

Dalbergia sissoo (Shisham) is a fast-growing, multipurpose leguminous tree species highly valued for its durable timber, nitrogen-fixing capacity, and significant role in agroforestry, social forestry, and reforestation programs across the Indian subcontinent. It contributes substantially to rural livelihoods, soil improvement, and ecological restoration. However, in recent years, widespread mortality of *D. sissoo* plantations has been reported from several regions, posing a serious threat to productivity, biodiversity, and ecosystem stability.

One of the principal causes of this large-scale decline is root rot disease incited by *Ganoderma lucidum* and related *Ganoderma* species. These soil-borne basidiomycetous fungi infect the root system and basal stem tissues, causing progressive wood decay and impairment of vascular function.

The pathogen disrupts water and nutrient transport, leading to gradual weakening and eventual death of affected trees. Characteristic symptoms include yellowing of foliage (chlorosis), wilting, dieback of branches, reduced growth, and the appearance of hard, bracket-shaped fruiting bodies near the collar or root zone as an indication of advanced infection.



Figure 1: Fruiting body (conk) of *Ganoderma* spp. emerging from the basal stem region of an infected tree. The hard, bracket-shaped structure with concentric brown zones and a white margin indicates advanced root rot infection and internal wood decay.

Disease Cycle of *Ganoderma lucidum*

- * *G. lucidum* is a soil-borne, wood-decaying basidiomycete fungus responsible for root and basal stem rot in several forest and agroforestry tree species, including *D. sissoo*. The disease cycle is perennial and slow-progressing, allowing the pathogen to persist for many years in plantations and forest soils.
- * The disease cycle begins with the production of basidiospores from mature fruiting bodies (conks) that develop on infected trees, usually at the collar region or exposed roots. These spores are released in large numbers and disseminated by wind, rain splash, insects, and mechanical means. When basidiospores land on susceptible hosts, they germinate under favorable conditions such as high soil moisture, warm temperatures, and the presence of wounds or stressed tissues.
- * Primary infection commonly occurs through roots, especially fine feeder roots or injured root tissues. The fungus may also enter through cut stumps, pruning wounds, or cracks near the basal stem. After penetration, *G. lucidum* establishes itself in the root cortex

and gradually invades the woody tissues, producing extensive mycelial networks. The fungus secretes ligninolytic and cellulolytic enzymes that degrade lignin and cellulose, resulting in white rot of the wood.

- * As the infection progresses, the pathogen spreads upward from the roots to the collar region and lower stem, disrupting water and nutrient

transport. Externally, infected trees show symptoms such as reduced vigor, yellowing of leaves, wilting, dieback, and eventual death. Internally, roots and basal stem tissues become spongy, fibrous, and structurally weak.

- * The fungus survives in the soil for long periods as mycelium in infected root debris and stumps, serving as a continuous source of inoculum. Under suitable environmental conditions, the fungus produces new fruiting bodies on dead or dying trees, completing the disease cycle by releasing fresh basidiospores. This ability to persist in soil and woody residues makes *G. lucidum* particularly difficult to manage and highlights the importance of integrated disease management strategies.

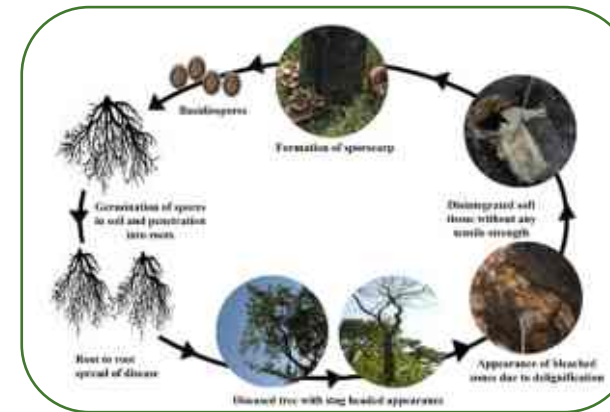


Figure 2. The disease cycle of *Ganoderma lucidum* on *Dalbergia sissoo* begins with the release of basidiospores from fruiting bodies, which infect the roots through wounds or natural openings. The fungus spreads internally, causing white root rot, disrupting vascular function, and leading to wilting, dieback, and eventual tree death. Its further spreads through root contact and persists in soil or woody debris, continuing the infection cycle.

About Trichoderma

Trichoderma is a cosmopolitan genus of soil-borne filamentous fungi, widely distributed in diverse habitats such as forest soils, agricultural fields, rhizospheres, decaying wood, and compost. Belonging to the family Hypocreaceae, *Trichoderma* species are among the most studied fungal groups due to their ecological versatility and biotechnological importance. They exhibit rapid growth, high adaptability, and strong antagonistic potential against several plant pathogens, including soil-borne fungi like *Fusarium*, *Rhizoctonia*, *Pythium*, and *Ganoderma*.

Mechanisms of Antagonism: *Trichoderma* species employ multiple strategies to suppress pathogens:

1. **Mycoparasitism**– Directly attacks and parasitizes other fungi by coiling around their hyphae, secreting **cell wall-degrading enzymes** like chitinases, glucanases, and proteases.
2. **Antibiosis**– Produces **secondary metabolites** (e.g., peptaibols,

polyketides, and volatile organic compounds) that inhibit pathogen growth.

3. **Competition**– Competes for **nutrients and space**, often outgrowing pathogenic fungi.

4. **Induced Systemic Resistance (ISR)**– *Trichoderma* can stimulate plant defense responses, enhancing resistance to pathogens.

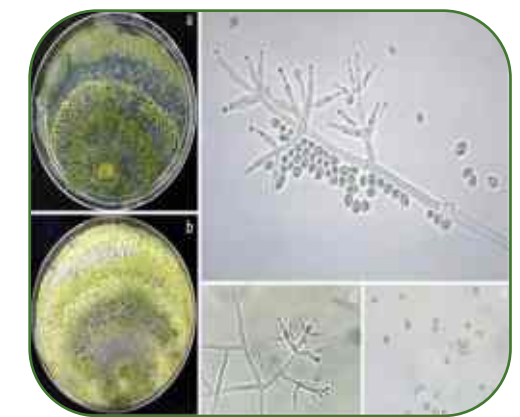


Figure 3. Morphological characteristics of *Trichoderma harzianum* isolates. (a–b) Colony morphology on PDA medium showing characteristic green sporulation. (c) Conidiophore branching with phialides bearing conidia. (d) Enlarged view of conidiophore with verticillate phialides. (e) Smooth-walled, globose to subglobose conidia as observed under light microscopy.

Biological Management of *Ganoderma* Root Rot

Biological management offers a sustainable and eco-friendly approach for suppressing *Ganoderma* root rot in *D. sissoo* plantations. Among the effective biocontrol agents, *T. harzianum* has shown promising results due to its antagonistic activity against soil-borne fungal pathogens. *Trichoderma* acts through multiple mechanisms such as mycoparasitism, competition for nutrients and space, production of antifungal metabolites, and stimulation of plant defense responses. Regular application helps maintain a healthy microbial balance in the rhizosphere and reduces pathogen proliferation.

Dosage and Preparation: Mix 10–15 grams of *T. harzianum* formulation (with viable spore count as per recommended standard) in 5 liters of clean water. Stir thoroughly to prepare a uniform suspension. The solution should be freshly prepared before application to ensure maximum viability of spores.

Method of Application: Create a shallow circular ring or furrow around the base of each tree, approximately 15–20 cm away from the collar region, depending on plant age. Apply the prepared *Trichoderma* suspension uniformly in the ring near the root zone, ensuring adequate soil moisture for effective colonization. Light irrigation after application may be given to facilitate movement of the biocontrol agent into the root zone. In nursery conditions, the solution can be applied as a soil drench in polybags or seed beds.

Timing of Application: Application should preferably be done during the early morning or late evening hours to avoid direct sunlight, which may reduce spore viability. Treatments are most effective when applied at the onset of the disease or as a preventive measure during plantation establishment. For better protection, repeat application at 30–45 day intervals, especially during the rainy season when disease incidence is high.

Additional Recommendations:

- ◇ Remove and destroy severely infected trees and root debris before application.
- ◇ Avoid mixing *Trichoderma* with chemical fungicides during application, as this may reduce its effectiveness.
- ◇ Maintain proper drainage and avoid water stagnation to reduce favorable conditions for *Ganoderma*.
- ◇ Regular and timely application of *T. harzianum* as part of an integrated disease management strategy can significantly reduce disease incidence, improve root health, and enhance long-term sustainability of *D. sissoo* plantations.

Precautions for Biological Management Using *Trichoderma harzianum*

1. **Use Certified Product:** Always use a quality-certified *Trichoderma harzianum* formulation with adequate viable spore count and within expiry date.
2. **Avoid Mixing with Chemicals:** Do not mix *Trichoderma* with chemical fungicides or apply immediately after fungicide treatment, as this may kill the beneficial fungus.
3. **Apply in Suitable Weather:** Avoid application during peak sunlight or high temperatures. Prefer early morning or evening hours to maintain spore viability.
4. **Maintain Soil Moisture:** Ensure adequate but not excessive soil moisture. Waterlogged conditions may reduce effectiveness and favor *Ganoderma* growth.
5. **Proper Dosage:** Follow the recommended dosage (10–15 g in 5 liters of water). Overuse does not increase effectiveness and may disturb microbial balance.
6. **Fresh Preparation:** Prepare the suspension freshly before application and avoid storing the diluted solution for long periods.
7. **Soil Application Only:** Apply near the root zone (soil drench) and avoid spraying on leaves unless specifically recommended.
8. **Remove Infected Debris:** Uproot and destroy severely infected trees, stumps, and root debris before application to reduce pathogen load.
9. **Maintain Field Hygiene:** Avoid movement of contaminated soil and tools from infected to healthy areas without proper sanitation.
10. **Repeat Application:** Repeat at recommended intervals (30–45 days) for sustained protection, especially during the rainy season.

Following these precautions ensures maximum effectiveness of *Trichoderma* and supports sustainable management of *Ganoderma* root rot.

Biological Management of *Ganoderma* Root Rot in *Dalbergia sissoo* (Shisham)

Biological management offers a sustainable and eco-friendly approach for suppressing *Ganoderma* root rot in *Dalbergia sissoo* plantations. Among the effective biocontrol agents, *Trichoderma harzianum* has shown promising results due to its pathogenic activity against soil-borne fungal pathogens across the Indian subcontinent programs.

Dosage & Preparation

- Mix 10–15 grams of *Trichoderma harzianum* in 5 liters of water.
- Stir thoroughly to prepare a uniform suspension.

Method of Application

- Create a shallow circular ring or furrow near the root zone.
- Apply solution evenly in the ring 15–20 cm from the tree collar, depending on plant age.

Timing of Application

Preferably early morning or evening



Avoid applying in direct sunlight.



Preferably early morning or evening.

Additional Recommendations

- Remove and destroy severely infected trees and root debris.
- Preferably early morning or evening hours.
- Avoid mixing *Trichoderma* with chemical fungicides.
- Maintain proper drainage to reduce *Ganoderma* growth.

Eco-friendly and sustainable approach to disease suppression

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