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Review Article

Biofortification: High zinc wheat programme – The potential agricultural options for alleviating malnutrition in Pakistan

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Abstract

The deficiency of micronutrients (zinc, iron, iodine and vitamin A) is persistently afflicting millions of people living across Africa, Southern Americas, Asia and Pakistan. Among these, the zinc deficiency syndrome is occurring by 47.6, 41.3, and 39.2% in pregnant, non-pregnant and children under 5 years, respectively in Pakistan. The reason being that majority of the people subsists on cereal-based diets, i.e., wheat. The commercially grown wheat varieties contain zinc about 25 mg/g, whereas about 40 mg/g zinc is required in daily diet.The potential risk of zinc deficiency could be mitigated through certain interventions i.e., mineral drugs, food supplements, diversity in diets, production of fortified foods, and genetic biofortification of staple food crops. Among these, quantum increase in zinc content in wheat grains through genetic manipulation would be basics to alleviate zinc deficiency in the malnourished communities. The objective of the programme is to enhance the concentration of zinc nutrient from 25 to 40 mg/g in wheat grains through conventional plant breeding techniques. Pakistan Agricultural Research Council, Islamabad in collaboration with Consultative Group on International Agricultural Research (CGIAR) and International Maize & Wheat Improvement Center (CIMMYT) and HarvestPlus, Pakistan started R&D works to develop biofortified high zinc wheat varieties containing around 40 mg/g in the year 2009. The biofortified wheat crop is developed through conventional plant breeding techniques. The germplasm inherited with high zinc nutrient are crossed with high yielding and adopted to ecological conditions. The varieties are high yielding, and inheriting zinc around 40 mg/g in the grains under both irrigated and rainfed production environments. The Government of Punjab has also given high priority to develop and consume biofortified high zinc wheat in its multi-sectoral Nutrition Strategy Plan 2015, as potential agricultural option to address malnutrition in the Punjab province.

1. Introduction

When you walk into any home in Pakistan, chances are that the aroma of warm *chapatis* (bread) will be the first thing that greets you. In the country of 180 million people, some form of bread, whether as *chapatis, naan*, or *roti*, accompanies every meal, while no meal is complete without bread. Food is one of the fundamental requirement of life, providing not just energy, but vital nutrients to help us grow and reach our full potential. Ironically, despite its highest consumption by 128 kg/capita/annum, compared to world average per capita wheat consumption is 100 kg / year. However, it is not providing sufficient daily dietary nutrient, particularly zinc requirement (Government of Pakistan, 2013).

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The deficiency of zinc nutrient is a ubiquitous problem both in humans and crop production (Fig. 1). Out of 25 trace elements, zinc is an essential for human health, as an component of organic compounds such as carbohydrates, fats, proteins and vitamins (Stein, 2010). The cereal crops including wheat is the inherently low in zinc nutrient in its grains. Moreover, further its cultivation on potentially zinc-deficient soils, results in reduction in zinc content in grain to a far greater proportion (Cakmak, 2014). In Pakistan, the currently grown wheat varieties contain on average 25 microgram, whereas, the daily dietary requirement is around 30- 40 microgram per gram. The consumption of wheat containing lower quantity of zinc and/or cultivating on potentially zinc deficient agricultural soils would lead to zinc malnutrition, predominantly among the low income populations (Cakmak, 2008; Graham, Asher, & Hynes, 1992; Welch & Graham, 2004; Zou et al., 2012).

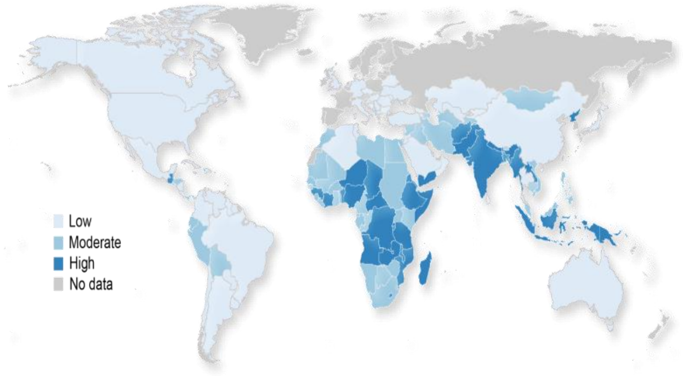

Figure 1: Prevalence of risk of zinc deficiency is based on the percent of children under 5 years of age with low height-for-age or growth stunting, and its public health significance is classified as low (≤20.0%), moderate (>20%–40%), or high (≥40%) Source: World Health Organization, Global Health Observatory Database: http://apps.who.int/ghodata/

1.1. Extent of malnutrition and consequences

Incredibly, micronutrient deficiencies (minerals and vitamins) are afflicting over three billion people worldwide (Kennedy, Nantel, & Shetty, 2003). According to FAO's Food Balance data, about 20% of the world population is at the risk of zinc deficiency (FAO, 2011). The most affected regions are the developing economies, Africa, South Asia, and Pakistan is no exception to it (World Bank, 2013). Pakistan is facing the crisis with some of the worst and most persistent rates of malnutrition in the world. Zinc nutrient ranks 5th among most important deficiency syndromes in the country. Malnutrition is also termed as "hidden hunger". One may seem healthy, but is likely to fall prey to illness and infections. Zinc is involved in a number of functions and a component of more than 200 enzymes system, maintaining immunity and progressive growth and development (Hotz & Brown, 2004).

According to NNS (2011), the prevalence of zinc deficiency is 47.6, 41.3, and 39.2 % in pregnant, non pregnant women and children under 5 years, respectively. The rates of malnutrition in children under 5 years are wasted 15.1%, underweight 31.5% and stunted 43.7% in the impoverished communities. The stunting rate has gone up from 41.6% to 43.7%, which translates into 6.3 to 11.8 million children during 1980s and 2011, respectively. Moreover, 25% of new born babies have low birth weight (Bhutta, 2004). The deficiency in the daily diets results in stunting, reducing immunity, lowering IQ, risk to diarrheal and respiratory diseases and increased risk for both mothers and infants during childbirth. The deficiency of zinc can result in young children being stunted irreversibly. Moreover, it is also impacting negatively on the country's economy by 2-3 % of GDP per annum (World Bank, 2013).

1.2. Strategies to combat malnutrition

Malnutrition is an abnormal physiological condition caused by inadequate, unbalanced or excessive consumption of macronutrients that provide dietary energy (carbohydrates, protein and fats) and micronutrients (vitamins and minerals) that are essential for normal human health. The principal risk factor for zinc deficiency includes diets low in zinc or high in phytates, mal-absorption disorder, and impaired utilization of zinc nutrient due to imbalanced nutrition habits (Graham, Welch, & Bouis, 2001).The potential risk of micronutrients malnutrition could be alleviated through clinical and food supplements, diversity in dietary habits, fortification of food products and consumption of biofortified staple food crops (World Bank, 2013). Among these options, biofortification of staple foods is one of the best evidenced solution and value for money for achieving reduction in malnutrition. Inclusion of fruits, vegetables, fish and animal products may take decades to be part of daily diets (World Bank, 2007).

Table 1: Potential Solutions for Micronutrient Deficiency

Interventions	Scope	Economics
Supplementations: Mineral drugs as clinical treatments	Recommended for severe deficiency	Short term
Fortification: Adding nutrients in food	Limited	Short term
Diversification: Choice in food selection and processing	Alternative food products	Economical, feasible and sustainable
Agronomic biofortification Application of Zinc through agronomic practices	Zinc enhancement through soil and foliar	Short term
Biofortification: Enhancing Zinc level through conventional plant breeding techniques	Wide scope and feasible	Cost effective and sustainable

1.3. Significance of bio-fortification

The biofortification of staple food crops is a process to enhance mineral and vitamin levels through conventional plant breeding techniques. This approach can be used effectively to mitigate malnutrition in people living in nutritionally fragile areas. This potential intervention has also been substantiated by Inter-Agency Report to the G20 on Food Price Volatility (FAO, 2013) and Copenhagen Consensus (2012) that consumption of biofortified staple food crop is the best agricultural option across stratified income groups. The biofortified staple crops can provide people, wherever they are, with better nutrition and improving public health.

1.4. Production and consumption of bio-fortified crops

Harvest Plus is leading a global effort to develop and disseminate staple food crops, enriched with minerals and vitamins that are eaten every day. It is an interdisciplinary program that works with public and private sector partners in more than 40 countries. In the contemporary world, the biofortified staple food crops are being produced and consumed in continents of Africa and Asia (Welch, 2008). This technology is in vogue in the countries, namely, zinc wheat (Pakistan, India); iron pearl millet (India, West Africa); iron and zinc lentil (India, Nepal, Bangladesh); iron and zinc sorghum (India, Mali); iron cowpeas (India); iron beans (Rwanda, D R Congo, Uganda); vitamin A maize (Zambia, Nigeria, Ghana); Vitamin A cassava (Nigeria, D R Congo); Vitamin A sweet potato (Uganda, Mozambique, Southern Africa); Vitamin A banana (D R Congo, Burundi) and iron zinc Irish potato (Rwanda, Ethiopia). Currently, about 0.86, 0.15 and 0.025 million farming families are consuming high iron beans in Rwanda and D R Congo, high vitamin A sweet potato in Uganda, and high iron pearl millet in India, respectively (HarvestPlus Annual Report, 2013).

2. Methodology for production of biofortified high zinc wheat

Wheat crop is being fortified i.e., to raise the level of zinc nutrient from 25 to 37 microgram zinc per gram in its grains part. Pakistan Agricultural Research Council (PARC) under the Ministry of National Food Security and Research (MNFS&R) with collaboration of Consultative Group on International Agricultural Research (CGIAR), International Maize and Wheat Improvement Center (CIMMYT), International Food Policy Research Institute (IFPRI), International Center for Tropical Agriculture (CIAT) and HarvestPlus has taken up this challenging task to develop and disseminate the biofortified high zinc wheat in the country. The biofortified wheat crop is produced through hybridization / genetic manipulation i.e., conventional plant breeding technique.

3. Results and achievements

The R&D efforts made by PARC have resulted in development of biofortified high zinc wheat varieties containing more than 40 microgram zinc per gram and also more than 70 microgram iron per gram in wheat grain. The varieties are high yielding, resistant to diseases and particularly to stem rust race of Ug99 and maintaining more than 100% zinc expression over the content in current commercial wheat varieties. The staking of traits with higher expression of zinc will provide upto 50% of daily zinc needs to the humans. The biofortified crops are bred with conventional techniques and as not a genetically modified product. The biofortified high zinc wheat varieties are going to be released during next one or two years. After the approval of variety, about 80,000 household farming families will be cultivating and consuming biofortified high zinc wheat within next three years. The federal and provincial governments have owned the programme as a potential option to improve nutrient status of the people. The program on biofortification of staple food crops has also been included in the 11th Five-Years Development Plan (2013-2018) and Pakistan Vision-2025. The Government of Punjab has prioritized the programme in its "Multi-sectoral nutrition strategy plan – 2015" to address malnutrition in the province. This program will open an era of development of biofortified crops enriched with essential minerals and vitamins to reduce the hidden hunger of micronutrients among the malnourished population of the country in the days to come.

4. Way forward

The food complimented with nutrition is the basics for healthy life. Moreover, it is the Fundamental Right of the citizens to have an access to nutritious food. In the context of food security, nutrition is an important malnutrition determinant, cutting across all sectors. Food security with provision of nutritional advocacy to suffice the humans recommended dietary allowance is to be ensured. Therefore, multi sectoral and multi thronged plans may be implemented to address malnutrition in a coordinated approach. The following interventions may be mainstreamed:

i) Adopting multi-sectoral nutrition strategy i.e., building confidence measures and coordination among agriculture, food, health and food industry.

ii) Persuation of multi-thronged approach including development of biofortified staple crops, enriched with minerals and vitamins.

iii) Academic training in nutrition at various strata of academic institutions.

iv) Massive media campaign

v) Sensitizing statesmen, planners and executives for greater funding in this area.

vi) Capital and human resource investment in agriculture sector for providing highly nutritious staple food crops, vegetables and fruits as well as in abundance quantity.

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