Colegio de Postgraduados

Rejuvenation of date palm (*Phoenix dactylifera* L.) through aerial root induction in high trunk sections

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ABSTRACT

Objective: This study aimed to evaluate the feasibility of rejuvenating mature date palms (*Phoenix dactylifera* L.) by inducing adventitious roots on elevated trunk sections and to synthesize the underlying physiological and agronomic principles that support this technique.

Design/Methodology/Approach: A structured literature review was conducted using the Scopus, Web of Science, SpringerLink, ScienceDirect, Wiley Online Library, and FAO databases. Search criteria focused on adventitious root biology, wound induced hormonal signaling, tissue plasticity, vegetative propagation, and documented cases of aerial rooting in date palm. The evidence was integrated to develop a conceptual field-based protocol for aerial root induction, detachment, and transplantation.

Results: Published studies demonstrate that date palm tissues retain substantial regenerative capacity when exposed to auxin stimulation, controlled wounding, adequate humidity, and moderate aeration. Research on the rooting of elevated offshoots confirms the species' ability to form functional adventitious roots beyond basal regions. These findings support the technical viability of inducing a new root system on elevated trunk sections.

Limitations/Implications: This review relies solely on published studies; no field-based experiments were conducted. The adoption of the technique may vary among cultivars and environmental conditions, particularly in arid regions subject to salinity and temperature extremes.

Findings/Conclusions: Aerial root induction represents a viable rejuvenation strategy for tall, aging date palms, allowing physiological renewal while maintaining genetic identity. This approach integrates well-established principles of adventitious root formation with practical field management, offering strong potential for orchard renovation and the conservation of high value cultivars.

Keywords: Aerial rooting, date palm, adventitious roots, vegetative propagation, rejuvenation.

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INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is among the most ancient and significant fruit species in the arid zones of North Africa, the

Middle East, and emerging desert agricultural regions, serving as a cultural, nutritional, and economic pillar (Zaid and Arias-Jiménez, 2002; Chao and Krueger, 2007). Over the centuries, cultivars have been selected for fruit quality, maturation time, and tolerance to extreme heat, drought, and salinity, resulting in marked phenotypic and genetic diversity (Elhoumaizi *et al.*, 2002).

Traditional clonal propagation relies on basal offshoots; however, offshoot production declines as the trunk elongates and the palm ages, reducing orchard renewal rates and threatening the conservation of elite cultivars (Chao and Krueger, 2007; Zaid and Arias-Jiménez, 2002). *In vitro* micropropagation via somatic embryogenesis or direct organogenesis has become a key tool for the large-scale multiplication of elite genotypes (Al-Khayri, 2007; Mazri and Meziani, 2015; Khokhar and Teixeira da Silva, 2017; Naik and Al-Khayri, 2016).

Nevertheless, high laboratory installation and operational costs, the need for specialized personnel, and prolonged culture periods limit its accessibility for small and medium producers (Mazri and Meziani, 2015; Mazri *et al.*, 2018). As a result, field-based rejuvenation techniques that build on existing knowledge of adventitious root physiology, wound signaling, and tissue regeneration potentially integrated with biotechnological inputs offer a promising alternative (Steffens and Rasmussen, 2016; Li *et al.*, 2021; Zhang *et al.*, 2024).

Inducing aerial roots on the upper trunk of mature palms could enable the formation of new, fully functional root systems from stem portions not typically utilized for propagation. This concept draws upon successful aerial layering of elevated offshoots (Al-Obeed, 2005) and recent advances in palm tissue regeneration and transformation (Zhang *et al.*, 2024).

MATERIALS AND METHODS

This study was conducted as a structured literature review. Scientific articles, book chapters, and technical reports were accessed through Scopus, Web of Science, SpringerLink, ScienceDirect, Wiley Online Library, and FAO repositories. Search terms included: date palm, adventitious roots, aerial rooting, rejuvenation, wound signaling, auxin, vegetative propagation.

Inclusion criteria

1. Studies on Phoenix dactylifera or closely related monocot species.
2. Research addressing adventitious root formation, hormonal regulation, tissue plasticity, or field-based propagation.
3. Publications with a verifiable DOI.
4. Relevance to physiological or agronomic processes supporting rejuvenation.

Data were analyzed thematically to identify key physiological mechanisms, environmental requirements, technical procedures, and limitations associated with aerial root induction.

Conceptual Protocol for Aerial Root Induction

Based on prior aerial layering of high offshoots (Al-Obeed, 2005) and established knowledge of adventitious root physiology, the proposed conceptual protocol includes:

- **Trunk section selection**: Young, functional tissue located below the crown.
- **Preparation**: Surface cleaning and controlled wounding (partial girdling or vertical incisions).
- **Auxin application**: Moderate concentrations, potentially combined with coconut water.
- **Substrate enclosure**: A fibrous, aerated, sterile substrate held in place with a protective wrap.
- **Microenvironment control**: High humidity without waterlogging; reduced temperature and salinity.
- **Rooting assessment and detachment**: Once dense root systems develop, the segment is cut and transplanted.

RESULTS AND DISCUSSION

Advances in micropropagation and somatic embryogenesis

Over recent decades, date palm micropropagation has been refined through the integration of direct organogenesis from apical meristems and somatic embryogenesis from foliar and meristematic explants (Al-Khayri, 2007; Mazri and Meziani, 2015; Khokhar and Teixeira da Silva, 2017).

Al-Khayri (2007) developed a reference protocol focused on embryogenic callus induction and subsequent embryo formation. The same author later demonstrated that the addition of coconut water enhances callus proliferation and somatic embryo production (Al-Khayri, 2010).

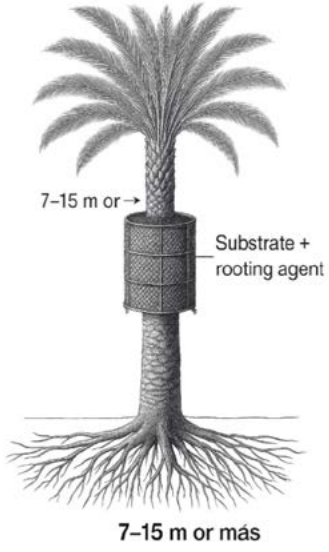

Figure 1. Aerial root induction structure installed 7-15 m above ground in mature date palm.

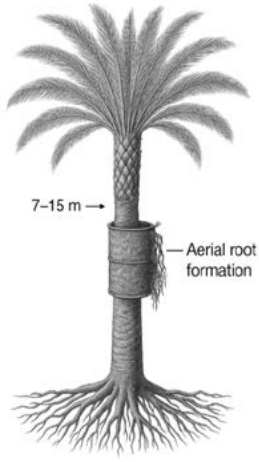

Figure 2. Intermediate stage showing partial substrate opening and emerging aerial roots (≈8 weeks).

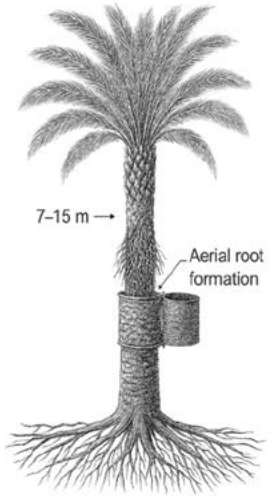

Figure 3. Advanced aerial root development after approximately 16 weeks.

Further studies have improved the composition of culture media, growth regulator concentrations, and osmoregulators, thereby increasing propagation efficiency and reducing somaclonal variation (Mazri *et al.*, 2018; Naik and Al-Khayri, 2016).

Physiological basis of aerial root induction

Adventitious root formation results from cellular dedifferentiation and reprogramming triggered by hormonal cues and environmental stimuli such as wounding, humidity, oxygen availability, and light (Steffens and Rasmussen, 2016; Li *et al.*, 2021).

Wound-induced signaling mediated by ROS, calcium waves, peptides, and defense signals activates regeneration pathways that support root initiation (Savatin *et al.*, 2014). The regenerative capacity of date palm trunk tissues under appropriate hormonal and environmental conditions has been demonstrated *in vitro* (Zhang *et al.*, 2024), reinforcing the feasibility of inducing roots *in situ*.

Salinity stress context

Date palms frequently grow in environments with moderate to high salinity. Such stress conditions alter root physiology, nutrient uptake, and regenerative potential (Alhammadi and Kurup, 2012). Transcriptomic studies reveal that salinity induces complex, tissue-specific gene expression networks in leaves and roots (Yaish *et al.*, 2017). Thus, aerial rooting systems must preserve humidity, limit salt exposure, and prevent wound zone desiccation.

PERSPECTIVES

Aerial rooting rejuvenates aging palms by generating physiologically young individuals while retaining genotype integrity. This supports germplasm conservation amid rising salinity, water scarcity, and other environmental stressors.

Future research should explore genotype-specific hormone responses, biochemical profiles of induced roots, and integration with environmental monitoring systems to enhance predictability.

CONCLUSIONS

Date palm tissues exhibit a high regenerative capacity under adequate hormonal and environmental conditions. Adventitious root induction on upper trunk sections is physiologically viable and aligns with established mechanisms of tissue plasticity, wound signaling, and stress response. In saline environments, successful aerial rooting requires precise management of water quality, humidity, and temperature. Integrating field-based aerial rooting with biotechnological tools offers a promising strategy for orchard renewal, germplasm conservation, and enhanced resilience under climate change.

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