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Successful management of wilt diseases in mango, guava and banana: An integrated approach

Wilt diseases in perennial fruit crops such as mango, guava, and banana pose a major threat to sustainable production owing to the soil-borne nature of the pathogens and limited management options. Mango wilt (*Ceratocystis fimbriata*), guava wilt complex (*Fusarium oxysporum* f. sp. *psidii*), and banana wilt (*Fusarium oxysporum* f. sp. *cubense*) collectively cause severe yield losses, orchard decline, and long-term soil infestation, rendering conventional control measures largely ineffective. To address this challenge, ICAR–CISH, Lucknow, has developed and validated integrated wilt management strategies and modules encompassing soil health restoration, deployment of resistant/tolerant rootstocks, fungicide application, use of bioformulations (ICAR-FUSICONT), and farmers' participatory management practices. Field validation of the mango wilt management module across multiple hotspot areas has achieved effective disease suppression, leading to improved plant vigour, enhanced productivity, and prolonged orchard longevity. The success of this integrated, eco-smart approach provides a sustainable, scalable, and resilient solution for managing soil-borne wilt pathogens in major subtropical fruit crops.

Keywords: Bioformulations, Integrated wilt management, Soil-borne pathogens, Subtropical fruit crops, Wilt diseases

WILT diseases pose a serious threat to the productivity and sustainability of mango, guava, and banana in subtropical regions. They cause rapid vascular blockage, root decay, canopy drying, and eventual plant death, often leading to substantial yield losses and long-term field infestation. The persistent nature of wilt pathogens, their survival in soil and plant debris, and their ability to spread through planting material, irrigation water, and cultural practices make their management extremely challenging. Traditional reliance on chemical control has shown limited effectiveness and poses risks of resistance development, environmental contamination, and adverse effects on soil health. Therefore, an integrated approach combining preventive and curative strategies is essential for successful wilt management. Integration of disease-free planting material, resistant varieties/rootstocks, soil health improvement, biological control agents, organic amendments, crop rotation, sanitation, and judicious chemical use has emerged as a sustainable solution. Such holistic management not only reduces disease incidence but also restores soil microbial balance and enhances overall crop resilience, ensuring long-term productivity and profitability for fruit growers. To address this challenge, ICAR–CISH, Lucknow, has developed and validated the following integrated wilt management strategies and modules.

MANGO WILT

The Incidence of mango wilt in India has been reported from almost all major mango-growing states and has become a serious issue. However, wilt-associated losses are highly site- and season-specific rather than uniform across the country. The disease is primarily caused by *Ceratocystis fimbriata*, although several other fungi, including *Lasiodiplodia theobromae*, *Fusarium oxysporum*, *F. solani*, and *Berkeleyomyces* spp., have also been found associated with wilt-affected trees. The disease may appear in the form of sudden wilt, slow decline, or branch drying, and infected trees eventually die if not attended to. Infection by the wilt fungus is mainly promoted by severe root damage caused by increased practices of deep ploughing and digging trenches for fertilizer and paclobutrazole application. Uncontrolled irrigation, waterlogging, intercropping, mechanical injuries, excessive use of paclobutrazole, improper fertilizer application, higher soil pH, depletion of the water table, and climate change are other factors that enhance mango wilt incidence.

Field surveys conducted by the institute have confirmed the occurrence of *Ceratocystis* wilt in about 42 out of 1,917 orchards surveyed in Uttar Pradesh, representing localized hotspots rather than statewide coverage, while international reports caution that unmanaged epidemics can lead to large orchard-level losses. This underscores

the urgent need for integrated management strategies to safeguard mango production in India.

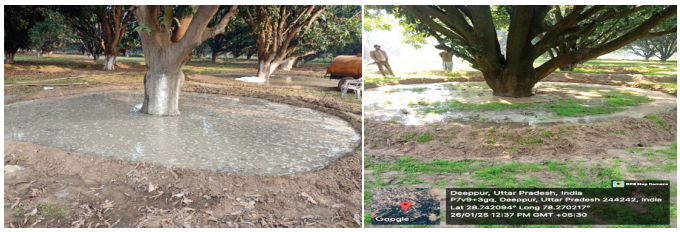
Management of mango wilt

Management of mango wilt is challenging because the fungus infects roots and vascular tissues long before visible symptoms appear, making early detection and control nearly impossible. An integrated management module developed by ICAR–CISH, Lucknow, was disseminated through on-farm demonstrations, farmer–scientist interactions, and extension materials across wilt hotspot regions of Uttar Pradesh. Long-term field trials (2015–2020) on cv. Dashehari achieved nearly 85% success, while subsequent evaluations (2024–25) on other cultivars recorded over 90% disease control. Although severely affected trees could not be revived, the module proved highly effective in minimizing further disease spread and ensuring orchard sustainability.

Sudden wilt Branch wilt Decline

ICAR-CISH mango wilt management module

- Practice minimal tillage around the tree trunk (1.0–2.5 m radius); avoid deep ploughing to prevent feeder root damage.
- Treat the root zone of wilt-affected and nearby trees with thiophanate-methyl soil drenching (0.004%) at 200 L/m^2.
- Apply CISH-*Trichoderma harzianum* or CISH-*T. viride* or CISH-*T. reesei* formulations six months after chemical treatment; repeat annually at the onset of monsoon.
- During the rainy season, spray the canopy with *Trichoderma* sp. (10^3 cfu/ml) or 0.1% propiconazole 25% EC or hexaconazole 5% EC.
- After pruning infected branches, seal cut ends with 5% copper sulphate or copper oxychloride 50 WP paste.
- Manage scolytid beetles by spraying *Beauveria bassiana* at 10^3 cfu/ml every 15 days during rainy, pre-, and post-winter periods.
- Use drip or controlled irrigation to prevent pathogen spread and maintain optimal soil moisture to support recovery of affected trees.
- Apply recommended doses of manures and fertilizers, and supplement with foliar nutrient sprays in affected orchards to promote plant vigour and recovery.



Application of Thiophanate-methyl 70WP in mango orchards

BANANA WILT

In recent years, banana cultivation has expanded rapidly in Uttar Pradesh and Bihar, covering nearly 69,380 ha and 31,070 ha, respectively. Among the cultivated varieties, Cavendish and Malbhog are predominant, with Cavendish being the most preferred due to its higher economic returns and moderate tolerance to the cold winters of subtropical regions.

Historical context of Fusarium wilt in banana

About a century ago, cv. Gros Michel was the most popular dessert banana worldwide. However, a severe outbreak of Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* Race 1 (Foc R1) wiped it out globally. Resistance found in a Cavendish clone at Kew Gardens, London, led to the development of cultivars such as Robusta, Williams, and Grand Naine (G-9). The Cavendish group became commercially dominant because of their resistance to Fusarium wilt, though cv. Robusta remained susceptible. The replacement of Gros Michel with resistant Cavendish largely mitigated Fusarium wilt at that time.

Emergence of Foc Race 4 and TR4

Currently, cv. Grand Naine (G-9) occupies nearly 50–60% of the banana area in India, supported by standard tissue culture protocols, a shorter crop cycle, and suitability for intensive management. However, intensive Cavendish cultivation under subtropical conditions in South Africa and Australia facilitated the emergence of Foc Race 4. Later, a more virulent form, Tropical Race 4 (TR4), appeared in the 1990s, devastating Cavendish in tropical and subtropical regions. According to the ProMusa database, TR4 has since spread to Jordan, Oman, Mozambique (2013), Lebanon, Pakistan (2015), Vietnam, Laos, Myanmar, Israel (2018), Cambodia, China, Latin America, and Peru. In India, TR4 was first reported in Bihar (2014) and later confirmed in G-9 plantations in the Sohawal block, Ayodhya (Uttar Pradesh), in 2018.

Spread and Economic Losses in North India

ICAR scientists initiated awareness, surveys, molecular

The adoption of module may vary in relation to severity of disease in an orchard

Condition of the orchard	Recommended modules
Trees looking poor in health but no tree wilted in the last five years	1, 3, 7, 8
Trees looking poor in health and one tree wilted in the orchard during the last one year	1, 3, 4, 5, 7 and 8
Trees looking or not looking poor in health but several trees wilted in an orchard during last 3-5 years	Adopt complete module

diagnostics, and management strategies following TR4 detection. Systematic surveys confirmed the disease in seven districts of Uttar Pradesh (Maharajganj, Gorakhpur, Sant Kabir Nagar, Ayodhya, etc.) and five districts of Bihar (Bhagalpur, Katihar, Purnia, etc.), with invasion suspected from Nepal. Disease incidence of 40–60% was recorded, causing crop losses worth Rs. 34.75 crores over 12,000 ha in the two states. Symptoms included progressive leaf yellowing, petiole bending, pseudostem splitting, and vascular browning. The pathogen, producing long-lived chlamydospores that survive for more than 20 years, spreads via irrigation water, planting material, tools, and human movement. Heavy reliance on suckers further aggravated dissemination.

Global Distribution and Economic Impact

Globally, TR4 is reported from 17 banana-growing countries, affecting 15,700 ha in the Philippines and over 70% of plantations in China's Guangdong and Hainan provinces. Annual losses are estimated at USD 121 million in Indonesia, USD 253 million in Taiwan, and USD 14 million in Malaysia. The pathogen's polycyclic nature enables multiple infection cycles, causing devastating yield losses. Management is hindered by the absence of durable resistant cultivars and limited chemical or biological control options, making exclusion, quarantine, and early prevention the most effective strategies.

Management Challenges and Early Efforts

In India, containment of TR4 was critical to protect remunerative Cavendish and traditional cultivars. Taiwan identified resistant clones (GCTV 215, GCTV 218), but commercial and horticultural limitations prevented adoption in India. Abandoning banana cultivation in U.P. and Bihar was not viable due to high farmer returns. Preventing spread into peninsular and northeastern India was thus paramount. Consequently, ICAR-CISH and ICAR-CSSRI launched a scheme in 2019 to evaluate biological suppression of TR4 using beneficial microbes.

Development of ICAR-FUSICONT Technology

A breakthrough came with the bioformulation ICAR-FUSICONT**,** based on *Trichoderma reesei* CSR-T-3. Laboratory assays showed 85.19% inhibition of TR4, while pot experiments and field trials in Bihar and U.P. confirmed 80–85% efficacy. LC-MS metabolomic profiling of CSR-T-3 treated plants revealed antifungal compounds such as β-caryophyllene, peptaibols, fengycin, and iturin C19, explaining pathogen suppression and host tolerance induction.

The ICAR-FUSICONT formulation was validated at hotspots in Ayodhya, Maharajganj, and Barabanki (U.P.) and Katihar (Bihar) through public–private–farmer partnerships. Community grower groups applied 3% FUSICONT soil drenches at 3, 5, and 12 months after planting, achieving 85–90% control and restoring farm incomes by Rs.163.8 lakhs from 273 acres.

Bio-Immunization and Patented Innovation

To strengthen sustainability, ICAR-CISH and ICAR-CSSRI developed an in vitro bio-immunization technology, engineering lipo-polypeptide biomolecules into tissue-cultured banana plantlets during organogenesis (Patent No. 202111003761, dated 28.01.2021). These bio-immunized plantlets, tested on 22,000 plants in Katihar (Bihar) and Sohawal (U.P.), combined with FUSICONT drenching, reduced TR4 incidence by 92–95%.

Plant condition before application of ICAR-FUSICONT

Improved wilt disease management following ICAR-FUSICONT application

GUAVA WILT

The guava wilt complex is mainly due to *Fusarium oxysporum* f. sp. *psidii* in association with nematodes (*Meloidogyne enterolobii*), which together create a persistent and hard-to-manage decline problem. In India, guava wilt is considered the most destructive disease of the crop, with reported yield losses ranging broadly from 5% up to 60% under severe conditions. In localized surveys around Lucknow, the losses have been documented to fall within this same 5–60% range. In state-level reports, in Karnataka, frontline demonstrations recorded disease incidence of 12–15% and associated yield loss of ~30% in severely affected plots. Also, earlier reports suggest that in West Bengal, the presence of wilt reduced yields in affected orchards from 113.5 q/ha to about 18–22.7 q/ha, indicating losses approaching 80% in extreme cases.

Guava Wilt Management

For sustainable management of the guava wilt complex, ICAR-CISH, Lucknow, has developed and validated a comprehensive, field-ready technology package covering the entire production chain from nursery to orchard, as mentioned below:

- Disease-free scion mother blocks must be maintained, and seedlings from wilt-affected orchards should be strictly avoided. Nursery beds should be raised and solarized with transparent polythene for 30–40 days or sterilized through steaming to eliminate soil-

borne pathogens. Potting mixtures should be fortified with Trichoderma harzianum or T. viride, and all nursery tools must be disinfected using 1% sodium hypochlorite or spirit. Any abnormal or suspect seedlings should be promptly discarded to ensure that only healthy, disease-free plants are supplied to the field.

- Soil fertility and microbial balance are to be improved through organic amendments such as well-decomposed FYM (25–30 kg/tree twice a year), neem cake (3–6 kg/tree), press-mud, or vermicompost to build a disease-suppressive rhizosphere.
- Trichoderma-enriched FYM (2–4 kg talc formulation t^1 FYM), incubated for 10–15 days, should be applied twice yearly (10–15 kg/tree). Aspergillus niger (validated by ICAR–CISH) and microbial consortia of Pseudomonas fluorescens and *Bacillus* spp. further strengthen pathogen suppression. Root dipping of seedlings in a biocontrol suspension ensures early and effective rhizosphere colonization.
- The resistant rootstocks developed through interspecific hybrids (Psidium guajava × P. molle) by ICAR–CISH show strong wilt tolerance and graft compatibility with elite cultivars (*Allahabad Safeda*, *Lalit*, *Shweta*, *Pant Prabhat*, L-49). These resistant rootstocks not only reduce wilt incidence but also ensure long-term orchard health and productivity.

CONCLUSION

Wilt diseases of mango, guava, and banana pose major constraints to subtropical fruit production due to their persistent, soil-borne nature and limited curative measures. Mango wilt, guava wilt complex, and banana Fusarium wilt (TR4) cause severe orchard decline and yield losses. ICAR-CISH, Lucknow, has developed integrated management technologies encompassing soil health restoration, clean planting material, resistant/tolerant rootstocks, bioformulations (ICAR-FUSICONT), and farmer-participatory modules. Field validation in mango and guava hotspot sites achieved 85–90% disease control, while bio-immunization in banana restored productivity. These eco-smart strategies offer sustainable, scalable solutions for managing wilt diseases and enhancing orchard resilience and farmer livelihoods.

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