

Assessing the impact of copper oxide nanoparticles on growth attributes and regenerative potential in date palm (*Phoenix dactylifera*) micropropagation

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Abstract

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Copper oxide nanoparticles (CuO-NPs; 0–40 mg L⁻¹) were applied in MS medium to evaluate microbial contamination, shoot regeneration, and multiplication in date palm (*Phoenix dactylifera* L. cv. Barhee). Compared to the untreated control (0 mg L⁻¹), copper oxide nanoparticles at 10 mg L⁻¹ eliminated microbial contamination without phytotoxicity, yielding the highest regeneration frequency (88.60%) and maximum shoot number (14.25 shoots jar⁻¹), whereas 40 mg L⁻¹ caused 21.6% culture mortality. Supplementation with 10 mg L⁻¹ CuO-NPs significantly increased shoot nutrient accumulation (N, P, K, Fe, Zn, Cu) relative to the control and other treatments ($p \leq 0.05$). Antioxidant enzyme activities (SOD, CAT, POD), total soluble carbohydrates (152.10 mg g⁻¹ DW), and free amino acids (8.05 mg g⁻¹ DW) reached maximum values at 10 mg L⁻¹, compared to the control, whereas soluble protein declined to 10.40 mg g⁻¹ DW at 40 mg L⁻¹, dropping below the untreated control. Root induction was highest at 10 mg L⁻¹ CuO-NPs, while higher concentrations (≥ 20 mg L⁻¹) suppressed rooting and induced root cellular modifications compared to the control. Plantlets derived from the 10 mg L⁻¹ CuO-NPs treatment achieved the highest ex vitro acclimatization survival rate (88%). Genetic fidelity analysis using monomorphic RAPD and ISSR markers confirmed genetic stability among regenerated plantlets relative to mother plants and control cultures.

Keywords

antioxidant activity, carbohydrate and nitrogen metabolites, copper oxide nanoparticles, date palm, genetic stability, histological analysis, micropropagation, nutrient uptake

Introduction

Date palm (*Phoenix dactylifera* L.) is a dioecious perennial monocotyledonous plant belonging to the Arecaceae family. Date fruit contains a wide variety of chemical constituents with valuable nutritive and medicinal properties (AL-MAYAH, 2025a; 2026a). Furthermore, the date palm represents the “tree of life,” creating a microclimate in arid and semi-arid regions that mitigates drought effects, maintains low-salinity soil moisture, and fosters a biodiversity hotspot for various plant and animal species under harsh desert conditions.

Conventionally, date palms are propagated by seeds or offshoots. However, seed-derived plants yield approximately 50% male palms which cannot be identified until flowering and exhibit high genetic heterogeneity. Consequently, to ensure orchard uniformity, traditional propagation relies on offshoots. Nevertheless, offshoot propagation is insufficient for large-scale commercial demand, making in vitro propagation the most practical alternative. Plant tissue culture provides a promising solution by overcoming traditional propagation bottlenecks, and its success largely depends on choosing the appropriate culture medium (AL-MAYAH,

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