

Callus culture and its role in genetic engineering of crops.

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Introduction

In the realm of plant biotechnology, callus culture stands as a foundational technique that bridges traditional plant propagation and modern genetic engineering. This method, which involves the in vitro cultivation of undifferentiated plant cells, has enabled scientists to manipulate plant genomes with precision, leading to the development of improved crop varieties. From disease resistance to enhanced nutritional content, callus culture plays a pivotal role in transforming agricultural landscapes [1, 2].

Callus culture refers to the in vitro growth of unorganized, undifferentiated plant cells known as callus on a nutrient medium under sterile conditions. Callus is typically induced from explants (such as leaf, stem, or root tissue) by exposing them to specific combinations of plant growth regulators, especially auxins and cytokinins. The resulting mass of cells lacks the structural organization of normal plant tissues but retains totipotency, meaning each cell has the potential to regenerate into a whole plant. This regenerative ability makes callus culture an ideal platform for genetic transformation [3, 4].

The process begins with the selection of a suitable explant and sterilization to prevent microbial contamination. The explant is then placed on a solid or liquid medium commonly Murashige and Skoog (MS) medium—supplemented with hormones like 2,4-Dichlorophenoxyacetic acid (2,4-D) and benzylaminopurine (BAP). Once established, callus can be maintained or subcultured for further use in regeneration or genetic modification [5, 6].

Genes conferring resistance to viruses, fungi, and bacteria have been introduced into crops like rice,

tomato, and potato using callus-based transformation. Genes for drought, salinity, and cold tolerance have been engineered into crops such as wheat and maize, enhancing resilience under climate stress. Golden Rice, enriched with provitamin A, was developed using callus culture and genetic engineering to combat vitamin A deficiency. Bt cotton and Roundup Ready soybean are examples of GM crops developed through callus-mediated transformation for pest and herbicide resistance. Callus culture also aids in germplasm conservation, especially for endangered or recalcitrant species. Cryopreservation of callus allows long-term storage of genetic material, which can be regenerated when needed [7, 8].

Moreover, callus culture facilitates somaclonal variation, a source of genetic diversity that can be exploited for crop improvement. Callus culture is widely used in functional genomics to study gene function, regulation, and expression. It provides a uniform and controllable system for: Advancements in tissue culture protocols and transformation technologies are addressing these limitations. The integration of callus culture with synthetic biology, nanotechnology, and machine learning holds promise for next-generation crop engineering. Automated culture systems and high-throughput screening are making the process more efficient and scalable.

Moreover, combining callus culture with multi-omics approaches (genomics, transcriptomics, proteomics) will deepen our understanding of plant responses and enable precision breeding [9, 10].

Conclusion

Callus culture is more than a laboratory technique—it is a gateway to genetic innovation in agriculture. By providing a platform for

transformation, regeneration, and experimentation, it empowers scientists to engineer crops that are more productive, resilient, and nutritious. As global challenges like climate change and food insecurity intensify, callus culture will remain a vital tool in shaping the future of sustainable farming.

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