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Genetic Biofortification to Improve Zinc and Iron Contents in Wheat

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Malnutrition due to deficiency of micronutrients particularly Zinc (Zn) and Iron (Fe) affects a very large proportion in the world. According to an estimate by World Health Organization, globally > 2 billion people suffer from deficiencies for Zn or Fe and at least one billion people suffer from a deficiency for Se (https://www.who.int/nutrition/topics/ida/en/). This has resulted in health problems like anemia, increased morbidity and mortality rates. In 2017, nearly 69% in Asia and 27% of children in Africa under the age of five suffered from malnutrition (https://www.who.int/nutgrowthd b/2018-jmebroch ure.pdf). To sort out this problem of hidden hunger, biofortification is thought to be the solution to reduce the incidence of micronutrient deficiencies. Biofortification is an approach to increasing the level of vitamins and minerals in a crop through conventional plant breeding, biotechnology, transgenic techniques, genomic approaches, or agronomic practices. Biofortified crops help in improving human health and nutrition. It is a cost-effective, long-term and sustainable method for combating concealed starvation. Most of the world's population is dependent on cereals like wheat, rice and maize for their dietary intake, therefore, the biofortification of cereals is essential. Wheat is the important staple food grown worldwide, and provides nearly 20% of calories and 40% of protein (Gupta et al., 2021). Keeping in view the importance of wheat across the world, this articles deals with the applications of different breeding methods like conventional plant breeding, marker assisted selection and transgenic approach for grain Zn and Fe biofortification in wheat.

Conventional plant breeding

A lot of effort has been made for developing wheat varieties biofortified for Zn and Fe. These efforts involved both, conventional breeding, and marker-assisted selection (MAS). Workers at CIMMYT developed more than 1500 SHWs which are rich in grain micronutrients (Rosyara et al., 2019). However, these were not suitable for their direct use in wheat breeding because many of these SHWs were developed using T. turgidum ssp. dicoccum/dicoccoides which were tall and had poor agronomic traits. The derivatives of the SHWs (derived from crosses with desirable high-yielding varieties) were useful for the transfer of high Zn and Fe genes to produce high-yielding biofortified wheat lines. Harvest Plus program during 2011–12 produced 6–7 lines having 75–150% higher Zn levels, high yield potential, resistance to rusts, and preferred end-use quality traits (Velu and Singh, 2013). Following these successful efforts, Fe and Zn rich variety namely WB 02, HPBW 01, Pusa Tejas (HI 8759), Pusa Ujala (HI 1605), MACS 4028 (durum wheat), PBW1Zn, Zinc Shakti (Chitra), Ankur Shiva, HD 3298, DBW 303 and DDW 48 were released in India (Yadava et al., 2020). Further, three bread wheat varieties are rich in Zn content viz., PBW 757, PBW 771 and HD 3171 developed by ICAR-IARI, New Delhi for North-Eastern Plains of India has highest content of Zn in the grains (Gaikwad et al., 2020). Moreover, HUW711 a biofortifed Zn wheat variety released by Banaras Hindu University, India. A Zn Biofortified variety 'Zincol2016' was released in Pakistan. Similarly, Zn biofortified wheat varieties Nohely-F2018 were released in Mexico and BARI Gom 33 was released in Bangladesh which showed a 7–8 mg/kg Zn advantage. Some of these varieties were developed using sources like alien germplasm and SHWs. For instance, 'Zinc Shakti' has genes from Ae. tauschii, 'Zincol2016' has genes from T. asetivum ssp. spelta and 'WB02′ and 'HPBW-01'have genes from *Ae. squarrosa* and *T. turgidum ssp. dicoccum*, respectively (Gupta et al., 2021).

Quantitative trait loci (QTL) Mapping

The advent of DNA markers technology greatly increased the opportunity to improve the nutritional value of wheat grain. The identification of molecular markerss linked to Fe and Zn concentration is a promising approach to improve wheat Fe and Zn concentrations (Velu et al., 2016). A high density single nucleotide polymorphism array was used to map the QTL fo Fe and Zn in 254 recombinant inbred lines (RIL). Seven QTL for Zn on 1DS, 2AS, 3BS, 4DS, 6AS, 6DL, and 7BL chromosomes and four QTL for Fe on 3BL, 4DS, 6AS, and 7BL chromosomes accounted for 2.2–25.1% and 2.3–30.4% of the total phenotypic variances, respectively (Wang et al., 2021). Likewise, a QTL mapping study was conducted using by Liu et al. (2019) using a RIL population between Roelfs F2007 × Chinese parental line. A total of 60 QTLs were identified of which 10 for grain Zn and nine for grain Fe concentrations. A number of studies have been conducted for the identification of QTLs resposnsible for Fe and Zn in wheat (Gupta et al., 2021).

Transgenic approach

Genetic engineering is one of the most important approaches to develop the nutrient-rich wheat varieties. Using this approach, a gene of interest can be transferred directly to an elite variety to increase the level of micronutrients, provided the nutrient should accumulate in the edible part of the crop without negative impacts on plant development and economic yield (Vanderschuren et al., 2013). In wheat, some efforts have been made to improve the Fe and Zn content using transgenic technology. The Fe content in wheat grain was improved by using ferritin gene i.e., TaFer 1-A (Borg et al., 2012). The gene improve the Fe content by 50 to 85% in grains by overexpressing the ferittin gene. Overexpression of a VACUOLAR IRON TRANSPORTER gene i.e., TaVIT2, in the endosperm of wheat showed a two times increase in Fe without any enhancement in antinutritional phytate content (Connorton et al., 2017). Likewise, overexpression of OsNAS2 in wheat grains enhanced the Fe concentration up to 80 µg/g under field conditions (Beasley et al. 2019).

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