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Opinion Article

Recent Advancements and Potential Applications of Wheat Genetic Transformation

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DESCRIPTION

Genetic transformation is a powerful technique for introducing novel genes or modifying existing ones in plants, with the aim of improving agronomic traits, enhancing stress tolerance, or adding value to crops. Wheat is one of the most important cereal crops in the world, providing food and feed for billions of people. However, wheat improvement through conventional breeding is hampered by its complex and polyploid genome, long generation time, and narrow genetic diversity. Therefore, genetic transformation offers an alternative and complementary approach for wheat improvement.

Wheat transformation can be achieved by two main methods: biolistic particle bombardment and Agrobacterium-mediated transformation. Biolistic transformation involves the delivery of DNA (Deoxyribonucleic Acid) coated micro projectiles into plant cells using a high-velocity device. This method has been widely used for wheat transformation since the first report in 1992. However, biolistic transformation has some drawbacks, such as low efficiency, high cost, multiple copy insertions, and DNA rearrangements.

Agrobacterium-mediated transformation relies on the natural ability of Agrobacterium tumefaciens to transfer a segment of its Ti plasmid (T-DNA) into plant cells. This method has several advantages over biolistic transformation, such as single-copy insertion, minimal DNA rearrangement, low cost, and high efficiency. The first report of Agrobacterium-mediated wheat transformation was published in 1997, but the method remained challenging and inefficient for many years.

In recent years, significant progress has been made in improving Agrobacterium-mediated wheat transformation by optimizing various factors, such as tissue culture medium, selection regime, vector type, and pre-treatment methods. A major breakthrough was achieved by Japan Tobacco Inc. (JT) who developed a highly efficient and reproducible Agrobacterium-mediated wheat transformation system called Pure Wheat. This system achieved transformation efficiencies of up to 90% for the model wheat genotype Fielder and up to 45% for several commercial wheat cultivars. However, the Pure Wheat system still showed genotype dependency for some wheat cultivars, indicating that further improvement is needed to overcome this limitation.

Genome editing has been successfully applied to various plant species, including wheat. Several studies have used TALENs or CRISPR/Cas (Clustered Regularly Interspaced Short Palindromic Repeats) to edit genes related to disease resistance, herbicide tolerance, grain quality, flowering time, and stress response in wheat. Genome editing offers several advantages over conventional genetic transformation, such as avoiding foreign DNA integration, reducing off-target effects, and facilitating regulatory approval.

Future prospects

Genetic transformation and genome editing are promising tools for wheat improvement that can complement conventional breeding and molecular marker-assisted selection. However, there are still some challenges and limitations that need to be addressed before these techniques can be widely adopted by breeders and farmers. Some of these challenges include:

- Improving the efficiency and stability of wheat transformation and regeneration across different genotypes and tissues
- Developing new vectors and delivery methods for efficient and precise genome editing in wheat
- Expanding the target range and specificity of SSNs for genome editing in wheat
- Identifying and validating novel genes and alleles for wheat improvement
- Evaluating the agronomic performance and environmental safety of transgenic and genome-edited wheat lines
- Addressing the ethical, social, and regulatory issues related to the use of genetic transformation and genome editing in wheat

In conclusion, genetic transformation and genome editing are powerful techniques that have opened new avenues for wheat improvement. With the rapid development of genomic tools and

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resources, such as the recently completed wheat reference genome, these techniques will enable the discovery and manipulation of novel genes and traits that can enhance wheat productivity, quality, and resilience in the face of changing climate and growing demand.