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CONFERENCE PROCEEDINGS ON SUSTAIN LIFE 2026 : EXPLORING BIOLOGICAL FRONTIERS FOR A GREENER PLANET



SEETHALAKSHMI RAMASWAMI COLLEGE
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RESEARCH DEPARTMENT OF ZOOLOGY
2026

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SEETHALAKSHMI RAMASWAMI COLLEGE (Autonomous)
Tiruchirappalli - 620 002
Tamil Nadu, India**

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© Dr. A. S. Maheswari, Dr. J. Viji, Dr. M. Isai

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STANDARDIZATION OF SUBSTRATE COMPOSITION FOR ENHANCED SEEDLING GROWTH AND GRAFT SUCCESS IN CASHEW (*ANACARDIUM OCCIDENTALE* L.) PROPAGATION

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Abstract

The production of genetically superior and physiologically robust planting material in cashew (*Anacardium occidentale* L.) is critically influenced by the physicochemical and biological characteristics of the nursery substrate. Substrate composition governs key parameters such as porosity, bulk density, water-holding capacity, aeration, nutrient availability, and microbial dynamics, which collectively determine rootstock vigour and graft union success. Conventional media comprising red soil, sand, and farmyard manure (2:1:1) are widely utilized; however, variability in texture and pathogen load often limits uniform seedling performance. Recent advances in nursery technology emphasize soilless substrates formulated with cocopeat, vermicompost, and perlite, which exhibit improved structural stability, enhanced cation exchange capacity, and superior root-zone aeration. Optimization of substrate pH (5.5 - 6.5) and electrical conductivity ($<1.0 \text{ dS m}^{-1}$) has been shown to promote nutrient uptake efficiency and reduce osmotic stress. Biological enrichment with neem cake and antagonistic fungi such as *Trichoderma viride* enhances rhizosphere health, suppresses soil-borne pathogens, and improves root proliferation. Standardized substrate formulations have demonstrated significant improvements in seedling growth attributes, root architecture, and graft success rates (85–90%) under polybag nursery conditions. Therefore, substrate standardization represents a fundamental strategy for improving propagation efficiency, ensuring uniform field establishment, and supporting sustainable cashew production systems.

Keywords

Cashew, Propagation, Soilless Substrate, Graft Success and Nursery Media

Introduction

Cashew (*Anacardium occidentale* L.) is an economically important tropical plantation crop valued for its edible kernels, cashew apple products, and export potential. The crop plays a significant role in enhancing rural livelihoods, generating employment, and contributing substantially to foreign exchange earnings in several developing countries, particularly India, Vietnam, Brazil, and African nations. India remains one of the leading producers, processors, and exporters of cashew kernels, and sustained productivity improvement is closely associated with the availability of high-quality planting material (Nair, 2010). Successful establishment of cashew orchards largely depends on the use of genetically uniform and physiologically vigorous planting material. Seed propagation results in high genetic variability; therefore, vegetative propagation techniques, especially softwood grafting, have been widely adopted for large-scale multiplication of elite clones (Sajeev & Saroj, 2015). Graft success, early establishment, and long-term productivity are strongly influenced by rootstock vigor, which is determined primarily by nursery management practices. Among these practices, substrate composition plays a pivotal role in regulating seedling growth and graft compatibility. The nursery substrate constitutes the immediate rhizosphere environment surrounding developing roots and directly affects plant growth through its physical, chemical, and biological properties. An ideal propagation medium should provide adequate mechanical anchorage, optimal aeration, balanced water-holding capacity, and sufficient nutrient availability while maintaining favorable microbial activity (Hartmann *et al.*, 2018). Proper gaseous exchange within the root zone is essential for root respiration and metabolic processes, whereas excessive compaction or poor drainage can restrict oxygen diffusion and impair root development. Traditionally, nursery media composed of red soil, sand, and farmyard manure have been extensively used in cashew propagation due to their accessibility and low cost. However, soil-based substrates frequently exhibit variability in texture, bulk density, and nutrient composition, leading to inconsistent seedling performance (Kumaresan *et al.*, 2024 (a)). Moreover, the presence of soil-borne pathogens, nematodes, and weed seeds often increases seedling mortality and reduces grafting efficiency (Bhat & Sujatha, 2013). Soil compaction and inadequate porosity further limit root proliferation and water-use efficiency, ultimately affecting graft union formation and plant establishment. Recent advancements in nursery technology emphasize the use of standardized and soilless substrates formulated using organic and inert materials such as cocopeat, vermicompost, perlite, and bio-enriched amendments. These substrates offer improved

structural stability, enhanced water retention, superior aeration, and reduced pathogen incidence compared with conventional soil media (Raviv & Lieth, 2008). Standardization of substrate composition therefore represents a critical component for improving propagation efficiency, ensuring uniform seedling growth, and enhancing graft success in cashew nurseries.

Role of Substrate Composition in Seedling Development

The composition of nursery substrates plays a fundamental role in regulating seedling growth, root architecture, and successful plant establishment during early developmental stages. The physical properties of the growing medium largely determine root-zone environmental conditions, influencing water relations, gaseous exchange, and mechanical stability of seedlings. Substrate porosity is particularly critical, as adequate air-filled pore space ensures sufficient oxygen availability for root respiration and metabolic activities. Restricted aeration results in anaerobic conditions that inhibit root elongation, nutrient absorption, and overall plant vigour (Hartmann *et al.*, 2018). Water-holding capacity represents another essential attribute of an ideal propagation medium. A well-balanced substrate should retain adequate moisture while allowing excess water drainage to prevent waterlogging. Cocopeat has emerged as an important component of modern nursery substrates owing to its high porosity, superior moisture retention capacity, and low bulk density, which collectively promote active root proliferation and uniform seedling growth. The addition of inert materials such as perlite further enhances substrate structure by improving aeration and drainage characteristics, thereby minimizing root-zone hypoxia and promoting healthy root development (Raviv & Lieth, 2008). In addition to physical attributes, chemical characteristics of nursery substrates significantly influence plant growth and physiological performance. Maintenance of slightly acidic substrate pH (5.5–6.5) enhances nutrient solubility, microbial activity, and nutrient uptake efficiency in cashew seedlings. Deviations from optimal pH levels may lead to nutrient fixation or toxicity, adversely affecting seedling development (Bunt, 2012). Electrical conductivity (EC) is another important parameter, as excessive soluble salts can induce osmotic stress, reduce water uptake, and impair root growth during early stages of plant establishment.

Organic amendments such as vermicompost play a crucial role in improving substrate fertility and biological activity. Vermicompost supplies essential macro- and micronutrients along with humic and fulvic substances that stimulate enzymatic activity, root initiation, and

microbial proliferation (Kumaresan *et al.*, 2014 (b)). The presence of beneficial microorganisms in vermicompost enhances nutrient mineralization and improves overall substrate health, leading to increased biomass accumulation and improved seedling vigour (Nadhiya *et al.*, 2024; Atiyeh *et al.*, 2000). Therefore, optimization of both physical and chemical properties of nursery substrates is essential for producing vigorous rootstocks capable of achieving higher graft success and improved field establishment in cashew propagation systems.

Biological Enrichment and Rhizosphere Health

Apart from physical and chemical characteristics, biological components of nursery substrates play a crucial role in determining rhizosphere functionality and seedling health. The rhizosphere represents a dynamic zone of interaction between plant roots and microorganisms, where biological processes regulate nutrient availability, disease suppression, and plant growth promotion. Enrichment of nursery substrates with organic amendments such as neem cake contributes to gradual nutrient release while simultaneously exhibiting pesticidal and nematicidal properties against soil-borne pathogens and harmful insects (Subramanian *et al.*, 2012). Neem-based amendments improve microbial diversity and enhance soil enzymatic activity, thereby promoting sustainable nursery management. Beneficial microorganisms, particularly antagonistic fungi such as *Trichoderma viride*, have gained significant importance in modern propagation systems. *Trichoderma* species colonize the rhizosphere efficiently and suppress pathogenic fungi through mechanisms including competition for nutrients and space, mycoparasitism, and production of antifungal secondary metabolites (Harman *et al.*, 2004). In addition to disease suppression, these beneficial microbes stimulate plant growth by producing phytohormones such as indole acetic acid and gibberellins, enhancing nutrient solubilization, and improving root system architecture. Increased root proliferation and enhanced microbial activity ultimately result in improved seedling vigor and higher survival rates during transplantation.

Standardization of Nursery Substrates

Standardization of substrate composition aims to develop a uniform, reproducible, and scientifically optimized growing medium capable of producing consistent and high-quality planting material. Traditional soil-based media often vary widely in texture, nutrient content, and microbial population, leading to non-uniform seedling growth and variable nursery

performance. The adoption of standardized soilless substrates has therefore emerged as an essential strategy in modern horticultural propagation systems (Raviv & Lieth, 2008).

Different substrates are used for plant propagation depending on crop requirement and propagation method. Commonly used substrates include soil, sand, vermiculite, perlite, cocopeat, peat moss, farmyard manure, compost, leaf mould, sphagnum moss, rice husk, sawdust, bark compost, rock wool, and combinations of these materials to provide adequate aeration, moisture retention, drainage, and nutrient availability for successful root and shoot development. Substrate combinations containing cocopeat, vermicompost, sand, and perlite have demonstrated superior performance compared with conventional nursery mixtures (Kumaresan *et al.*, 2023 (c)). Cocopeat provides high moisture retention and structural stability, vermicompost enhances nutrient availability and biological activity, sand improves drainage, and perlite increases aeration within the root zone. Such integrated substrates create an optimal environment for root development by maintaining balanced air–water relationships and nutrient supply (Bunt, 2012). Experimental studies indicate that seedlings raised in standardized substrates exhibit significant improvements in plant height, stem diameter, leaf production, chlorophyll content, and biomass accumulation. Improved root architecture enhances nutrient uptake efficiency and strengthens plant tolerance to transplant shock, thereby ensuring successful field establishment and uniform orchard development.

Influence on Graft Success

Graft success in cashew propagation is strongly influenced by the physiological condition and vigour of the rootstock. Healthy rootstocks grown under optimized substrate conditions exhibit enhanced cambial activity, rapid callus formation, and efficient vascular differentiation between scion and rootstock tissues. These physiological processes are essential for successful graft union formation and subsequent growth of grafted plants (Hartmann *et al.*, 2018). Standardized substrates promote balanced nutrient availability and improved carbohydrate accumulation in rootstocks, which facilitates faster healing and establishment of graft unions. Enhanced root activity ensures efficient translocation of water, nutrients, and assimilates to the scion, resulting in improved survival and growth performance. Studies have reported graft success rates exceeding 85–90% in cashew when soilless substrate systems are employed under controlled nursery conditions (Sajeev & Saroj, 2015). Uniform rootstock development further reduces variability among grafted plants and increases overall nursery productivity.

Advantages of Soilless Propagation Media

The adoption of standardized soilless substrates offers multiple agronomic and operational advantages in nursery production systems. Soilless media significantly reduce the incidence of soil-borne diseases and nematode infestation due to the absence of field soil contamination. Improved water-holding capacity combined with enhanced aeration promotes efficient water-use efficiency and minimizes irrigation requirements. Uniform substrate composition ensures consistent seedling growth and simplifies nutrient management practices. Additionally, lightweight substrates facilitate easy handling, transportation, and large-scale commercial propagation of planting material. Improved sanitation, reduced weed incidence, and enhanced transplant survival rates further contribute to the economic viability of soilless nursery systems. Consequently, standardized soilless substrates represent a sustainable and efficient approach for producing high-quality cashew planting material suitable for modern horticultural production systems (Raviv & Lieth, 2008).

Future Perspectives

Future advancements in cashew propagation are expected to rely on the integration of standardized substrate technologies with modern nursery management systems aimed at improving propagation efficiency, plant uniformity, and resource-use sustainability. The adoption of precision nursery techniques, including automated irrigation and fertigation systems, sensor-based moisture monitoring, and controlled environmental conditions, can significantly enhance seedling growth and graft success by maintaining optimal root-zone moisture and nutrient balance (Hartmann *et al.*, 2018). Increasing emphasis is being placed on the incorporation of microbial biofertilizers and plant growth-promoting rhizobacteria (PGPR) into nursery substrates to enhance nutrient availability, stress tolerance, and disease resistance. Beneficial microorganisms such as *Trichoderma*, *Pseudomonas*, and *Bacillus* species are expected to play a central role in sustainable cashew propagation through improved rhizosphere functioning and reduced dependency on chemical inputs (Harman *et al.*, 2004). Integration of bio-enriched substrates with organic amendments will contribute to environmentally sustainable nursery systems while maintaining high productivity.

Another important research direction involves the development of region-specific substrate formulations tailored to local climatic conditions, water quality, and available organic resources. Standardized ready-to-use nursery media produced commercially can ensure uniform substrate quality, reduce labor requirements, and facilitate large-scale

multiplication of elite planting material. Commercial substrate technologies are particularly important for expanding organized cashew nurseries and meeting the increasing demand for grafted plants required for orchard rejuvenation and area expansion. Furthermore, incorporation of biodegradable containers, climate-resilient propagation practices, and digital nursery management tools will support sustainable production systems under changing climatic conditions. Adoption of such innovative approaches will enhance propagation efficiency, improve transplant survival, and contribute to long-term sustainability of cashew cultivation. Consequently, future nursery systems integrating standardized substrates, biological inputs, and precision management practices are likely to become the cornerstone for large-scale production of high-quality grafted cashew plants (Raviv & Lieth, 2008).

Conclusion

Standardization of substrate composition is a key determinant for achieving enhanced seedling growth and higher graft success in cashew (*Anacardium occidentale* L.) propagation. Optimized soilless substrates enriched with organic amendments and beneficial microorganisms create a favourable root-zone environment by improving aeration, moisture retention, nutrient availability, and microbial activity. Such conditions promote vigorous rootstock development, uniform seedling growth, and efficient graft union formation. The adoption of scientifically validated substrate formulations minimizes nursery losses, improves transplant survival, and ensures consistent production of high-quality planting material. Therefore, integration of standardized substrates with improved nursery management practices offers a sustainable approach for strengthening cashew propagation systems and supporting long-term productivity and expansion of cashew cultivation.

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