PLANT SCIENCE TODAY
Vol XX(1): 1-XX
https://doi.org/10.14719/pst.16462

eISSN 2348-1900
OPEN ACCESS

Review Article | Plant Biotechnology 2026, Volume XX, Issue X, pp. 1-XX

Unlocking the propagation potential of *Jasminum* species: A systematic review of conventional methods and modern biotechnology

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Abstract

Jasminum spp. are economically important ornamental and aromatic crops valued for their fragrance, essential oils, medicinal properties and commercial applications in the floriculture industry. However, the commercial propagation and genetic improvement remain constrained by poor seed set, reproductive barriers, low multiplication rates and species-specific responses to conventional propagation methods. This systematic review synthesises current evidence on conventional propagation, *in vitro* regeneration, germplasm conservation and emerging biotechnological interventions in *Jasminum*. A comprehensive literature search was conducted following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines using Scopus, ScienceDirect, J-Gate, Web of Science and Google Scholar databases to identify relevant peer-reviewed publications on propagation, tissue culture, molecular characterisation and advanced biotechnological approaches. The available literature indicated that stem cutting remains the most efficient and commercially preferred propagation method, with rooting success largely influenced by cutting type, plant growth regulators and environmental conditions. Among *in vitro* approaches, nodal explants cultured on Murashige and Skoog (MS) media supplemented with appropriate auxin-cytokinin combinations consistently produced superior regeneration responses. Molecular markers, particularly simple sequence repeats (SSRs), inter simple sequence repeats (ISSRs) and random amplified polymorphic DNA (RAPDs), have enhanced germplasm characterisation and breeding, whereas applications of synthetic seed technology, somatic embryogenesis, clustered regularly interspaced short palindromic repeats (CRISPR)/Cas genome editing and nanotechnology remain limited in *Jasminum*. This review highlights major knowledge gaps and inadequate validation of emerging biotechnological approaches. Integrating conventional propagation with modern biotechnological tools will be essential for efficient germplasm conservation, rapid multiplication, genetic improvement and sustainable commercial production of *Jasminum* spp.

Keywords: biotechnology; germplasm conservation; *Jasminum* spp.; micropropagation; systematic review; vegetative propagation

Received: 01 July 2026. **Accepted:** 09 September 2026. **Available online:** Version 1.0: 18 November 2026.

Cite this article: Anushka K, Thamaraiselvi SP, Ganga M, Geethanjali S, Gurusamy K. Unlocking the propagation potential of *Jasminum* species: A systematic review of conventional methods and modern biotechnology. Plant Science Today. 2026;XX(X):1-XX. https://doi.org/10.14719/pst.16462

Introduction

The family Oleaceae comprises a diverse group of woody trees, shrubs, climbers and lianas distributed worldwide and is taxonomically classified into five tribes, namely Myxopyreae, Jasmineae, Forsythieae, Fontanesieae and Oleeae. Among these genera, *Jasminum*, with 200 species, is a diverse genus belonging to the tribe Jasmineae, which also comprises *Mendora* and the recently recognised genus *Chrysojasminum* (1). Jasmine is one of the most economically important ornamental and aromatic crops cultivated throughout tropical and subtropical regions. Owing to its distinctive fragrance, jasmine flowers are extensively utilised in the loose flower market, garland-making, perfumery, the cosmetic industry and essential oil production. These diverse applications have earned jasmine the titles of the “Belle of India” and “Queen of Fragrance” (2). The commercial importance of *Jasminum* is primarily attributed to its rich composition of volatile secondary metabolites, which contribute significantly to the fragrance and flavour industries (3). Among the cultivated species, *Jasminum sambac* (L.) Aiton, *Jasminum auriculatum* Vahl, *Jasminum grandiflorum* L. and *Jasminum multiflorum* (Burm.f.) are of major commercial importance, whereas underutilised species such as *Jasminum nitidum* Skan, *Jasminum calophyllum* Wall. ex G.Don, *Jasminum rigidum*

Zenker and *Jasminum flexile* Vahl represent valuable genetic resources due to their extended flowering period and off-season blooming potential (4, 5).

Beyond the ornamental significance, several jasmine species possess considerable medicinal value owing to the presence of diverse bioactive compounds such as phenolics, flavonoids, terpenoids, tannins, glycosides, coumarins, sterols, esters and fatty acids. These secondary metabolites are highly responsible for the diverse pharmacological activities, including antioxidant, antimicrobial, anti-inflammatory and antidiabetic effects, highlighting the therapeutic potential of jasmine (6, 7).

Commercial cultivation of jasmine relies predominantly on vegetative propagation because seed propagation is constrained by poor seed set, reproductive barriers, low germination and prolonged juvenile phases (8). Conventional propagation approaches such as stem cutting, layering and grafting remain the backbone of commercial multiplication. Species-specific rooting responses, environmental conditions and plant growth regulator treatments often influence their efficiency. Recent advances in *in vitro* propagation, molecular characterisation, genome editing, germplasm conservation and other emerging biotechnological tools have opened new opportunities for rapid multiplication and genetic improvement of *Jasminum*. However, the available information remains fragmented across individual studies, making it challenging to identify the most effective propagation strategies and future research priorities. Despite the economic importance of Jasmine, information on conventional propagation, *in vitro* regeneration, germplasm conservation and emerging biotechnological interventions remains fragmented across the literature. This systematic review synthesises current evidence to critically evaluate existing propagation strategies, compare their effectiveness and identify research gaps. Furthermore, it highlights future research priorities and advanced biotechnological approaches that could strengthen germplasm conservation, genetic improvement and the sustainable commercial production of *Jasminum* spp.

Materials and Methods

This systematic review was conducted in accordance with the PRISMA 2020 guidelines to ensure transparency and reproducibility. A systematic approach was employed to identify, screen and synthesise the published literature on propagation strategies, biotechnological interventions and germplasm conservation and utilisation in *Jasminum* spp. (9). The methodology adopted for this review is outlined below.

Literature search

A comprehensive search was conducted across several reputable databases, including Scopus, ScienceDirect, J-Gate, Web of Science and Google Scholar. This approach aimed to ensure the comprehensive retrieval of a substantial number of scholarly works. The literature search was performed from 1 January to 28 February 2026 using the inclusion terms, namely '*Jasminum'* and 'Jasmine', combined with additional terms such as 'propagation', 'micropropagation', 'stem cutting', 'tissue culture', 'germplasm conservation', 'genetic diversity', 'CRISPR' and 'nanotechnology'. The Boolean operators AND, OR and NOT were used to combine search terms, such as "Jasminum" OR "Jasmine" AND "propagation" OR "micropropagation" OR "tissue culture", while NOT was used to exclude records and studies that are irrelevant to the propagation, conservation and biotechnological improvement of *Jasminum* spp. The review included peer-reviewed original research articles, review papers, conference proceedings and short communications published in the English language. Literature was included irrespective of publication year to capture both historical and recent developments. Studies relevant to *Jasminum* propagation, crop improvement and biotechnology were considered for inclusion. Publications from disciplines irrelevant to the scope of the review, including social sciences, business and economics, nursing, arts and humanities and astronomy, were excluded during the screening process.

Selection of suitable records

The references retrieved from the literature search were imported into Zotero (https://www.zotero.org/), a reference management software, where each record was organised according to its respective database of origin. Duplicate records were identified and removed using Zotero's built-in duplicate detection feature. To ensure data accuracy, the reference library was manually examined to identify and merge any remaining duplicate entries that were not detected automatically. The finalised dataset was then used for title and abstract screening in accordance with the predefined inclusion and exclusion criteria.

A total of 412 records were identified through a comprehensive database search. After the removal of 18 duplicate records and 7 irrelevant records, 387 unique records were retained for title and abstract screening, as illustrated in Fig. 1. The screening included studies addressing the conventional propagation methods and biotechnological approaches for *Jasminum* spp., while studies that did not address propagation, tissue culture, germplasm conservation, or related biotechnological interventions in *Jasminum* were excluded according to the predefined eligibility criteria (Fig. 1). In addition, the reference list of relevant articles was manually screened to identify any additional eligible studies.

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https://doi.org/10.14719/pst.16462

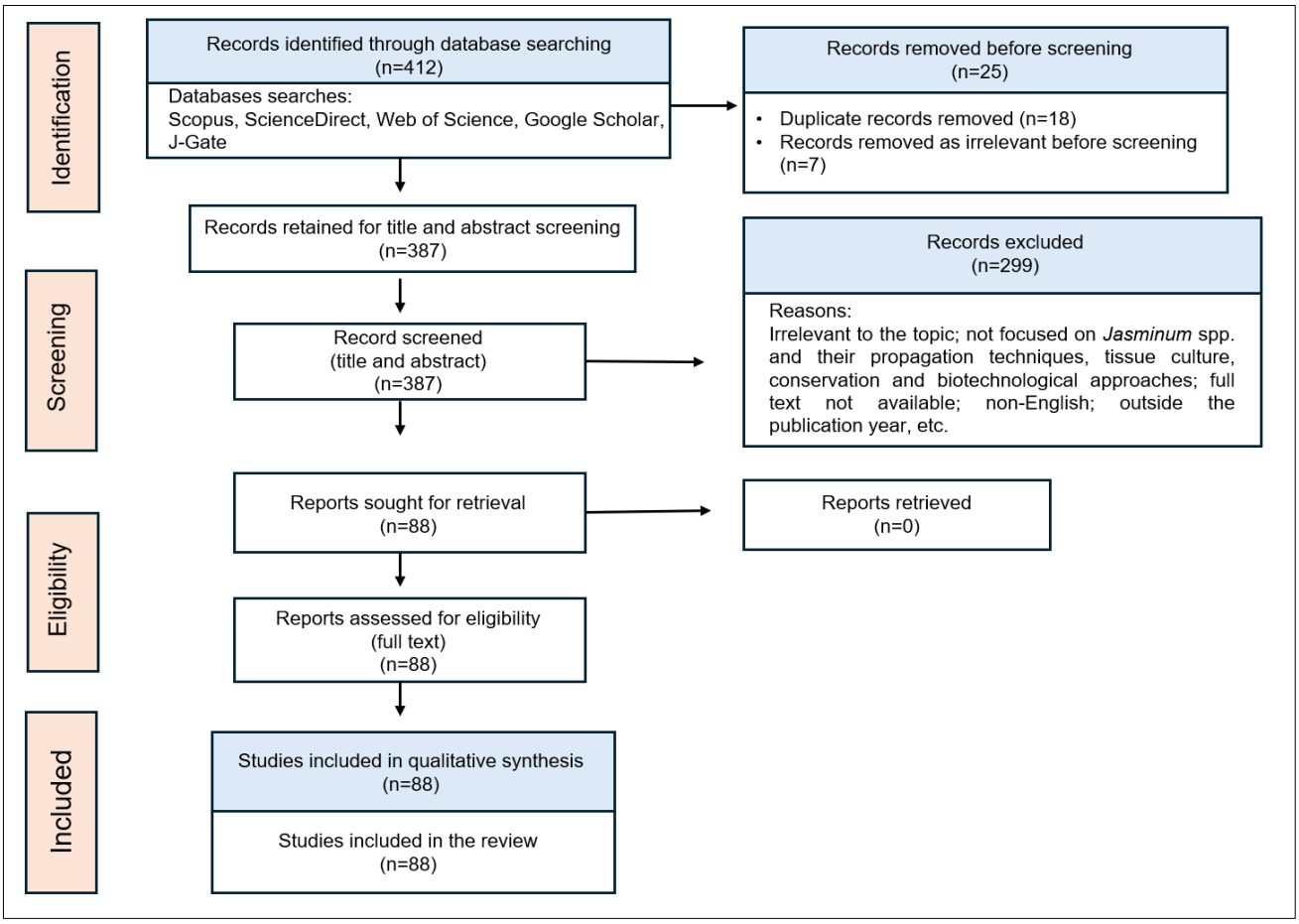


Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 flow diagram illustrating the study selection process for the systematic review of propagation and biotechnological approaches in *Jasminum* spp.

After the screening and full-text eligibility assessment, 88 studies met the inclusion criteria and were incorporated into the qualitative synthesis. The literature selection process is presented in the PRISMA 2020 flow diagram.

Quality assessment of included studies

The methodological quality of the included studies was assessed using predefined criteria developed for this review, as no validated quality assessment tool specific to *Jasminum* propagation studies was identified. The assessment considered the study objectives, methodological details, treatment conditions, clarity of results and reproducibility of propagation protocols. Each criterion was assessed as “Yes” or “No” based on the information mentioned in the studies. This assessment helped evaluate the overall reliability and completeness. Owing to the methodological heterogeneity among studies, the literature and evidence were synthesised narratively rather than quantitatively.

Results and Discussion

Identification of suitable records

The literature search identified 412 records from 5 electronic databases, namely Scopus, ScienceDirect, Web of Science, J-Gate and Google Scholar, ensuring comprehensive coverage of the available literature on conventional and biotechnological propagation of *Jasminum* spp. After removing 18 duplicate records and 7 irrelevant records, 387 unique records were screened based on their titles and abstracts. Following the eligibility assessment, 88 studies satisfied the predefined inclusion criteria and were retained for qualitative synthesis.

The included studies covered diverse aspects of *Jasminum* propagation, including seed propagation, vegetative propagation, *in vitro* regeneration, micropropagation, germplasm conservation and emerging biotechnological tools. Considerable variation was observed in *Jasminum* spp., explant types, culture media, plant growth regulators, propagation techniques and experimental conditions across studies. This methodological heterogeneity precluded a quantitative meta-analysis. Therefore, the findings were synthesised narratively according to the propagation approach and the

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biotechnological application. The review also highlighted limited evidence on advanced techniques such as synthetic seed, molecular marker-assisted breeding and genome editing approaches, indicating important opportunities for future research in *Jasminum* improvement and conservation. The complete literature search process is illustrated in the PRISMA 2020 flow diagram (Fig. 1).

Physiological basis of jasmine propagation

Clonal propagation is the preferred method for multiplying the *Jasminum* spp. because it ensures true-to-type plants while preserving desirable traits such as yield, quality, flower fragrance and uniformity (10). Unlike seed propagation, prolonged juvenile period of 3 to 5 years and various phenotypic traits, clonal propagation ensures the rapid and uniform multiplication of elite cultivars, making it the primary approach adopted for commercial and large-scale cultivation (11).

Reproductive biology and fertility constraints

Floral morphology and pollination biology

Members of the Oleaceae family, including *Jasminum* spp., exhibit a broadly similar reproductive pattern despite considerable taxonomic diversity. Flowers are arranged in terminal or axillary cymes and are single, star-shaped and mostly white. The buds are slender and pointed and the corolla is tubular, with variation in flower size and petal number among species. Calyx development ranges from rudimentary to well-defined. Each flower typically contains two stamens and a single style (12). Fruit morphology varies among *Jasminum* spp.; however, *Jasminum mesnyi* Hance fruits are small, black, bilobed berries from a superior bicarpellary ovary with one to two seeds per locule. The fruit wall is very thin. Its thick, fleshy seed coat gives a berry-like appearance rather than a true fleshy pericarp (13). Seeds usually feature a thin testa for efficient germination, contain an oily endosperm, which provides a source of carbon available to the germinating seedling and typically have a straight embryo along the seed length. Dispersal occurs through birds' ingestion of the berry-like fruits (14).

Reproductive barrier

Seed propagation in jasmine faces severe pre-fertilisation barriers, including the rapid loss of pollen viability after anthesis and a restrictive window of stigmatic receptivity. Fertile species such as *J. calophyllum* maintain high pollen viability for up to 72 hr, whereas species like *J. sambac*, especially double- and multi-petaled types, show reduced fertility due to abnormal pollen development and early pistil senescence. Although pollen may germinate on the stigma, the pollen tube is often blocked within the style and fails to reach the ovary, leaving embryo sacs unfertilised and preventing seed development (Table 1). This failure is primarily driven by the premature senescence of stigmatic and stylar tissues during flowering, which deprives pollen tubes of essential cellular support and ultimately results in poor fertilisation and complete failure of seed set (15–17).

Fertility hierarchy among species

Across *Jasminum* spp., the reproductive traits group species into a fertility hierarchy. *Jasminum flexile*, *J. calophyllum* and *J. auriculatum* function as robust seed-setting parents, maintaining a high level of fertility. In contrast, *J. grandiflorum* exhibits significantly diminished fertility and *J. sambac* has a complex interplay between defective pollen development, pistil senescence and multiple post-fertilisation barriers (Table 1).

Conventional propagation approaches

Stem cutting

Evidence accumulated over the past three decades consistently indicates that stem cutting is the most reliable and widely adopted method for the vegetative propagation of *Jasminum* spp. Sexual propagation through seeds is hindered by reproductive barriers and poor seed set (18). Consequently, propagation through cutting has emerged as the cornerstone of the commercial cultivation of jasmine. Cutting is the simplest and most reliable method for raising the jasmine plant stock, where a new, independent plant is grown from a part of the parent plant. Successful propagation of jasmine through stem cutting is governed by species-specific parameters, including the cutting type, optimal auxin concentration and environmental conditions (19). Thus, propagation via cutting represents an efficient strategy for large-scale production of *Jasminum* spp. and forms the backbone of both traditional practices and modern commercial floriculture practice. The major conventional propagation approaches are summarised in (Fig. 2).

Species specificity

Stem cutting is the most effective and commercially preferred propagation method in the *Jasminum* crop, although the rooting success is highly species- and cutting-type-dependent. Softwood cutting shows rapid root initiation under favourable conditions due to high meristematic activity and endogenous auxin levels. However, their high moisture content makes them highly prone to desiccation (20). In contrast, semi-hardwood cuttings provide superior rooting, improved survival and greater nursery establishment due to balanced physiological maturity and carbohydrate reserves, i.e., treated with indole-3-butyric acid (IBA) typically at concentrations ranging from 1000 to 2000 mg L^{-1}, making them suitable propagules for large-scale multiplication (21). Hardwood cuttings possess high carbon reserves and greater structural stability, but show lower rooting efficiency due to advanced lignification that restricts endogenous hormone and cell dedifferentiation (22).

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Table 1. Comparative reproductive characteristics and fertility status of selected *Jasminum* spp.

Species	Pollen viability and performance	Profile of fruit and seed set	Fertility status	Reference
Jasminum sambac	Low viability and tube arrest	No fruit set under open or cross-pollination	Functionally sterile	(15–16)
Jasminum auriculatum	Moderate to high viability	Profuse open-pollinated fruit set	Highly fertile potential seed parent	(16)
Jasminum flexile	High viability and long pollen tubes	Good fruit and seed set with strong cross-compatibility	Highly fertile	(16)
Jasminum calophyllum	High viability and receptive stigma	Good open-pollinated fruit set	Highly fertile	(16)
Jasminum grandiflorum	Moderate viability	Sparse fruit set, malformation and embryo abortion	Low fertile	(16)

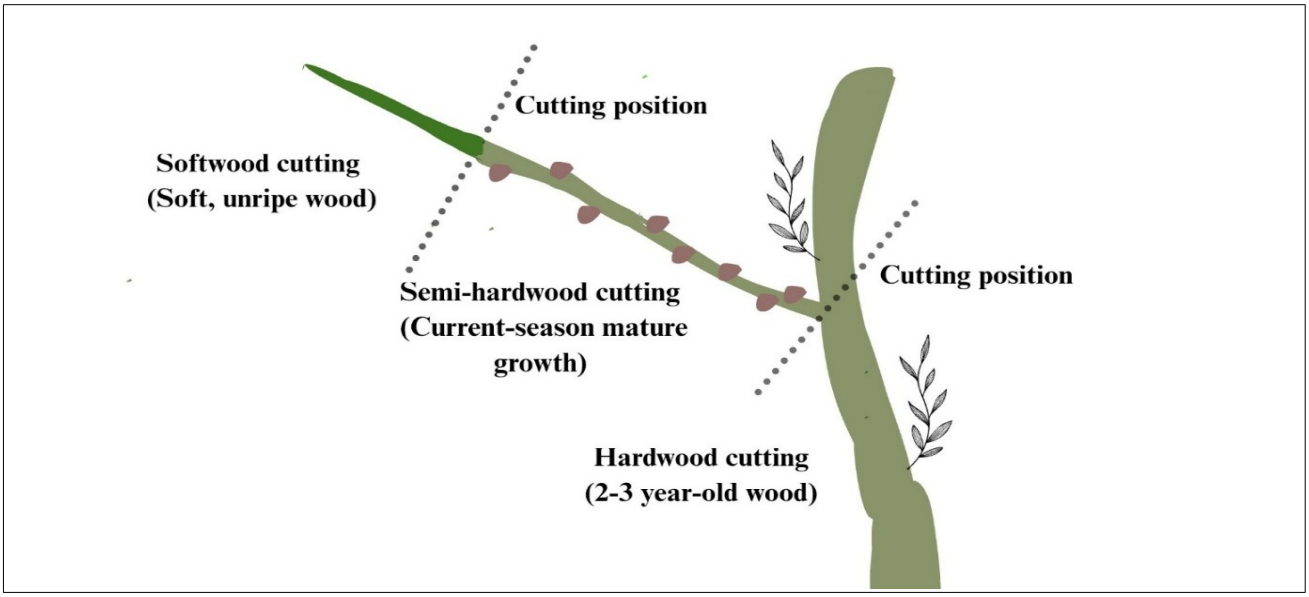


Fig. 2. Schematic representation of softwood, semi-hardwood and hardwood stem cuttings used for vegetative propagation of *Jasminum* spp.

Collectively, these studies show that semi-hardwood cuttings treated with indole-3-butyric acid (IBA) consistently outperform hardwood cuttings across commercially cultivated *Jasminum* spp. (23). *Jasminum sambac* semi hardwood cutting treated with IBA at 1500 mg L^{-1} resulted in 66.11 % success (24). Collectively, these studies show that semi-hardwood cuttings treated with Indole-3-butyric acid (IBA) consistently outperform hardwood cuttings across commercially cultivated *Jasminum* spp. (25). On the other hand, hardwood cuttings of *J. grandiflorum* treated with 1-naphthaleneacetic acid (NAA) at 4000 mg L^{-1} outperformed, with 84.33 % success. Similarly, wild jasmine species *Jasminum parkeri* (Dunn) Banfi performed better with 300 mg L^{-1} NAA treatment (26). While *Jasminum humile* (L.) Banfi performed better with a wider dose of NAA at 4500 mg L^{-1}, resulting in 73.33 % survival (27).

Mechanism

The cutting mechanism is a multi-stage physiological process, guided by both physiological stress and hormonal signalling. Adventitious root formation in stem cuttings is a multistage physiological process regulated by wound responses and hormonal signalling (28). *Jasminum* involves a coordinated sequence of wound-induced physiological factors leading to adventitious root formation. By excision, endogenous auxin accumulates at the basal end of the cutting, stimulating cell dedifferentiation and root primordia formation from the cambial and phloem parenchyma tissues. These primordia differentiate and form vascular connections with the parent stem, resulting in functional adventitious roots (29, 30). The rooting efficiency is influenced by the cutting physiology, carbohydrate reserves and auxin levels.

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Physiological and environmental determinants for rooting success

The success of adventitious root formation in *Jasminum* stem cuttings is influenced by a combination of physiological characteristics and environmental conditions. Node-bearing cuttings generally exhibit superior rooting performance because the nodal region contains actively dividing meristematic cells and higher endogenous auxin concentration, which promotes cell dedifferentiation and root primordium initiation (31). Temperature is another critical factor, with an optimal range of 18–24 °C providing enhanced metabolic activity, cell division and subsequent root development. However, the optimum temperature may vary depending on the species and growing conditions (32). High relative humidity is essential during the rooting phase, as it helps to minimise transpiration and prevents desiccation of unrooted cuttings, thereby improving survival. Moreover, low to moderate light intensity supports photosynthesis while reducing water loss and physiological stress, creating favourable conditions for adventitious root formation (33). Collectively, these physiological and environmental factors play a crucial role in maximising rooting efficiency and the successful establishment of *Jasminum* propagules (Table 2).

Layering

Layering is an alternative vegetative approach in which adventitious roots develop on stems while they remain attached to the mother plants. Among the different techniques, mound or stool layering is the most suitable for *Jasminum* due to its sturdy growth habit, whereas for the climbing type of jasmine, such as *Jasminum officinale* L. and *Jasminum polyanthum* Franch. tip layering is occasionally adopted (34, 35). Although layering ensures a high survival rate and a true-to-type plant, its commercial application is limited by the prolonged rooting period (1–18 months), low multiplication rate, labour-intensive work and seasonal dependence (36). Consequently, recent developments indicated that layering is primarily valuable for the propagation and conservation of elite *Jasminum* genotypes rather than for large-scale commercial multiplication (37).

Grafting

Grafting, which integrates the desirable traits of two distinct plants into a single system and has limited application in *Jasminum* propagation. It offers potential advantages where tolerance to external factors like soil-borne pathogens, salinity and other abiotic stresses is required. The use of vigorous rootstocks can improve plant adaptability, manipulate plant geometry, facilitate early flowering and support the propagation of elite cultivars under poor field conditions (38–40). Poor seed set in *Jasminum* spp. restricts the availability of suitable rootstocks and the high labour requirements and production costs also limit its commercial adoption. Overall, grafting remains a specialised technique with potential for stress management and germplasm improvement rather than routine large-scale propagation.

Limitations of conventional propagation

Conventional propagation methods like stem cuttings and layering remain the foundation of commercial *Jasminum* multiplication, but are constrained by low multiplication rates, clonal deterioration, disease transmission and species-specific rooting responses. These limitations restrict the rapid production of high-quality planting material. This is required for expanding cultivation and conserving elite germplasm. Consequently, micropropagation has emerged as a promising alternative for the rapid, year-round production of genetically uniform and disease-free plants under controlled conditions (41).

In vitro propagation and tissue culture

Micropropagation

Micropropagation has emerged as a powerful alternative to conventional propagation for rapid, large-scale multiplication of *Jasminum* spp. Micropropagation enables the production of genetically uniform, true-to-type, pathogen-tested planting material under controlled conditions, overcoming limitations associated with poor seed set and low multiplication rates (42, 43). In addition, micropropagation facilitates year-round plant production and plays a significant role in the conservation and genetic improvement of elite and endangered *Jasminum* (44, 45). The major stages involved in *Jasminum* micropropagation are illustrated in (Fig. 3).

Explant selection

Explant selection is a primary determinant of regeneration efficiency, multiplication rate and genetic fidelity during *in vitro* propagation of *Jasminum* (46). Various vegetative parts as explants, including nodal segments, shoot apices, stems, leaves, internodes, petals and axillary buds, have been evaluated across different species (41). Among these, nodal segments are widely used due to their high potential for regeneration and consistent shoot proliferation in species such as *Jasminum azoricum* L. and *Jasminum officinale* L. (47, 48). Fresh juvenile tissues exhibit superior morphogenic proficiency and multiplication efficiency compared with mature explants (49). Some unconventional explants, such as petals, leaf bits and stem segments, have also exhibited regeneration potential in *Jasminum malabaricum* Wight (50, 51).

Overall, current evidence identifies nodal explants as the most reliable source for rapid shoot multiplication across commercially important *Jasminum* spp. (50).

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Table 2. Comparative responses of selected *Jasminum* spp. to different cutting types and plant growth regulator treatments

Species	Cutting types	Growth regulator (mg L^{-1})	Survival (%)	References
Jasminum sambac	Semi hardwood	IBA 1000	88.60	(19)
	Hardwood	NAA 2000	84.75	(29)
	Semi hardwood	IBA 1500	88.33	(24)
	Semi hardwood	IBA 1500	66.11	(25)
Jasminum grandiflorum	Terminal	IBA 1000	48.15	(19)
	Hardwood	NAA 4000	84.33	(23)
Jasminum parkeri	Hardwood	NAA 300	96.67	(26)
Jasminum humile	Semi hardwood	NAA 4500	73.33	(27)
Jasminum multiflorum	Terminal	IBA 1000	72.23	(19)
	Hardwood	IBA 1500	14.00	
	Semi hardwood	IBA 500 + NAA 250	40.00	(45)
	Terminal cutting	IBA 500 + NAA 250	85.36	

IBA: indole–3–butyric acid; NAA: naphthaleneacetic acid.

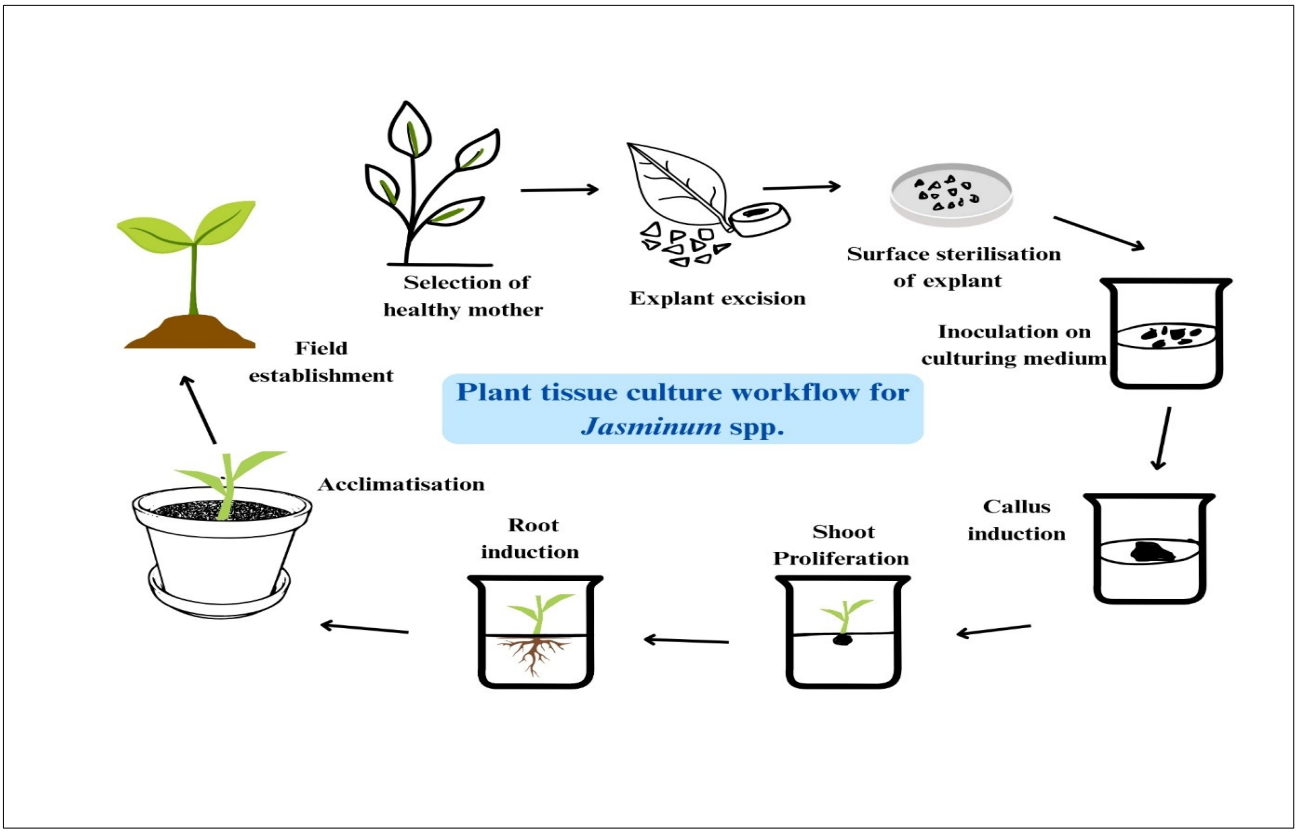


Fig. 3. Schematic workflow of *in vitro* micropropagation in *Jasminum* spp., showing explant selection, culture initiation, shoot multiplication, rooting, acclimatisation and field establishment.

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Culture media and sterilisation

The selection of basal medium and an effective sterilisation protocol are critical for successful *in vitro* propagation of *Jasminum*. Murashige and Skoog (MS) medium is the most adopted basal medium due to its consistent performance in shoot proliferation and callus induction, while Modified Murashige and Skoog medium (MMS), Woody Plant Medium (WPM), Gamborg's B5 medium (B5) and Driver and Kuniyuki Walnut (DKW) have been evaluated for species-specific responses (52). In *J. sambac,* WPM supplemented with α-naphthaleneacetic acid (NAA) and 6-benzyladenine (BA) promotes enhanced callus induction, whereas Murashige and Skoog (MS) medium supplemented with 2,4-dichlorophenoxyacetic acid (2,4-D) alone or in combination with indole-3-acetic acid (IAA) provides a superior callogenesis response in *J. grandiflorum* (53, 54). Hence, the basal medium requirements vary among the species. Murashige and Skoog-based media remain the preferred choice for *Jasminum* propagation.

Successful callus culture in jasmine depends on efficient surface sterilisation. The standard protocols involve the washing of selected explants with detergent and Tween-20, followed by treatment with sodium hypochlorite (NaOCl) and ethanol (55). Treatment with 1 % NaOCl for 10 min followed by 70 % ethanol effectively reduced microbial contamination in *J. Nudiflorum* (56). Similarly, young leaf explants provided the highest sterilisation efficiency 86.79 % when subjected to surface sterilisation with 10 % Clorox for 10 min followed by 10 % Clorox for 5 min, while the explants subsequently produced high callus induction on modified MS medium supplemented with kinetin (1 mg L^{-1}) and 2,4-D (0.1 mg L^{-1}) (57). Hence, the finding shows that sterilisation efficiency and culture response are influenced by both explant type and species, emphasising the need for protocol optimisation in *Jasminum* crops.

Organogenesis and hormonal regulation

Plant regeneration in *Jasminum* spp. is initiated by wound-induced dedifferentiation. The explant excision reprogrammes the differentiated cells into actively dividing meristematic tissues that are capable of organogenesis (58, 59). Callus induction is generally regulated by the interaction between auxins and cytokinins, with NAA and 2,4-D commonly used to induce callus, whereas BA and 6-benzylaminopurine (BAP) help to promote shoot proliferation and IBA is a preferred auxin for root induction (60, 61). Across published evidence, the regeneration efficiency varies among *Jasminum* spp., which indicates that the hormonal regulation is genotype dependent.

Species within the Oleaceae family are typically resistant to seed propagation and frequently exhibit genotype-dependent responses to *in vitro* culture conditions, especially concerning hormonal regulation. Auxins and cytokinins are the primary growth regulators governing callus induction, shoot proliferation and root formation, with NAA and 2,4-D commonly used for callus induction and IBA for rooting (60–62). 6-Benzyladenine is widely adopted due to its stability, low cost and effectiveness in promoting shoot development (63). Mannitol has also been reported to enhance shoot proliferation, uniformity and culture quality while reducing basal callus formation in Oleaceae cultures (64, 65). In *Jasminum* spp. plant regeneration is initiated by wound-induced dedifferentiation, where excised tissues are reprogrammed into meristematic cells capable of organogenesis (59, 60).

Rooting and acclimatisation

Rhizogenesis and acclimatisation are critical stages in *Jasminum* micropropagation as they influence plantlet survival and field establishment. Across published studies, IBA has been widely adopted for root induction in full- or half-strength MS medium due to its strong rooting response and better root quality (47, 56, 66, 67). Acclimatisation is achieved through transferring rooted plantlets from *in vitro* conditions to shaded *ex vitro* environments with high humidity, which supports functional root development and reduces plant shock (68). Survival rates of *in vitro Jasminum* plantlets reported in the literature range from 70 to 92 % depending on genotype, rooting protocol and acclimatisation conditions. Persistent constraints include microbial contamination, genotype-specific responses, weak root systems and acclimatisation losses. Therefore, optimisation of rooting media and stepwise acclimatisation is essential for reliable commercial-scale propagation of elite germplasm.

Germplasm conservation and breeding applications

Germplasm conservation

Conservation of *Jasminum* spp. germplasm is essential to prevent genetic erosion from habitat loss, climate change, urbanisation and overexploitation. However, the conservation and utilisation of *Jasminum* genetic resources are challenging due to several species exhibiting poor seed set, low seed viability and reproductive barriers. Field gene banks are the primary conservation strategy for maintaining elite cultivars, wild genotypes and genetically diverse accessions. In addition, *in vitro* conservation and micropropagation provide efficient complementary approaches for the rapid multiplication and maintenance of disease-free and genetically uniform planting material (69, 70). Approaches such as tissue culture also support the ex-situ conservation of rare and endangered species, reducing pressure on wild populations and aiding restoration efforts (71).

Breeding applications

Micropropagation accelerates breeding programmes by enabling rapid clonal multiplication of elite genotypes and preservation of superior hybrids with traits such as fragrance, flower yield, abiotic and biotic stress tolerance and disease resistance. These approaches maintain genetic fidelity and ensure continuous availability of uniform and quality planting material for cultivar development (72).

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Future biotechnological prospects

Somatic embryogenesis

Somatic embryogenesis is a promising regeneration pathway that can produce a complete plant from somatic cells under controlled *in vitro* conditions. In ornamental woody plants, somatic embryogenesis has the potential for rapid clonal multiplication, commercial-scale propagation and germplasm conservation (73, 74). However, the studies on somatic embryogenesis in *Jasminum* remain scarce and indicate the need for species-specific protocol development and validation (Table 3).

Synthetic seed

Synthetic seed is a substantial innovation that has emerged as a promising approach for the propagation, germplasm conservation and exchange of elite plant germplasm through artificial encapsulation of somatic embryos and other vegetative propagules. The technology facilitates efficient storage, handling, transportation and large-scale multiplication while preserving genetic fidelity (75, 76). In *Jasminum*, where conventional seed propagation is constrained by poor fertility, low seed set and limited hybrid seed production, the synthetic seed offers significant potential for germplasm conservation and breeding applications. However, *Jasminum*-specific research work on synthetic seed production remains limited and standardised encapsulation, regeneration and field establishment protocols are yet to be developed. Future investigations should focus on optimising synthetic seed technology to adopt its application in conservation and commercial propagation (77).

Molecular markers

Molecular characterisation has emerged as a biotechnological tool for genetic diversity analysis, germplasm conservation and precision breeding in *Jasminum* spp. Molecular markers such as simple sequence repeats (SSRs), inter-simple sequence repeats (ISSRs) and randomly amplified polymorphic DNA (RAPD) have been widely adopted to assess cultivar identification, genetic diversity, clonal fidelity and phylogenetic relationships (78). Among these, SSR markers are considered the most informative due to their codominant inheritance, high polymorphism, reproducibility and genome-wide distribution, making them valuable for marker-assisted selection and germplasm conservation (79). In contrast, ISSR and RAPD markers provide rapid and cost-effective approaches for preliminary diversity assessment (80, 81). Integrating molecular studies with morphological and biochemical evaluations will strengthen germplasm conservation, parental selection and cultivar development in the *Jasminum* crop. However, the availability of species-specific markers and genomic resources remains limited for the varied *Jasminum* spp., highlighting the need for marker development and genome-assisted breeding strategies.

Clustered regularly interspaced short palindromic repeats (CRISPR)/ CRISPR-associated protein (Cas) and genome editing

Genome editing technologies, particularly clustered regularly interspaced short palindromic repeats (CRISPR)/ CRISPR-associated protein (Cas) have transformed functional genomics and precision breeding by enabling targeted modification of genes controlling economically important traits (82–84). In ornamental crops, for example, *Chrysanthemum* × *morifolium* (Ramat.) Hemsl., *Dianthus caryophyllus* L., *Dendrobium officinale* Kimura & Migo, *Salvia* spp. and *Crocus sativus* L., it has been used to improve flower colour, fragrance, stress and disease tolerance (85). However, CRISPR/Cas applications in *Jasminum* remain largely underexplored and integrating CRISPR/Cas with robust *in vitro* and molecular markers may accelerate the development of elite *Jasminum* cultivars with improved traits.

Nanotechnology

Recent advances have identified nanotechnology as a promising tool for precision delivery of nutrients and growth regulator compounds in plants (86). Both metallic and non-metallic nanoparticles, including silver nanoparticles (AgNPs), iron nanoparticles (FeNPs), zinc nanoparticles (ZnNPs), selenium nanoparticles (SeNPs) and silicon nanoparticles (SiNPs) etc., have been reported to modulate plant physicochemical traits and physiological performance, as well as promote rooting, reduce microbial contamination and improve tolerance to abiotic stress (87). Green synthesis methods, such as producing silver nanoparticles with ornamental plant petal extract, have broadened the applications of nanoparticles in antioxidant improvement and biomedical studies (88). For *Jasminum*, such approaches may help improve efficiency and support conservation, but experimental validation remains limited. At present, the use of nanotechnology on regeneration response, genetic stability and field performance in *Jasminum* is still limited, indicating the need for species-specific evaluation. The future biotechnological strategies are presented in (Fig. 4).

Research gaps and future perspectives

Despite progress in propagation and *in vitro* culture, *Jasminum* crop still face major bottlenecks in efficient multiplication and genetic improvement.

The species-specific differences in rooting, regeneration and plant growth regulator responses hinder the development of universal protocols. While poor seed set, low hybridisation success and reproductive barriers continue to limit the breeding process, conventional strategies are labour-intensive and inefficient for large- or commercial-scale production, whereas micropropagation is still challenged by contamination, genotype dependence and acclimatisation losses.

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https://doi.org/10.14719/pst.16462

Table 3. *In vitro* propagation protocols for selected *Jasminum* spp. using different explants and growth regulator combinations

Species	Explant	Cytokinin (mg L^{-1})	Auxin (mg L^{-1})	Rooting (%)	Survival (%)	Reference
Jasminum azoricum	Nodal	BA 4.0 + Kin 2.0	IBA 1.0	70.00	85	(48)
Jasminum sambac	Nodal	BA 1.0	½ MS + IBA 0.5	80.00	85	(66)
Jasminum grandiflorum	Nodal	BAP 1.0	IBA 1.5	60.00	75	(67)
	Nodal	KN 1.0	IBA 1.5	45.00	70	(67)
Jasminum nudiflorum	Nodal	BAP 3.0 + KN 0.5	IBA 2.0	63.93	89.67	(56)
Jasminum officinale	Nodal	BAP 4.0 + KN 2.0	IBA 0.1	94.00	92	(46)

BA: 6-benzyladenine; BAP: 6-benzylaminopurine; KN: kinetin; IBA: indole-3-butyric acid; MS: Murashige and Skoog medium.

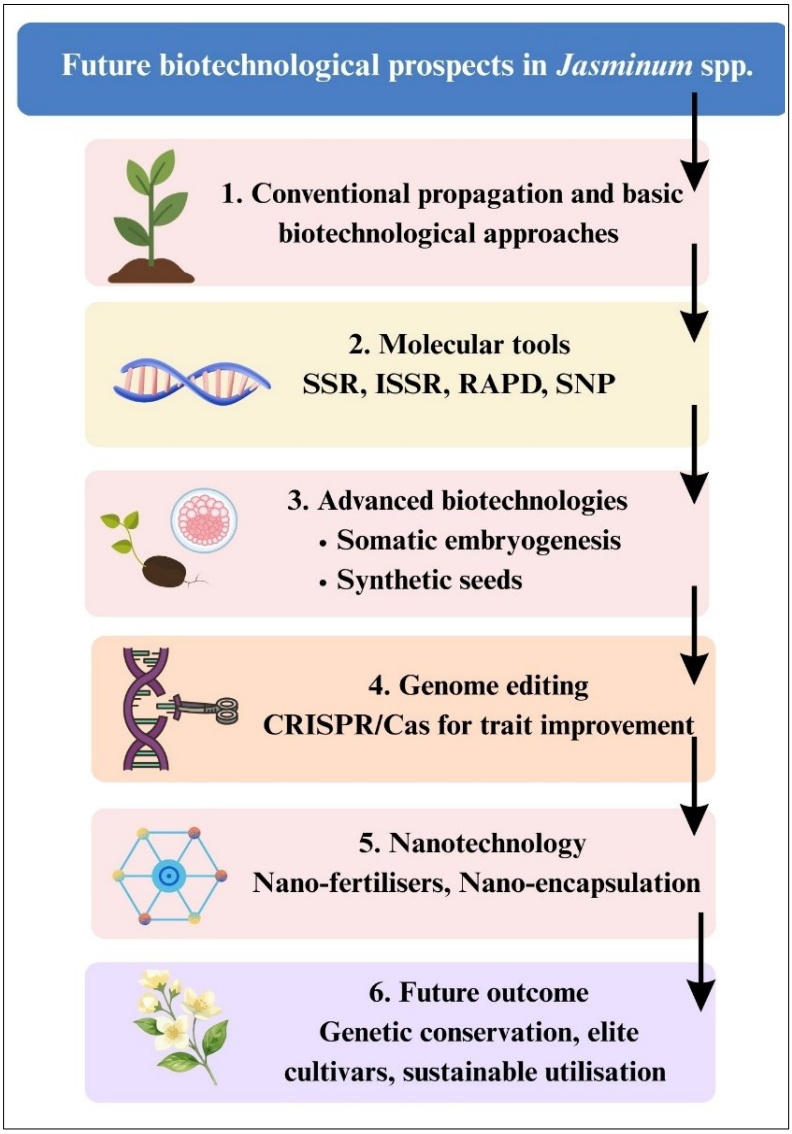


Fig. 4. Emerging future biotechnological roadmap for the genetic improvement, conservation and sustainable utilisation of *Jasminum* spp.

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Critical gaps persist in biotechnological approaches, such as somatic embryogenesis, synthetic seed, genome editing and nanotech-based propagation. In addition, limited genomic resources, poor characterisation of germplasm and the lack of standardised transformation systems have slowed biotechnological advancement in *Jasminum* spp.

Conclusion

Jasminum is an economically important ornamental and aromatic crop with considerable demand and value in floriculture and perfumery industries. However, large-scale multiplication still relies mainly on conventional propagation approaches, particularly stem cuttings, while poor seed set, reproductive barriers, low multiplication rates and clonal deterioration remain major constraints to the conservation and improvement of *Jasminum* germplasm. The evidence synthesised in this review shows that semi-hardwood cuttings treated with an appropriate concentration of indole-3-butyric acid (IBA) remain the most effective and commercially feasible method for propagation, whereas *in vitro* propagation using nodal explants on Murashige and Skoog (MS) medium supplemented with suitable plant growth regulators offers an efficient alternative for rapid multiplication and conservation of elite germplasm. Although advances in tissue culture, somatic embryogenesis, molecular biotechnology, genome editing and nanotechnology provide promising opportunities for genetic improvement and conservation, their application in *Jasminum* remains limited and requires further validation. Future research should focus on developing standardised propagation protocols and integrating conventional propagation with advanced biotechnological tools to achieve sustainable conservation and commercial improvement of *Jasminum* germplasm.

Acknowledgements

The authors would like to extend their sincere gratitude to the Department of Floriculture and Landscaping, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore, for providing academic support during the preparation of this review.

Authors' contributions

AK designed the illustrations, performed the literature review and prepared the manuscript. SPT verified the data, developed the structure of the paper and supervised the writing. MG revised the manuscript and provided suggestions to improve the assessment. SG and KG assisted in outlining the illustrations and table and supported in writing. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly solely for grammar checking and language editing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Additional information

Peer review: Publisher thanks the Sectional Editor and anonymous reviewers for their contribution to the peer review of this work.

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https://doi.org/10.14719/pst.16462