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REVIEW ARTICLE

AGRONOMIC BIOFORTIFICATION PRACTICES IN MAJOR FOOD CROPS: A REVIEW

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ABSTRACT

Large population of human beings in developing countries is mainly reliant on a staple diet of cereals, such as rice, wheat, maize and sorghum *etc.* Unfortunately all of our major cereal food crops lack certain essential vitamins and minerals, as milled cereal grains are poor sources of lysine, vitamin A, folic acid, iron, zinc and selenium, which are essential for normal growth and metabolism of human beings. This review paper aims to enrichment of micronutrient in major food grains have been considered as a sustainable strategy for immediate solution to tackle the problems of micronutrient deficiencies in human beings. Agronomic biofortification is a potential cost-effective and sustainable agronomic way to enrich the micronutrient content of food grains. It is an upcoming strategy for dealing the deficiencies of micronutrients in the developing world.

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INTRODUCTION

Large population of human beings in developing countries is mainly reliant on a staple diet of cereals, such as rice, wheat, maize and sorghum which are basically low in mineral nutrients especially iron and zinc. Nutritional deficiencies like iron, zinc, vitamin A *etc.*, are causes almost $2/3^{rd}$ of the childhood death throughout the world. Malnutrition is a significant public health issue in most of the developing world like Africa and Asian countries. This is due to lack of consumption of fresh fruits, vegetables, meat and fish in their daily diet because of their poor economic conditions. One of the ways to address malnutrition problem is through development of nutrient rich food grains by way of development of new genotypes or through micronutrient management. In Asia about 35 per cent of children between age group of 0 and 5 years suffer from Zn or Fe-deficiencies, 250 million suffer from vitamin A deficiency and 58 per cent of pregnant women in developing countries are anemic from iron deficiency (Cababallero, 2002). The micronutrient enrichment of staple food crops has been considered as a sustainable strategy for immediate solution to tackle the problems of micronutrient deficiencies in human beings.

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Biofortification is a potential cost-effective and sustainable agronomic way to enrich the micronutrient content of food grains. It is an upcoming strategy for dealing the deficiencies of micronutrients in the developing world. World Health organization (WHO, 2000) is estimated that biofortification of iron could help in curing two billion people suffering from iron deficiency-induced anemia. The mineral elements like Zn, Fe and Cu are as crucial for human health as organic compounds such as carbohydrates, fats, protein and vitamins. The daily dietary intake of young adult is ranges from 10-27 mg for Fe, 2-3 mg for Cu and 15 mg for Zn (WHO, 2002). Intake less than these values can cause slow physiological processes. These micronutrients deficiencies in soil are not only hampering the crop productivity but also are deteriorating produce quality. High consumption of cereal based foods with low contents of micronutrients is causing health hazards in humans. The contents of micronutrients in food can be elevated either by supplementation, fortification or by agricultural strategies i.e., Agronomic biofortification.

Importance of micronutrients in human beings

The mineral elements like Zn and Fe are as crucial for human health as organic compounds such as carbohydrates, fats, protein and vitamins. As per the (WHO, 2000) the daily dietary should have Zn intake of infants 5 mg/day, children 10 mg/day, women 12 mg/day, pregnant women 15 mg/day, lactating women 16 mg/day and men 15 mg/day and Fe intake of, birth to 6 months 0. 27 mg/day, 1-3 year 7.0 mg/day, 4-8 years 8 mg/day, 9-51 year 10 mg/day and pregnancy women 27 mg/day. Intake of Zn and Fe less than quantity specified WHO may leads to slow physiological processes because zinc deficiency retarded the growth, skeletal abnormalities, delayed wound healing, increased abortion risk, and diarrhea (Salgueiro, *et al*. 2000). Iron deficiency induced anemia is most widespread micronutrient deficiency and it results in impaired physical growth, mental development and learning capacity (Bouis 2003). These micronutrients deficiencies in soil are not only hampering the crop productivity but also are deteriorating produce quality.

Agronomic biofortification practices for improving micronutrient concentration in major food crops

Soil Zn deficiency in major wheat growing areas leads to inherently low grain Zn concentration and is considered as a major factor in low human Zn intake (Alloway, 2009). Compared to the breeding approach, agronomic biofortification (E.g. application of Zn fertilizers) represents a short-term solution to the problem (Cakmak, 2008). Soil Zn applications are, however, less effective in increasing grain Zn, while foliar Zn applications result in remarkable increases in grain Zn concentration in wheat (Cakmak *et al.,* 2010). Foliar Zn application significantly improved the grain Zn concentration of maize by 27% and 37% and of wheat by 28% and 89% during the first and second growing seasons, respectively. The maize grain Fe concentrations during both growing seasons were also enhanced by foliar Zn application. The foliar application of Zn realized higher grain Zn recoveries of 35.2% and 42.9% in maize as well as 26.4% and 32.3% in wheat during the first and second growing seasons, respectively (Wang *et al.,* 2012). Low dietary intake of Fe and Zn appears to be the major reason for the widespread prevalence of Fe and Zn deficiencies in human populations. The recent efforts made to develop Fe and Zn rich maize genotypes for Africa and some such genotypes are released to overcome the Fe and Zn deficiencies (Welch and Graham, 2003).

Agronomic biofortification is more readily achievable in short run (Cakmak, 2008). It has been shown to be possible to increase grain Zn concentration of wheat by 3-fold through a combination of soil and foliar zinc applications (Yilmaz *et al.,* 1997). Recently documented that Zn foliar application is a simple way for making quick correction of plant nutritional status, as reported for maize (Grzebisz *et al*. 2008) and wheat (Erenoglu *et al*. 2002). Most of staple cereals (Maize and wheat) contain low Zn levels, most of which is lost during grain processing. Populations with monotonous diets consisting mainly of cereals are especially prone to Zn deficiency, which affects about two billion people (Sperotto *et al.,* 2012). The Harvest Plus initiative of the CGIAR consortium is working with national and international partners to alleviate deficiencies of these mineral nutrients by biofortifying staple food crops (Rice, Maize and Wheat) with essential minerals and vitamins; an approach considered to be the most economical solution to human micronutrient deficiency (Welch and Graham, 2004; Bouis, 2007; Cakmak, 2008; Peleg *et al.,* 2009). Chomba *et al*., (2010) reported that feeding biofortified maize can meet zinc requirements and provide an effective dietary alternative to regular maize for this vulnerable population. The mean ± SD total daily zinc intake (milligrams per day) from the biofortified maize (5.0 ± 2.2) was higher ($P < 0.0001$) than for the control maize (2.3 ± 0.9). Intake of zinc from the fortified maize (6.3 ± 2.6) did not differ from the biofortified maize. Fractional absorption of zinc from control maize (0.28 ± 0.10) did not differ from the biofortified maize (0.22 ± 0.06).

Total daily absorption of zinc (milligrams per day) from the biofortified maize (1.1 ± 0.5) was higher ($P = 0.0001$) than for the control maize (0.6 ± 0.2), but did not differ from the fortified maize (1.2 ± 0.4) reported by Chomba *et al*., (2010). Kalayci *et al.* (2000) reported that increases in grain Zn concentrations of maize were also statistically significant, these improvements were not at a level of practical significance. This shortage of efficiency might have been resulted from constraints against translocation of Zn from other plant parts into developing grains and/or greater dilution due to greater biomass and grain yield of maize as compared to wheat. Mohsin *et al.* (2014) observed that Zn (2%) applied in combination to maize as seed priming and subsequently at eight leaf stage as foliar application imparts better growth, quality and grain yield of maize. Biofortification of corn grain, Zn-coated urea was as good as foliar application. The effect of spraying, was highly significant ($p<0.01$) on grain yield and the highest yield of maize was belonged to Fe + Zn treatment (19650 kg/ha) whereas, the copper treatment produced the lowest grain yield (11350 kg/ha).

Agronomic biofortification practices for growth, yield and quality of major food crops

The experimental results showed substantial difference in all physiological and yield parameters except plant height and stem diameter. Statistically maximum grain yield (8.76 $t{\cdot}ha^{-1}$) was obtained with foliar spray of $ZnSO_4$ at 9 leaf stage in case of Monsanto-6525. As regard to quality parameters, Pioneer-32F 10 and Hycorn-8288 accumulated more zinc contents in grains but Monsanto-6525 attained more zinc concentration in straw. Foliar spray of $ZnSO_4$ at 9 leaf stage produced 19.42% more zinc content in grains as compared to other $ZnSO_4$ treatments (Anjum *et al.,* 2014). Further, they observed that foliar application of $ZnSO_4$ at 9 leaf stage accumulated 19.4% more Zn content in maize grains and 12.4% more Zn concentration in straw as compared to soil application and also resulted in higher crop growth rate. On an average, Monsanto-6525 and Pioneer-32F 10 have 80% and 50% more grain yield than Hycorn-8288 hybrid. Maximum marginal rate of return (1145%) was obtained by planting Pioneer-32F 10 with foliar application of 1% $ZnSO_4$ solution at 9 leaf stage. Ghaffari *et al.,* (2011) recommended that single spray of Multi-nutrients along with recommended dose of NPK is feasible for enhancing yield, quality and nutrient use efficiency of maize hybrid Poineer-32B33 and also economically more viable as compared to control. Balanced fertilization, where NPK fertilizer should be applied along with Zn in a Zn deficient soil, is essential for increasing productivity of maize and in turn to alleviate Zn deficiency in soil, plant, animal and human continuum (Preetha and Palaniyandi Stalin., 2014). Similarly other study was carried out by Potarzycki, W. Grzebisz. (2010) in their three -year field study, where zinc fertilizer was applied to maize plants at the 5th leaf stage indicated that maize crop responded significantly to zinc foliar application in two of three years of study. The optimal rate of zinc foliar spray for achieving significant grain yield response was in the range from 1.0 to 1.5 kg Zn/ha. Further, they observed increase in grain yield was to the tune of 18% (mean of three years) as compared to the treatment NPK fertilizer. Plants fertilized with 1.0 kg Zn/ha significantly increased both total N uptake and grain yield. Zinc is the most accumulated micronutrient in the above ground part of the maize hybrids studied, followed by manganese, copper and boron, which is the least absorbed micronutrient (Borges *et al.*, 2010).

Dhaliwal *et al.* (2013) found that foliar application of zinc ($ZnSO_4.7H_2O$) at 0.5 per cent significantly increased the plant height, SPAD value and grain yield of maize compared to unsprayed control. Grain yield of maize varieties (from 29.9 to 34.1 q ha^{-1}) was increased due to foliar application of Zn. Mohsin *et al.* (2014) observed that Zn (2%) applied in combination to maize as seed priming and subsequently at eight leaf stage as foliar application imparts better growth, quality and grain yield of maize. Balanced fertilization, where NPK fertilizer should be applied along with Zn in a Zn deficient soil, is essential for increasing productivity of maize and in turn to alleviate Zn deficiency in soil, plant, animal and human continuum reported by Preetha and Palaniyandi Stalin. (2014).

Conclusion

Now a days, only application of macro nutrients leads to deficiency of micro nutrients in soil as well as in food grains. Agronomic biofortification is a holistic approach to eliminate micronutrient deficiency in food crops through agronomic practices by the means of soil and foliar applications. The micronutrient enrichment of staple food crops has been considered as a sustainable strategy for immediate solution to tackle the problems of micronutrient deficiencies in human beings and animals.

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