



Propagation Techniques and Nursery Management of *Cassia fistula*: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Cassia fistula L. (Amaltaas) is a valued ornamental and medicinal tree species, but its large-scale propagation is often limited by physical seed dormancy caused by a hard, impermeable seed coat. This review summarises the available information on propagation techniques and nursery management practices that can support improved germination, seedling vigour and nursery survival. The major seed-based approaches include mechanical scarification, hot-water treatment, acid scarification and plant growth regulator application, particularly gibberellic acid. These treatments are discussed in relation to dormancy release, germination improvement and practical nursery use. The review also considers vegetative propagation through stem cuttings, grafting, air layering and tissue culture, which may be useful when true-to-type multiplication of selected superior plants is required. Nursery management practices, including suitable media, bed preparation, sowing depth, irrigation, weeding, sanitation and integrated pest and disease management, are also important for producing healthy planting material. The literature indicates that no single method is universally applicable, as treatment response may vary with seed source, maturity, storage condition,

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treatment duration and nursery environment. Standardised nursery protocols are therefore needed to connect dormancy-breaking treatments with seedling quality and field establishment. Therefore, propagation success in *Cassia fistula* depends on combining appropriate pre-sowing treatments with locally suitable nursery management practices.

Keywords: *Cassia fistula*; seed dormancy; pre-sowing treatment; mechanical scarification; acid scarification; gibberellic acid; hot-water treatment; vegetative propagation; nursery management; seedling vigour.

1. Introduction

Amaltaas (*Cassia fistula* L.), commonly known as the golden shower tree or Indian laburnum, belongs to the Leguminosae family and is rich in flavonoids and bioflavonoids, which are recognised for their antioxidant and anti-inflammatory properties (Gilman & Watson, 1993). *Cassia fistula* is a highly attractive ornamental plant and a medium-sized, multipurpose deciduous tree species capable of growing in poor, shallow soils as well as in relatively fertile soils. Commonly known as the Golden Shower tree, it is characterised by dense clusters of conspicuous yellow flowers that cover its slightly drooping branches (Ali, 2014). These flowers are followed by dark-brown cylindrical pods, approximately two feet in length, which remain persistent on the tree (Gilman & Watson, 1993). *Cassia fistula* is a medium-sized deciduous tree that may attain a height of about 10 m, with a straight trunk reaching up to 5 m in length and 1 m in diameter, along with spreading branches. The stem bark is pale grey, smooth and slender in young plants, but becomes dark brown and rough with age (Dadhaniya et al., 2020). The leaves are alternate and pinnate, measuring 30-40 cm in length, with 4-8 pairs of ovate leaflets that are 7.5-15 cm long and 2-5 cm broad, with entire margins and petiolules measuring 2-6 mm.

Seed-treatment chemicals have also been reported to improve germination percentage, seedling vigour and root development. Proper application of seed treatment is essential to avoid under-treatment, which may reduce protection, as well as over-treatment, which may result in unnecessary expenditure and adversely affect seed health (Bargah et al., 2025). Treating seeds with essential nutrients offers several benefits, the foremost being improved plant germination (Rout et al., 2017).

Seed dormancy in *C. fistula* is mainly due to an impermeable seed coat that restricts water and gas exchange, thereby making propagation difficult (Al-Menaie et al., 2010). Overcoming this dormancy through pre-sowing techniques is important for ensuring successful and uniform seedling growth (Bargah et al., 2024). Plant propagation involves the multiplication of plants through sexual (seed) and asexual (vegetative) methods. Sexual propagation promotes genetic diversity and adaptability, whereas vegetative propagation maintains the true-to-type characteristics of elite cultivars (George et al., 2008; Bargah et al., 2024). Micropropagation has been established for rapid plant multiplication, while shoot-tip culture is used to produce parasite-free nuclear stock, particularly material free from viral infections. In addition, techniques such as anther and pollen culture have been applied to accelerate the development of improved varieties, whereas protoplast culture is used for the production of hybrid plants (Bhardwaj et al., 2024). Recent evidence indicates that seed dormancy in *Cassia* is restricted to physical dormancy associated with a water-impermeable seed coat; in *C. fistula*, the seed-coat lens functions as the principal water-entry structure during dormancy release (Rodrigues-Junior et al., 2020; Wen et al., 2024). Because physical dormancy responses may vary with environmental and management factors, review-based recommendations should be interpreted in relation to local nursery conditions (Harrison et al., 2025). Recent nursery studies on tree species further show that growing media can influence germination, seedling vigour and early seedling quality, supporting the need to consider nursery conditions alongside pre-sowing treatments (Gamit et al., 2024).

2. Literature Search Methodology

The literature for this review was collected primarily through Google Scholar using keywords such as *Cassia fistula*, seed germination, seed dormancy, pre-sowing treatments, nursery management, vegetative propagation and tissue culture. Peer-reviewed research articles, review papers, books and technical reports published in English were selected based on their relevance to the topic. The collected literature was critically examined and synthesised to prepare the present review.

Table 1. Taxonomic classification of *Cassia fistula* L.

Taxonomic Rank	Classification
Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Fabales
Family	Fabaceae
Genus	<i>Cassia</i>
Species	<i>Cassia fistula</i> L.

3. Distribution of *Cassia fistula*

Cassia fistula L. is popularly known as Amaltas or the Golden Shower tree. It is an important medicinal and ornamental tree species belonging to the Fabaceae family. The plant is considered native to the Indian subcontinent and Sri Lanka, but it is widely distributed in many tropical and subtropical regions of the world (Rajwade et al., 2025). Because of its attractive yellow flowers, medicinal value and adaptability to diverse climatic conditions, *C. fistula* has been introduced and cultivated in countries such as China, Thailand, Mauritius, South Africa, East Africa, Brazil, Mexico and the West Indies (Darro et al., 2022). It naturally grows in tropical regions characterised by warm to hot climates and moderate rainfall (Rout et al., 2017). This tree can also be found in dry deciduous forests, open woodlands, roadsides, gardens, parks and agroforestry systems. *Cassia fistula* grows well in well-drained soils and shows tolerance to dry conditions (Vishnoi et al., 2017). *C. fistula* requires adequate light and warmth for proper growth and flowering. The tree has adapted to different tropical zones outside its original habitat and is used as a street tree in various countries because of its ornamental value and ecological importance (Dofuor et al., 2023; Lamichhane et al., 2016; Bargah et al., 2025).

Cassia fistula L. is very common in India and is widely distributed in the tropical and subtropical parts of the country. It is commonly observed in forests, rural areas, parks, gardens, roadsides and other habitats. *C. fistula* grows in dry deciduous forests and mixed forests in various parts of the country (Soliman & Abbas, 2013). *Cassia fistula* is also abundant in several states, including Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Telangana, Odisha, West Bengal, Bihar, Chhattisgarh and Assam (Danish et al., 2011). It is widely cultivated in public gardens, institutional compounds and residential landscapes, mainly because of its ornamental and medicinal value (Khanna & Arora, 1984).

C. fistula thrives in high temperatures and wet weather and can also survive during dry periods. In southern India, particularly in Kerala, the species has cultural and religious significance and is known as Kanikonna (Duraipandiyar & Ignacimuthu, 2007). Traditionally, it is associated with the Vishu Festival and is designated as the state flower of Kerala. In central and northern India, the tree is widely planted along highways, parks, railways and urban roads as an avenue tree (Al-Menaie et al., 2010). This use is mainly due to its attractive yellow hanging flowers and its ability to grow in diverse environments (Lamichhane et al., 2016; Rungjindamai et al., 2016).

3.1 Research Gap

Although this review discusses several reports on seed and vegetative propagation of *Cassia fistula*, the information remains dispersed across dormancy-breaking treatments, vegetative methods and nursery management practices. A consolidated account is therefore required to relate these components to practical nursery production and seedling establishment.

3.2 Objective

The objective of this review is to summarise propagation techniques and nursery management practices for *Cassia fistula*, with emphasis on pre-sowing treatments, vegetative propagation, tissue culture and seedling management under nursery conditions.

4. Propagation Techniques of *Cassia fistula*

4.1 Propagation by Seed

Seed propagation is the primary method of sexual reproduction in higher plants and underpins natural regeneration, crop production and plant breeding (Hartmann & Kester, 1983). Successful seed propagation depends on seed physiological status, dormancy characteristics and the ability of the embryo to germinate under favourable environmental conditions. The seed-treatment methods used to improve germination are discussed below.

Mechanical scarification: Mechanical scarification effectively overcomes hard-seed-coat dormancy in leguminous species such as *Cassia fistula* by making the impermeable testa more permeable to water, thereby initiating germination with minimal tissue damage compared with some chemical or thermal treatments (Bajaniya et al., 2018; Navrang et al., 2026). In *C. fistula*, mechanical scarification has been reported to increase seed germination from 20% to 80%, performing slightly below sulphuric acid treatment for 15-20 min. Although advanced techniques such as TiO₂ nanoparticle electrospaying have enhanced germination in species such as lettuce (Feizi & Mousavi, 2016), their efficacy in hard-seeded species remains insufficiently documented, and the requirement for specialised technical apparatus limits their practical utility (Kumar et al., 2024a).

Hot-water treatment: *Cassia fistula* seeds possess a hard and impermeable seed coat that causes physical dormancy (Kumar et al., 2023). Hot-water scarification is commonly employed to overcome seed dormancy and enhance germination. Treatment with boiling water for 10, 15, 20 or 30 min has been used to assess the effects of different scarification durations on subsequent seedling development and vigour (Soliman & Abbas, 2013). Seed-immersion treatments have also been reported to produce seedlings with high vigour (Yones & Basher, 2025; Singh et al., 2026). Similarly, Al-Menaie et al. (2010) observed that scarification of *C. fistula* seeds with H₂SO₄, followed by immersion in hot water at 50°C, resulted in a higher germination percentage (Kumar et al., 2022a).

Acid scarification: Sulphuric acid (H₂SO₄) has been successfully used for the scarification of impermeable seeds. Therefore, experiments have aimed to determine the effects of different concentrations of GA₃ and H₂SO₄ scarification on the germinability of cassia seeds obtained from India (Dewangan & Ramchandra, 2018). Acid scarification followed by hot-water treatment can improve seed germination. Seeds treated with H₂SO₄ for 2 min followed by hot water at 100°C for 6 min showed the highest germination (92-96%), whereas control and low-temperature treatments produced the lowest values (Rajwade et al., 2025; Yadu et al., 2026). Overall, higher water temperature after acid treatment significantly improved germination in *Cassia fistula* (Ahmad & Khattak, 1980).

Growth regulator treatment: Current studies indicate a significant effect of different GA₃ concentrations on the germination and seedling growth of *Cassia fistula* seeds (Mandwa et al., 2024). Germination rates increased with increasing concentrations and then declined (Rout et al., 2017). Chemical scarification has also been associated with increased germination in hard-coated seeds (Kumar et al., 2022a). Gibberellic acid (GA₃) can act as a substitute for light and temperature and promote germination in several plants by overcoming seed dormancy (Rout et al., 2016). Gibberellic acid solutions may help break seed dormancy, shorten germination time and increase germination percentage (Limanpure & Kumar, 2018).

4.2 Propagation by Vegetative Parts

Vegetative propagation maintains the true-to-type characteristics of elite cultivars. The choice of method depends on species biology, production goals and resource availability (Hartmann & Kester, 1983). Vegetative propagation of herbaceous plants can be carried out relatively easily, as many species produce bulbs, rhizomes, corms, tubers, offsets, suckers and stolons, which serve as natural vegetative propagating structures (Mohale et al., 2025). However, vegetative propagation in tree species is more difficult and is commonly achieved through the application of hormones, particularly in stem cuttings, which subsequently induce the formation of adventitious roots and shoots (Hartmann & Kester, 1983).

Cuttings: Semi-hardwood cuttings may be taken in summer, while hardwood cuttings may be taken in winter. Sections of a plant stem, root or leaf are cut and then placed in a suitable microenvironment or culture medium to support development (Khanna & Arora, 1984). In most cases, the new independent plants are genetically identical to the parent plant, providing sufficient starting material for producing marketable or finished plants (Tirkey et al., 2026). This method is useful to breeders because it is a convenient and inexpensive way to increase plant numbers (Netam et al., 2025).

Grafting: Grafting is widely used for fruit trees, ornamental cultivars and species that are difficult to root from cuttings. Common techniques include whip-and-tongue grafting, cleft grafting and bud grafting onto compatible rootstocks (Sarun, 2026c). Grafting is used to combine superior scions with resilient rootstocks, especially in agroforestry trees (Verma et al., 2026). It allows early fruiting and improved tolerance to soil and climatic stresses (Shukla et al., 2025a).

Air layering: Air layering is useful for species that are difficult to root from cuttings. It involves removing the bark from the middle portion of a branch and then covering the exposed area with moss and plastic wrapping (Shukla et al., 2025b). Roots form within the moss, and the rooted portion can then be cut and separated from the plant. For optimal root development, air layering is best carried out in spring on branches produced during the previous season or in mid- to late summer on branches produced during the current season (Pandey et al., 2018).

Tissue culture: In recent years, tissue culture has been used to study and cultivate the physiological behaviour of isolated plant organs, tissues, cells, protoplasts and even organelles (Singh et al., 2022). Tissue culture can be divided into three broad categories. The most common approach is to isolate organised meristems, such as shoot tips or axillary buds, and induce them to develop into complete plants (Faisal et al., 2006). This method of propagation is commonly called micropropagation. Adventitious shoots are produced on leaf, root and stem segments or on calluses derived from these organs (Parveen & Shahzad, 2012). The third method of propagation involves inducing somatic embryogenesis in cell and callus cultures (George et al., 2008). This commercial technique is primarily based on micropropagation, in which rapid propagation is achieved from small stem cuttings, axillary buds and, to a limited extent, somatic embryos in suspension cultures and bioreactors (Soni et al., 2025).

4.3 Nursery Management of *Cassia fistula*

Nursery management refers to the organised production and care of seedlings or vegetatively propagated plants under controlled conditions until they are suitable for transplanting into the field (George et al., 2008). Well-managed nurseries ensure the supply of high-quality planting material, which is essential for crop productivity (Tekam et al., 2025).

A nursery is a specialised area where seedlings or vegetatively propagated plants are raised under controlled conditions until they are ready for field planting (Singh et al., 2003).

Effective nursery management integrates environmental control, sanitation, nutrition and skilled labour to ensure high survival and vigorous growth (Tiwari et al., 2024).

Bed preparation: *Cassia fistula* exhibited better growth in a soil mixture with a ratio of 2:1:1. Soil texture is an important modifying factor that influences the proportion of precipitation entering the soil and becoming available to plants (Kumar & Ramchandra, 2018). Clay soils retain the greatest amount of moisture per unit volume and support tree growth by providing sustained moisture, whereas sandy soils retain less moisture per unit volume but allow more rapid percolation of precipitation water than clay soils (George et al., 2008). The polythene bags were punctured to improve drainage and filled with media prepared by mixing one part soil, one part well-rotted FYM and one part sand (Singh et al., 2003). The polythene bags were placed in flat beds at proper spacing (Chandra et al., 2024).

Sowing method: The seeds were sown in April according to their sowing period. The prepared pots were manually seeded with pre-treated *C. fistula* seeds (Singh et al., 2003). One seed was inserted at a depth of 1-1.5 cm in the centre of each cell, and the same medium was then gently placed over it (Sinha et al., 2026). The trays

were kept in a partially shaded nursery environment to protect them from direct sunlight and intense rain (Vaishnav et al., 2025).

Irrigation: Watering was carried out as required. Optimum moisture in the germination medium was maintained during seed germination and growth. Efficient irrigation systems, such as overhead sprinklers and misting, ensure a uniform moisture supply without waterlogging (Vishnoi et al., 2017).

Weeding: Weeds were completely removed along with their roots as soon as they appeared, and the polybags were kept clean by uprooting weeds at regular intervals (George et al., 2008).

Pest and disease management: *Cassia fistula*, like most trees, is generally resilient when grown under appropriate conditions. Most disease problems arise from environmental stress, poor planting or mechanical damage (Dofuor et al., 2023). Integrated pest management is a sustainable strategy for managing pests and diseases in nurseries and reducing the environmental impact of pesticides (Verma et al., 2025). IPM uses a range of cultural, biological, physical and chemical methods to reduce pest populations and minimise the development of resistance. Nursery practices include planting disease-resistant varieties, maintaining proper plant spacing to improve air circulation and regularly removing diseased plant debris (Jayalekshmi et al., 2026). These practices can reduce the risk of fungal diseases such as powdery mildew and Botrytis blight (Mishra et al., 2026). Switching from overhead irrigation to drip irrigation is an effective strategy for preventing excessive moisture on leaves, which is a major cause of fungal outbreaks (Lamichhane et al., 2016). Proper crop rotation and soil disinfection are also widely adopted practices to reduce the accumulation of soil-borne pathogens (Table 2).

Table 2. Nursery diseases and pest management

Disease / Pest	Symptoms	Causal Organism / Pest	Management Practices	Citation
Leaf Spot	Cercospora spp., Colletotrichum spp.	Brown and black circular spots on leaves, premature leaf fall.	Remove infected leaves, maintain field sanitation, spray Copper oxychloride (0.3%) or Mancozeb (0.25%).	(Dofuor et al., 2023)
Powdery Mildew	Oidium spp.	White powdery growth on leaf surface curling and drying of leaves.	Spray wettable sulfur (0.2%), improve air circulation, avoid overcrowding.	(Borkar et al., 2022)
Root Rot	Fusarium spp., Rhizoctonia solani	Yellowing, wilting, root decay.	Use well-drained soil, apply Trichoderma viride, avoid excess irrigation.	(Rungjindamai, 2016)
Anthracnose	Colletotrichum gloeosporioides	Dark sunken lesions in leaves and twigs.	Prune infected twigs, use Carbendazim (0.1%) spray.	(Rungjindamai, 2016; Dofuor et al., 2023)
Dieback Disease	Fungal pathogens	Drying branches from tip downward.	Pruning of infected branches, Bordeaux mixture spray.	(Dofuor et al., 2023)
Aphids	Aphis spp.	Sap sucking, curling and yellowing of leaves.	Neem oil spray (5 ml/L), release ladybird beetles, Imidacloprid in severe cases.	(Lamichhane et al., 2016)
Whiteflies	Bemisia tabaci	Yellowing, honeydew secretion, sooty mold.	Yellow sticky traps, neem extract spray, proper field sanitation.	(Lamichhane et al., 2016)
Mealybugs	Planococcus spp.	Cottony masses on stems and leaves, stunted growth.	Prune affected parts, soap solution spray, biological control agents.	(Mani & Shivaraju, 2016)
Caterpillars and Defoliators	Various lepidopteran larvae	Feeding holes and defoliation.	Hand collection, light traps, spray Bacillus thuringiensis (Bt).	(Jayalekshmi et al., 2026)
Bark Eating Caterpillar	Indarbelaquadri notata	Holes with frass on stem and bark damage.	Insert cotton soaked in kerosene/chlorpyrifos into holes and seal with mud.	(Kumari et al., 2025; Kumari et al., 2025)
Termites	Odontotermes spp.	Root and stem damage, drying of seedlings.	Soil drenching with chlorpyrifos, field sanitation, organic manure application.	(Josephraj Kumar, 2016)

4.4 Critical Analysis of Literature

The available literature indicates that several pre-sowing treatments, including mechanical scarification, hot-water treatment, acid scarification and gibberellic acid (GA₃) application, effectively improve seed germination in *Cassia fistula*. However, the reported germination percentages and treatment efficiencies vary considerably among studies because of differences in seed source, seed maturity, treatment duration, environmental conditions and nursery practices. Although sulphuric acid scarification generally produces high germination rates, its practical application in forest nurseries is limited by safety and handling concerns. Likewise, vegetative propagation techniques and tissue culture have shown potential for true-to-type multiplication, but standardised and cost-effective protocols for large-scale commercial production are still lacking. Overall, the existing evidence highlights the need for region-specific and standardised propagation and nursery management practices to improve seedling quality, field establishment and large-scale cultivation of *Cassia fistula*.

5. Conclusions

Cassia fistula is an important ornamental and medicinal tree species with potential for avenue planting, landscape development, agroforestry and conservation. Its propagation is mainly carried out through seeds, but germination is restricted by hard seed-coat dormancy. Pre-sowing treatments such as mechanical scarification, hot-water treatment, acid scarification and gibberellic acid application can improve germination and seedling uniformity. These treatments should be selected according to nursery facilities, safety requirements, material availability and expected production scale. Vegetative propagation methods, such as stem cuttings, grafting, air layering and tissue culture, may be useful where true-to-type multiplication of selected plants is required. However, these methods require better species-specific standardisation before large-scale use. Effective nursery management is equally important for producing vigorous and healthy seedlings. Suitable potting media, proper sowing depth, regulated irrigation, regular weeding, sanitation and integrated pest and disease management contribute to better seedling growth and survival. The review indicates that combining scientifically tested pre-sowing treatments with good nursery practices can improve the propagation success of *C. fistula*. Future work should focus on standardised protocols, comparative germination studies, vegetative propagation success rates and the field performance of nursery-raised seedlings.

6. Limitations

This review is limited by its narrative design and does not apply a formal systematic search, screening or quality-assessment protocol. Some information on propagation and nursery management is general and may not be fully specific to *Cassia fistula*. Reported responses may vary with seed source, maturity, storage, treatment duration, nursery medium and local environment. Vegetative propagation and tissue-culture methods require more species-specific validation before broad recommendation.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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