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Micropropagation of Banana (Musa spp.): Evaluating Tissue Culture Techniques for Large-Scale, Disease-Free Plantlet Production

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Abstract

Banana (Musa spp.) is one of the world's most important fruit crops, playing a significant role in food security and the global economy. Conventional propagation through suckers is limited by low multiplication rates and the risk of pathogen transmission. Tissue culture-based micropropagation has emerged as an efficient method for producing large numbers of disease-free, genetically uniform banana plantlets. This article reviews major techniques used in banana tissue culture, including shoot-tip culture, somatic embryogenesis, and temporary immersion systems (TIS). Challenges such as somaclonal variation, contamination, and cost limitations are discussed, along with strategies for enhancing large-scale commercial production.

Banana (Musa spp.) is cultivated in more than 130 countries, with major production hubs in Asia, Africa, and Latin America. Globally, it ranks among the top five most important food crops, serving as both a staple food and a significant export commodity. Beyond its role in human diets, banana cultivation supports the livelihoods of millions of smallholder farmers and plays an essential role in local and global economies. The fruit is rich in carbohydrates, vitamins, and minerals, particularly potassium and vitamin B6, making it a vital component of food security in tropical and subtropical regions.

Banana (Musa spp.) is one of the most important fruit crops globally and plays a critical role in food security and the economy of the world. Conventional propagation with suckers usually limits rapid multiplication and has a risk of pathogen transfer. The tissue culture technique of micropropagation has emerged as a useful way to rapidly produce clones of bananas that are free of disease and which are genetically uniform. This paper reviews some of the main ways used in the tissue culture of bananas including: shoot-tip culture, somatic embryogenesis, and temporary immersion cultures (TICs). We discuss challenges that include somaclonal variation, contamination, and cost issues, as well as possible solutions that can enable increased production in commercial situations. Banana (Musa spp.) is produced in over 130 countries, with significant production areas being in Asia, Africa, and Latin America. Globally, it is one of the most important five food crops (Karam and Shang, 2020), serving not only as a staple food but also as an important export product. In addition to its value as a food source, banana production sustains millions of smallholder farmers around the world, and plays a critical role in regional and

global economies. Bananas are a good source of carbohydrates, vitamins, and minerals including potassium and vitamin B6, and are a critical food security crop in tropical and subtropical regions.

Traditional propagation using suckers is slow and inefficient, yielding only a limited number of plants per year. Each mother plant can produce only 5–10 suckers annually, which is insufficient to meet the high demand for planting materials in both commercial and subsistence farming. More critically, this conventional method is highly prone to transmitting fungal, bacterial, and viral diseases through planting material, thereby perpetuating epidemics in banana fields (Vuylsteke, 1989). These challenges have driven research and investment into biotechnological solutions. Among them, micropropagation through tissue culture has become the preferred method for rapid, large-scale production of healthy and genetically uniform planting material.

The development of banana tissue culture techniques began in the late 20th century, marking a turning point in the industry's ability to supply clean planting stocks on a commercial scale. Early studies demonstrated the feasibility of regenerating banana plants in vitro, and over time, these methods were refined into standardized protocols that are now widely adopted in commercial laboratories and research institutions (Cronauer & Krikorian, 1984).

The most widely used technique is shoot-tip culture, which involves excising meristematic tissue from the apical or axillary buds and culturing it under aseptic conditions. In vitro conditions, supported by carefully formulated media containing plant growth regulators such as cytokinins and auxins, stimulate multiple shoot formation from a single explant. This technique is not only highly efficient in producing thousands of uniform plantlets from a single mother plant but also significantly reduces the chances of systemic disease transmission. For instance, Banana Bunchy Top Virus (BBTV) and Fusarium oxysporum f. sp. cubense—the causal agent of Panama disease—are minimized when plantlets are regenerated from disease-free meristematic tissues (Heslop-Harrison & Schwarzacher, 2007).

Beyond shoot-tip culture, somatic embryogenesis has been explored as an advanced approach for mass propagation. This method involves inducing callus formation from immature flowers or zygotic embryos, which then develop into somatic embryos capable of regenerating whole plants. Somatic embryogenesis has the advantage of producing a very high multiplication rate, but it also poses challenges, including technical complexity and the risk of somaclonal variation, which can alter desirable traits. Despite these limitations, somatic embryogenesis has been successfully applied in breeding programs for generating large populations of uniform plants for field testing.

Recent innovations in Temporary Immersion Systems (TIS) represent a breakthrough in banana tissue culture. TIS involves culturing plant tissues in liquid media with intermittent immersion, which provides better aeration, reduces hyperhydricity, and improves nutrient uptake compared to traditional solid media cultures. Studies have shown that TIS-grown plantlets exhibit enhanced vigor, stronger root systems, and higher survival rates upon transfer to soil, making this technique increasingly attractive for commercial scale-up (Escalant et al., 1994).

Somatic embryogenesis offers an alternative approach, enabling plant regeneration from embryogenic callus derived from immature flowers or zygotic embryos. While it has the advantage of producing a large number of uniform embryos, it is technically demanding and prone to somaclonal variation. Recent advancements in temporary immersion systems (TIS) have improved plantlet vigor by providing better aeration, reducing hyperhydricity, and lowering production costs (Escalant et al., 1994).

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Micropropagation addresses several critical challenges in banana cultivation. It ensures disease-free plantlets, thereby mitigating the risk of spreading soil-borne pathogens and viral infections that are difficult to control in the field. Additionally, it enables rapid multiplication, producing thousands of plants from a single explant within a year. However, challenges remain, including high initial costs, contamination risks during in vitro culture, and genetic instability due to somaclonal variation.

To overcome these, research is focusing on optimizing culture media, refining TIS systems for cost-effectiveness, and integrating molecular markers for early detection of off-types. Furthermore, strengthening quality control and certification protocols can enhance the reliability of tissue culture-derived banana plants for commercial farming. Micropropagation of banana through tissue culture is a transformative technology for sustainable banana production. It enables large-scale propagation of disease-free, uniform plantlets, essential for meeting global demand. Despite challenges related to cost, variation, and contamination, continued innovation in culture systems and quality assurance will ensure its role as a cornerstone of modern banana agriculture.

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