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REVIEW PAPER

WHEAT BIOFORTIFICATION – A POTENTIAL KEY TO HUMAN MALNUTRITION

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Abstract

Wheat production is required to double by 2050 in order to facilitate the global food assurance. Along with the rise in wheat production, improvement of the nutrient value of wheat varieties is another crucial challenge faced by wheat breeders. It is well established that more than 40% people in the world are at a risk of malnutrition caused by the deficiency of Fe, Zn and protein in their food. Numerous strategies are adopted by scientists, breeders and food industries to combat the problem. In this context, biofortificaton has become a successful method for increasing, either genetically or agronomically, the micronutrient content in crop plants. Recently, substantial progress has been made in the use of molecular marker systems and quantitative trait loci (QTL) to augment the wheat iron, zinc and protein content. Determining the role of GPC-B1 gene in controlling the iron, zinc and protein content in wheat genotypes is a promising discoveries. Although the gene is found to be associated with an elevated micronutrient content, it is also responsible for a decrease in yield. In order to simultaneously achieve both high nutrient content and elevated yield, major efforts are required to reveal the genetic control of these traits. Moreover, identifying the wheat genomic resources with an elevated nutrient content can be crucial. Employment of the next generation sequencing methods and use of molecular markers in marker assisted selection appears to be a promising approach to attaining the objective of breeding nutrient rich varieties. Combining advanced molecular biology and plant breeding techniques for wheat development is a potential strategy in achieving a healthy, 'hidden hunger' free world.

Keywords: biofortification; grain protein content; malnutrition; wheat.

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INTRODUCTION

The saying "Health can be improved by food, not medicine" is the foundation of wheat breeding and biofortification programmes (Powell 2007). More than three billion people, basically from developing countries, are the victims of micronutrient deficiencies, also known as 'hidden hunger'. The spread of hidden hunger is mainly attributed to the scarcity of essential micronutrients like iron, zinc and vitamin-A in food (Sramkova et al. 2009). Although approximately forty-nine nutrients are considered crucial for human metabolic activities (Welch, Graham2004), deficiency of any one of them can affect metabolic process, leading to poor health and sickness (Ramakrishnan et al. 1999, Grantham-Mcgregor, Ani 1999, Branca, Ferrari 2002). Hidden hunger retards the physical and mental development and impairs the work efficiency of people. As per the estimation of World Health Organization (2009), one fourth of the world population is suffering from anaemia. This deadly disease has been listed among the 25 most deleterious diseases in the world for more than two decades (Murray, Lopez 2013). Major part of the populations in developing countries cannot afford a micronutrient loaded diet composed of fruit and animal based products but depends on staple crops like wheat, rice and maize. Hence, steps are taken forward to enhance the micronutrient supply in human food including mineral supplementation, dietary changes and fortification of wheat flour with required vitamins and minerals. In the latter scenario, consumption of biofortified crops, bred for an elevated micronutrient content, may serve as a sustainable solution to the problem. Development of micronutrient affluent crops, either through conventional breeding process or by molecular practices, is an effective tool that can help to eradicate micronutrient deficiencies. Biofortified crops will nourish the poor across the world, and considerable improvement in the supply of these nutrients to the targeted people can be already seen (Welch, Graham 2004).

BIOFORTIFICATION AND ITS PROCESS

Biofortification is the increment in the micronutrient bioavailability of cereal crops achieved with conventional breeding or genetic engineering based techniques (Dellapenna 1999, Nestel et al. 2006, Brinch-Pederson et al. 2007, Johns, Eyzaguirre 2007, Hotz, Mcclafferty 2007, Tiwari et al. 2010). It is advantageous over fortification owing to its capacity of improving the nutrient content of plants during development, and is therefore becoming more approachable to poor communities. Additionally, micronutrients accumulated in crop grains facilitate the crop production, especially when plants are grown in micronutrient deficient soils (White, Zasoski 1999). Both, agronomic and genetic biofortification are widely used for nutritional improvement, mainly in hidden hunger suffering regions of the world (Bouis et al. 2011, Velu et al. 2014). Agronomic biofortification relies on the addition of fertilizers for the micronutrient enrichment of edible parts of crops (Cakmak 2008, Velu et al. 2014). Although it is an effective approach to handling malnutrition, genetic biofortification is a more sustainable solution. Genetic biofortification, including traditional breeding and transgenic methodology, leads to the introduction of nutritionally rich crop varieties in wheat improvement programmes (Gomez-Galera et al. 2010).

Biofortification is a multidisciplinary process relying on the skilled expertise of several breeders, geneticists, nutritionists and economists. It starts with a survey of a more diverse and nutritious germplasm that can be crossed with high yield genotypes to produce varieties distinguished by both high yield and nutrient content (Bouis, Welch 2010, Waters, Sankaran 2011). Developed varieties are further tested for bioavailability and storage of nutrients in various environmental and growth conditions. Among these varieties, most proficient lines should pass some efficiency tests, where quantifiable amounts of nutrients are determined, and finally be released as a novel variety (Dunwell 2014). Both food scientists and economists carry out research to assess the effect of utilizing biofortified crops on human health (Welch 2005). Specialists may consider promoting the crops whose taste or colour changes on increasing the nutrient content. Different colours can enable customers to identify the more nutritious products (Miller, Welch 2013). HarvestPlus is contributing to the production and distribution of different forms of micronutrient rich (mainly iron, zinc and vitamin A) food worldwide, mainly in developing countries (Brown 1991).

ROLE OF WHEAT AS A BIOFORTIFIED CROP

Wheat has gained a tremendous position among cereal crops because of its nutritional value. Owing to the viscoelasticity of wheat dough, wheat flour has become a necessary ingredient of bread and other foodstuffs, and therefore wheat is the main source of nutrition in developing countries. Researchers confirm that the presence of micronutrient enhancement traits in the wheat genome facilitate the improvement of a nutrient content in genotypes with no yield loss (Uauy et al. 2006, Bouis, Welch 2010,). Implementing plant breeding progress is one of the appropriate approaches to the eradication of malnutrition; however, micronutrient bioavailability is a major concern (Welch 2005). Although many researchers are working on increasing the nutrient quality of wheat grains, more efforts are necessary to overcome the challenge of nutritional disorders.

ADVANCES IN WHEAT BIOFORTIFICATION

Until now, much progress has been made in the field of wheat biofortification, where such important questions as the uptake of zinc and iron, and their accumulation in grains, genetic causes behind this accumulation, micronutrients' bioavailability and their genetic variation at different wheat ploidy levels have been investigated. Several scientists have determined that, as well as being controlled by several genes, the transport of micronutrients in plants, their translocation and bioavailability are reliant on the genetic variation and growth conditions (Cakmak 2002, 2008, Bouis, Welch 2010). Different transporters are involved in signaling Fe and Zn mobilization (Sperotto et al. 2012, Deinlein et al. 2012). Despite their high total content in grain, the bioavailability of Fe and Zn is less dependent on their accumulation in the aleurone layer than it is lost during milling (Borg et al. 2012) and made unavailable because of the binding with phytates (Guttieri et al. 2006).

Crop improvement strategies through plant breeding are basically dependent on the wheat genetic variation with respect to the micronutrient content. Wheat ploidy and evolution have their own roles in shaping the Zn and Fe content. Cakmak et al. (1999) emphasized the contribution of A and D genomes in developing zinc efficiency and hence in determining high Zinc efficiency in hexaploids in comparison to tetraploids. Researchers have shown that wild relatives of commercial wheat varieties possess a comparably higher grain iron and zinc content than modern/cultivated wheat cultivars (Cakmak 2002, van der Kamp et al. 2014). Harvest-Plus is a key project of the Consultative Group on International Agricultural Research (CGIAR) to assess the natural genetic variation for grain nutrient content in the wheat germplasm. They have targeted more than 3000 varieties for iron and zinc screening under different environmental and growth conditions that may be involved in further wheat improvement plans. Potential germplasm, including wheat ancestors like emmer wheat, were engaged in breeding programmes to transfer a high micronutrient trait to selected genotypes, making it more effective for quality consumption (Cakmak 2002, Ortiz- Monasterio et al. 2007).

Recently, substantial progress has been made in the use of molecular marker systems, quantitative trait loci (QTL) and next generation sequencing techniques to augment the wheat iron, zinc and protein content (Bernardo 2008, Balyan et al. 2013, Borrill et al. 2014,). Initially, Joppa et al. (1997) proposed and further Uauy et al. (2006) validated that the GPC-B1 gene located on chromosome 6BS is a major QTL linked with an elevated Fe, Zn and protein content in wild emmer wheat (*Triticum turgidum* ssp. *dicoccoides*). Xuhw89 is one of the tightly associated SSR markers to the GPC-B1 locus (Distelfeld et al. 2006). Although several molecular and physiological strategies are used to determine the significance of this gene and related transcription factors in *T. turgidum* accessions, their non-functionality in

T. durum and *T. aestivum* posed new challenges for the proper utilization of the trait. Thus, gene introgression from wild emmer wheat leading to chromosomal substitution lines was proven to be a sustainable approach (Cakmak et al. 2010). Some other noteworthy mapping studies determined two different QTLs on 2A and 7A chromosomes associated with the grain Fe content and one QTL on 7A chromosome linked with the grain Zinc content (Tiwari et al. 2009). On the one hand, chromosome 5B has been found to be linked withan elevated iron, zinc, manganese and copper content Velu et al. (2014); on other hand, Genc et al. (2009) found one QTL and four QTLs allied with the grain Fe and Zn content, respectively, in a double haploid population. Additionally, some researchers concentrated on the regulation of the Fe and Zn content in wheat grain by silencing homeo- and paralogous genes of GPC-B1 in wheat (Avni et al. 2014). With the advancement of molecular marker technologies over the last several years, SNP markers are also being used in this direction to perform association mapping of these crucial traits with different wheat genotypes (Akhunov et al. 2009, Chen et al. 2011, Edae et al. 2013, Saintenac et al. 2013). The determined genes and linked molecular markers can facilitate greatly marker assisted breeding programmes. However, some of the genes like GPC-B1 responsible for a high Fe, Zn and protein content are simultaneously associated with a decrease in yield. In order to achieve both high nutrient content and elevated yield simultaneously major efforts are required to reveal the genetic control of these features.

CONCLUSIONS

Employing molecular biology and wheat breeding methods in agronomic biofortification has achieved a considerable success in terms of diminishing food malnutrition across the contemporary world. However, the use of wild germplasm genetic variability promises a sustainable solution to increasing the nutrient content as well as bioavailability of those nutrients, which are both crucial problems to be addressed. Additionally, climate change and global warming emerge to be major problems, negatively affecting the Fe and Zn content in wheat grains. Other than the scientific advancement, it is necessary to develop social vigilance, so that farmers can effectively use these improved nutrient rich wheat varieties for production.

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