolute control	37.5	19.8	15.3	11	25.8	12.7	5.5	4.5
T_2: RDF: 50:25:00 kg N:P_2O_5:K_2O ha^{-1}	39.8	21.9	16.0	11.8	27.6	13.2	5.6	4.5
T_3: T_2 + 15 kg $ZnSO_4$ ha^{-1} + *Azospirillum* and *Trichoderma viride* seed treatment	42.2	24.2	18.2	12.9	28.2	14.4	5.8	4.5
T_4: T_2 + Enriched FYM 1	45.5	22.4	17.9	14.0	29.5	14.9	5.8	4.6
T_5: T_2 + Enriched FYM 2	48.6	22.9	19.3	14.4	29.9	15.4	5.9	4.7
T_6: T_2 + Enriched FYM 3	50.2	23.5	21.3	15.6	29.9	15.7	6.2	4.8
T_7: T_2 + Enriched FYM 4	53.0	25.3	22.1	14.9	30.3	15.1	6.1	4.8
T_8: T_2+ Enriched vermicompost 1	49.4	23.3	22.1	14.9	30.3	15.1	6.1	4.8
T_9: T_2+ Enriched vermicompost 2	50.3	25.3	22.2	15.6	30.5	15.8	6.2	4.9
T_{10}: T_2 + Enriched vermicompost 3	51.5	26.3	24.4	16.2	30.6	16.3	6.3	5.3

Treatments	Treatments		Zn (ppm)		Mn (ppm)		Cu (ppm)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T_{11}: T_2 + Enriched vermicompost 4	53.9	27.6	26.6	16.9	31.1	16.8	6.6	5.6
General mean	47.88	23.92	20.96	14.51	31.63	15.03	6.05	4.88
S.E.m (±)	0.47	0.70	0.87	0.46	0.46	1.58	0.04	0.06
CD (p = 0.05)	1.41	2.11	2.61	1.35	NS	NS	NS	NS

4.5 Agronomic Biofortification on Different Crops

Verma *et al*. (2017) found that the foliar spray of $ZnSO_4$ (0.5%) + Urea (2%) + Thiourea (500 ppm) gave significantly higher number of primary and secondary branches plant^{-1}, number of pods plant^{-1}, weight of seeds plant^{-1} and grain yields (q ha^{-1}) as compare to other treatments. The variety of lentil KL-320 gave higher response than KLB-303 variety. Lentil variety KL-320 showed better response to the foliar spray of $ZnSO_4$ (0.5%) + Urea (2%) + Thiourea (500 ppm) treatment.

Saha *et al.* (2015) observed that conjoint application of Zn and S @ 10 kg ha^{-1} and 50 kg ha^{-1} respectively resulted increase in nut yield of groundnut up to 73.4% over the control. Moreover, it also increased uptake of S and Zn from 11.4 to 21.0 kg ha^{-1} and 0.14 to 0.40 kg ha^{-1} respectively. Similarly, More *et al.* (2015) found that the nutrient uptake of groundnut was enhanced significantly by the application of Zn and B as compared to control.

In pigeonpea, Gowda *et al*. (2014) recorded more number of pods plant^{-1}, seed yield plant^{-1} and seed yield kg ha^{-1} by the soil application of $ZnSO_4$ (25 kg ha^{-1}) along with foliar spray of 19:19:19 (0.4%) followed by soil application of $ZnSO_4$ (25 kg ha^{-1}) along with foliar spray of 00:00:50 (0.3%) and interaction effect was significant by application of $ZnSO_4$ (25 kg ha^{-1}) along with foliar spray of 19:19:19 (0.4%).

Yadav *et al*. (2011) studied the agronomic biofortification of wheat through iron and zinc enriched organics and a significant impact of iron and zinc enriched organics were found on soil properties as well as wheat quality and production. The application effect of Fe-Zn enriched organics with recommended dose of N and P_2O_5 (RDNP) were increased both grain as well as biomass yield of the wheat by 2.3 to 6.6% as compared to direct and by 5.6 to 10.3% as compared to no application of the micronutrients. The grain and biomass yield of the wheat were significantly influenced among different treatments of FYM, RDNP and organic enriched Fe-Zn. The treatment T_4 (100% RDNP along with 4 kg Fe + 2 Kg Zn ha^{-1} in 500 kg FYM ha^{-1} with pre-sowing application of 2.5 t FYM ha^{-1}) and T_6 same to T_4 (except 4 Kg Fe + 2 Kg Zn in 500 Kg vermicompost) were gave highest grain and biomass yield of wheat, respectively.

Kumar *et al*. (2008) studied the effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat and the growth attributes like plant height, fresh and dry matter yield, percent dry matter enhanced with increasing Cu levels and was maximum at 1.5 mg kg^{-1} Cu while the number of tillers was minimum at this level. The grain yield at 1.5 mg kg^{-1} Cu was enhanced by 62.9% from the control. The increase in weight of 1000 grains ranged from 33.93 to 41.35 g as compared to control (32.58 g). Harvest index (%) also increased and varied from 39.42 to 47.73 in different treatments in comparison to control (35.92). Moreover, Kamala and Karthikeyan (2019) revealed that continuous better rearing performance of mulberry silkworm, (*Bombyx mori*) in terms of growth of the larvae (28.985%), silk gland weight (111.392%) and silk yield (194.44%) as compared to control was obtained after supplementing of nanoparticles of vitamin B_2. Thus, nanoparticles of vitamin B_2 can be utilized as a fortification agent for enhancing the silk production.

5. Conclusion

Biofortification helps to overcome the malnutrition in human beings and it help in increment of nutritional quality in daily diets. Agronomic biofortification with the help of fertilizer and micronutrient through soil as well as foliar application would be very rapid and practical approach to maximize mineral uptake and grain mineral accumulation in food crops immediately. There is a need to undertake more extensive research on the basis of soil testing advisory services for increasing bioavailability of micronutrient in food grains and government policies make more liable for agronomic biofortification of cereal food grains with Zn and Fe needs to be launched in a mission mode to combat their deficiencies in humans. Thus, agronomic biofortification strategy appears to be essential in keeping sufficient amount of available Zn in soil solution and maintaining adequate Zn transport to the seeds during reproductive growth stage. It would be a very attractive and useful strategy in solving Zn deficiency related health problems globally and effectively.

6. References

Barua, D., Saikia, M., 2018. Agronomic biofortification in rice varieties through zinc fertilization under aerobic condition. *Indian Journal of Agriculture Research* 52, 89-92.

Cavender, N.D., Atiyeh, R.M., Michael, K., 2003. Vermicompost stimulates mycorrhizal colonization of roots of *Sorghum bicolor* at the expense of plant growth. *Pedobiologia* 47, 85-89.

Chaudhary, D.P., Sapna, Mandhania, S., Kumar, R., 2012.

Inter-relationship among nutritional quality parameters of maize (*Zea mays*) genotypes. *Indian Journal of Agricultural Sciences* 82(8), 34-37.

Christian, P., Smith, E.R., 2018. Adolescent Undernutrition: Global Burden, Physiology, and Nutritional Risks. *Annals of Nutrition and Metabolism* 72, 316-328.

Deshlahare, H., 2019. Biofortification of zinc and iron in chickpea (*Cicer arietinum* L.) through agronomic intervention. M.Sc. (Ag) Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur, India, p. 75.

Douds, D.D., Nagahashi, Pfeffer, P.E., Kayser, W.M., Reider, C., 2005. On farm production and utilization of arbuscularmycorrhizal fungus inoculum. *Canada Journal of Plant Science* 85, 15-21.

Eknath, B.S., 2018. Agronomic biofortification in rabi grain sorghum (*Sorghum bicolor* L.) under rainfed condition. M.Sc. (Agri.,) Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India, p. 58.

Gowda, K.M., Halepyati, A.S., Koppalkar, B.G., Rao, S., 2014. Response of pigeonpea (*Cajanus cajan* L.) to application of micronutrients through soil and foliar spray of macronutrients on yield, economics and protein content. *Karnataka Journal of Agriculture Science* 27(4), 460-463.

Habib, A.S., Md. A. Roy, T.S., Md. Amin, R., Md. Haques, Z., Md. Rokonuzzaman, Sarker, P., 2018. Response of zinc on growth, yield and quality of blackgram (*Vigna mungo* L.). *International Journal of Agronomy and Agricultural Research* 13(4), 73-79.

Harris, D., Rashid, A., Miraj, G., Arif, M., Yunas, M., 2008. 'On-farm' seed priming with zinc in chickpea and wheat in Pakistan. *Plant and Soil* 306(1), 3-10.

Imran, M., Rehim, A., 2016. Zinc fertilization approaches for agronomic biofortification and estimated human bioavailability of zinc in maize grain. *Archives of Agronomy and Soil Science* 63(1), 106-116.

Kamala, M., Karthikeyan, A., 2019. Effect of nutritional fortification of nanoparticles of riboflavin on the growth and development of mulberry silkworm, *Bombyx mori* L.. *Research Biotica* 1(1), 23-30.

Kumar, A.H., Kubsad, V.S., 2017. Effect of fortification of organics with iron and zinc ongrowth, yield and economics of rabi Sorghum. *Journal of Farm Science* 30(4), 547-549.

Kumar, R., Mehrotra, N.K., Nautiyal, B.D., Kumar, P., Singh, P.K., 2008. Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (*Triticum aestivum* L.). *Journal of Environmental Biology* 30(4), 485-488.

More, S.B., Dabke, D.J., Dodake, S.B., 2015. Effect of different levels of zinc and boon on growth, yield, quality and nutrient uptake by groundnut (*Arachis hypogea* L.) variety TG-26 under newly terraced laterite soils of Konkan. *Indian Society of Coastal Agricultural Research* 33(1), 78-82.

Saha, B., Saha, S., Saha, R., Hazra, G.C, Mandal, B., 2015. Influence of Zn, B and S on yield and quality of groundnut (*Arachis hypogea* L.). *Legume Research* 38(6), 832-836.

Saleem, I., Javid, S., Bibi, F., Ehsan, S., Niaz, A., Ahmad, Z.A., 2016. Biofortification of maize grain with zinc and iron by using fertilizing approach. *Journal of Agriculture and Ecology Research* 7(4), 1-6.

Singh, U., Kumar, N., Praharaj, C.S., Singh, S.S., Kumar, L., 2015. Ferti-Fortification: an easy approach for nutritional enrichment of chickpea. *An International Quarterly Journal of Environmental Sciences* 9(3&4), 731-736.

Verma, C.B., Pyare, R., Aslam, M., Verma, V.K., Singh, V., Sharma, H., 2017. Enhancing growth, yield and quality of lentil through foliar spray of zinc, urea and thiourea under rainfed condition. *Agriways* 5(2), 123-127.

Wei, Y., Shohag, M.J.I., Yang, X., Yibin, Z., 2012. Effects of foliar iron application on iron concentration in polished rice grain and its bioavailability. *Journal of Agricultural and Food Chemistry* 10,1-5.

White, P.J., Broadley, M.R., 2009. Biofortification of crops with seven mineralelements often lacking in human diets iron, zinc, copper, calcium, magnesium, selenium and iodine. *New Phytologist* 182, 49-84.

Yadav, R.S., Patel, A.M., Dodia, I.N., Aglodiya, A.V., Patel, G.A., Augustine, N., 2011. Agronomic bio-fortification of wheat (*Triticum aestivum* L.*)* through iron and zinc enriched organics. *Journal of Wheat Research* 3(1), 46-51.