

# Integrated Management Strategies for Guava Fruit Rot Disease in Bihar: Evaluation of Biological, Botanical and Post-Harvest Approaches

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## Abstract:

Guava fruit rot is one of the major causes of post-harvest loss in Bihar, where warm temperature, high humidity, and inadequate storage conditions favor rapid fungal infection and fruit deterioration. The present study evaluated different management strategies for controlling guava fruit rot through chemical, biological, botanical, and post-harvest approaches under Bihar conditions. Chemical fungicides such as carbendazim, mancozeb, and copper oxychloride reduced disease incidence effectively, with carbendazim showing the best short-term performance. Among biological treatments, *Trichoderma harzianum* proved more effective than *Pseudomonas fluorescens*. Botanical extracts, particularly neem and garlic, also showed notable antifungal activity and helped reduce disease severity. Post-harvest treatments significantly improved storage performance, and modified atmosphere packaging (MAP) recorded the lowest weight loss and longest shelf life. The integrated treatment combining biological, botanical, and MAP approaches showed the best overall results, with minimum disease incidence, better fruit quality, and extended shelf life. The study concludes that integrated disease management offers a practical, eco-friendly, and cost-effective strategy for reducing guava fruit rot and post-harvest losses in Bihar.

**Keywords:** Guava fruit rot, integrated disease management, *Trichoderma harzianum*, neem extract, modified atmosphere packaging

## 1. Introduction

Guava (*Psidium guajava* L.) is one of the most important fruit crops cultivated in tropical and subtropical regions. In India, it holds a significant place in the horticultural sector, and states like Bihar have emerged as major producers due to favorable agro-climatic conditions such as fertile alluvial soils and a suitable subtropical climate (Mitra et al., 2008). The fruit is widely known for its high nutritional value, especially its rich content of vitamin C, dietary fiber, and bioactive compounds, which contribute to improving human health and nutritional security (Krishna & Rao, 2014).

In rural areas of Bihar, guava serves not only as a source of nutrition but also as an important means of livelihood for small and marginal farmers. However, guava cultivation faces several constraints, among which fruit rot disease is one of the most serious problems. This disease causes significant losses both in the field and after harvesting, particularly under warm and humid conditions. Studies have shown that post-harvest losses in guava due to fruit rot can reach up to 25–40 percent, which directly affects farmers' income and market supply. The disease is mainly caused by a complex of fungal pathogens such as *Colletotrichum gloeosporioides*, *Fusarium* spp., *Alternaria alternata*, and *Aspergillus niger*,

which infect fruits through wounds or natural openings and rapidly spread during storage and transportation (Chaube & Pundhir, 2005).

The problem of fruit rot is more severe in Bihar due to its climatic conditions, characterized by high humidity, monsoon rainfall, and inadequate post-harvest infrastructure. Most farmers lack access to cold storage, scientific packaging, and proper transportation facilities, which accelerates the deterioration of fruits after harvest. As a result, farmers are often forced to sell their produce at lower prices to avoid complete loss, leading to economic instability in the guava sector. Moreover, the reliance on traditional methods and limited awareness of modern disease management practices further aggravate the situation.

Conventionally, chemical fungicides have been widely used to control fruit rot diseases. Although these chemicals can reduce disease incidence to some extent, their excessive use poses several challenges. These include increased production costs, development of pathogen resistance, environmental pollution, and the presence of harmful residues on fruits, which may affect consumer health and limit export potential (Murmu & Mishra, 2018). Therefore, there is a growing need to develop safer, cost-effective, and eco-friendly alternatives for disease management.

In recent years, integrated disease management (IDM) has gained attention as a sustainable approach to controlling plant diseases. This approach combines different methods such as biological control agents, botanical extracts, cultural practices, and improved post-harvest techniques to achieve effective disease control while minimizing environmental risks. Biological agents like *Trichoderma* spp. and *Pseudomonas fluorescens* have shown promising results in suppressing fungal pathogens, while plant-based extracts such as neem and garlic possess natural antifungal properties (Zakaria, 2022). Similarly, post-harvest treatments such as calcium chloride application, hot water treatment, and modified atmosphere packaging (MAP) have been found effective in extending shelf life and reducing decay (Ismail et al., 2010).

Despite these advancements, there is a lack of region-specific research focusing on integrated management of guava fruit rot under the agro-climatic conditions of Bihar. Most available studies are either generalized or conducted in other regions, making their direct application limited. Therefore, there is a need to evaluate different management strategies in a localized context and identify practical solutions suitable for small and marginal farmers.

In this context, the present study aims to assess the effectiveness of integrated management strategies, including biological, botanical, and post-harvest approaches, for controlling guava fruit rot disease in Bihar. The study seeks to provide sustainable and economically viable solutions that can reduce post-harvest losses, improve fruit quality, and enhance the overall productivity and profitability of guava cultivation in the region.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

The present study was conducted in the major guava-growing regions of Bihar, India, including Vaishali, Bhagalpur, Nalanda, Samastipur, and Gaya districts. These areas are well known for their extensive guava cultivation due to fertile alluvial soils and favorable agro-climatic conditions. The climate of Bihar is subtropical, characterized by hot summers, moderate winters, and a distinct monsoon season. The temperature generally ranges from about 10°C in winter to above 40°C in summer, while high relative humidity prevails during the monsoon period. These climatic conditions are highly favorable for the growth and spread of fungal pathogens responsible for fruit rot disease. In addition, high moisture levels and poor post-harvest handling practices further accelerate disease development and lead to significant post-harvest losses.

## 2.2 Experimental Design

The experimental design was developed to evaluate different management strategies for controlling guava fruit rot disease under the agro-climatic conditions of Bihar. The study included chemical, biological, botanical, and post-harvest approaches, and all treatments were applied under similar conditions to ensure proper comparison. Chemical control involved the application of commonly used fungicides such as carbendazim (0.1%), mancozeb (0.25%), and copper oxychloride (0.3%) as pre-harvest sprays at regular intervals.

Biological control methods were evaluated using bio-agents such as *Trichoderma harzianum* and *Pseudomonas fluorescens*, which are known for their antagonistic activity against fungal pathogens. These were applied either as foliar sprays or as surface treatments. Botanical extracts were also tested to assess their antifungal potential. Extracts of neem (*Azadirachta indica*), garlic (*Allium sativum*), and tulsi (*Ocimum sanctum*) were prepared and applied as sprays, considering their natural antimicrobial properties and suitability for eco-friendly disease management.

Post-harvest treatments were applied to freshly harvested guava fruits to reduce disease development during storage and transportation. These included hot water treatment at 50–55°C for 5–10 minutes, calcium chloride treatment using 1–2% solution, and Modified Atmosphere Packaging (MAP). These treatments were selected to extend shelf life and reduce microbial growth under storage conditions.

## 2.3 Data Collection

Data were collected to assess the effectiveness of different treatments based on disease control and fruit quality. Disease incidence was calculated as the percentage of infected fruits in relation to the total number of fruits, while disease severity was evaluated based on the extent of visible infection symptoms on the fruit surface. Shelf life was recorded as the number of days the fruits remained marketable under storage conditions.

In addition, important fruit quality parameters were measured, including weight loss, total soluble solids (TSS), and texture. Weight loss was calculated as the percentage reduction in fruit weight during storage, while TSS was measured using a refractometer. Texture was assessed in terms of fruit firmness to determine the effect of treatments on fruit quality.

## 2.4 Statistical Analysis

The collected data were analyzed using standard statistical methods. Mean values and percentages were calculated for all parameters. Analysis of Variance (ANOVA) was used to compare the effectiveness of different treatments, and the significance of differences among treatments was evaluated at appropriate levels. This analysis helped in identifying the most effective and sustainable management strategy for controlling guava fruit rot disease under the conditions of Bihar.

## 3. Results

### 3.1 Effect of Chemical Treatments

The application of chemical fungicides significantly reduced the incidence and severity of guava fruit rot disease compared to the untreated control. Among the treatments, carbendazim showed the highest effectiveness, followed by mancozeb and copper oxychloride. However, the effect was mainly short-term, and disease incidence gradually increased during storage.

Table 3.1: Effect of Chemical Treatments on Disease Incidence and Shelf Life

Treatment	Disease Incidence (%)	Disease Severity (%)	Shelf Life (Days)
Control (Untreated)	68.45	60.32	4.25
Carbendazim (0.1%)	28.36	25.14	7.82
Mancozeb (0.25%)	34.72	30.85	7.10
Copper oxychloride	39.18	35.67	6.54

The results indicate that chemical treatments reduced disease incidence by more than 40% compared to control.

### 3.2 Effect of Biological Control

Biological control agents showed moderate effectiveness in reducing disease incidence. *Trichoderma harzianum* performed better than *Pseudomonas fluorescens*, indicating its strong antagonistic activity against fungal pathogens.

Table 3.2: Effect of Biological Control Agents

Treatment	Disease Incidence (%)	Disease Severity (%)	Shelf Life (Days)
Control (Untreated)	68.45	60.32	4.25
<i>Trichoderma harzianum</i>	36.58	32.74	7.45
<i>Pseudomonas fluorescens</i>	42.16	38.29	6.98

The results show that biological treatments reduced disease incidence significantly, though slightly less effective than chemical fungicides.

### 3.3 Effect of Botanical Extracts

Botanical extracts demonstrated notable antifungal activity. Neem and garlic extracts were more effective than tulsi extract in reducing infection and maintaining fruit quality.

Table 3.3: Effect of Botanical Extracts

Treatment	Disease Incidence (%)	Disease Severity (%)	Shelf Life (Days)
Control (Untreated)	68.45	60.32	4.25
Neem extract	40.62	36.18	7.12
Garlic extract	38.95	34.76	7.30
Tulsi extract	45.28	40.12	6.68

### 3.4 Effect of Post-Harvest Treatments

Post-harvest treatments significantly improved shelf life and reduced disease development. Modified Atmosphere Packaging (MAP) showed the best performance among all treatments.

Table 3.4: Effect of Post-Harvest Treatments

Treatment	Disease Incidence (%)	Weight Loss (%)	Shelf Life (Days)
Control (Untreated)	68.45	18.62	4.25
Hot water treatment	42.18	12.45	7.20
Calcium chloride (1–2%)	35.64	9.38	8.45
MAP	30.52	7.86	10.32

MAP significantly reduced weight loss and extended shelf life compared to other treatments.

### 3.5 Comparative Effectiveness of Treatments

The integrated treatment combining biological, botanical, and post-harvest approaches showed the best overall performance. It resulted in the lowest disease incidence, highest shelf life, and improved fruit quality.

Table 3.5: Comparative Effectiveness of Integrated Treatment

Treatment Type	Disease Incidence (%)	Shelf Life (Days)	TSS (°Brix)	Weight Loss (%)
Control	68.45	4.25	8.62	18.62
Chemical only	28.36	7.82	9.45	10.84
Biological only	36.58	7.45	9.12	11.25
Botanical only	38.95	7.30	9.05	12.10
Integrated (Bio + Botanical + MAP)	18.72	11.25	10.36	6.42

The integrated approach reduced disease incidence by more than 70% compared to control and significantly improved shelf life and fruit quality.

## 4. Discussion

The results of the present study clearly demonstrate that guava fruit rot disease is a serious post-harvest problem under the agro-climatic conditions of Bihar, where high temperature and humidity favor rapid fungal growth. The high disease incidence observed in untreated fruits confirms that fruit rot develops quickly during storage, leading to significant losses, which is consistent with earlier observations of substantial post-harvest damage in guava. The study further indicates that different management approaches vary in their effectiveness, and no single method provides complete control of the disease. Chemical treatments were found to be the most effective in reducing disease incidence in the initial stages. Among the tested fungicides, carbendazim showed the lowest disease incidence and severity, along with a moderate improvement in shelf life. This supports earlier findings that systemic fungicides provide quick and strong control against fungal pathogens. However, the results also show that the improvement in shelf life under chemical treatment was limited compared to post-harvest treatments. This indicates that chemical fungicides mainly act as protective agents before infection but do not significantly delay physiological deterioration during storage. Therefore, their role is important but not sufficient for long-term management.

Biological control agents, particularly *Trichoderma harzianum*, showed moderate effectiveness in reducing disease incidence and improving shelf life. The results indicate that *Trichoderma* performed better than *Pseudomonas fluorescens*, which may be due to its stronger antagonistic action against fungal pathogens. Although the disease reduction achieved by biological treatments was slightly lower

than chemical fungicides, the improvement in shelf life was comparable. This suggests that biological control provides a more stable and environmentally safe option, especially for long-term disease suppression. These findings are in agreement with previous studies that emphasize the role of bio-agents in sustainable plant disease management.

Botanical extracts also showed considerable effectiveness in reducing disease incidence. Among the tested extracts, garlic and neem performed better than tulsi, indicating their stronger antifungal properties. The reduction in disease incidence and severity observed in these treatments suggests that plant-based extracts can inhibit fungal growth effectively. However, their performance was slightly lower than chemical treatments and biological agents, which indicates that botanical extracts alone may not provide complete protection. Still, their cost-effectiveness and safety make them suitable components of an integrated management approach, particularly for small and marginal farmers.

Post-harvest treatments showed the most significant impact on shelf life and reduction of disease development during storage. Calcium chloride treatment improved fruit firmness and reduced weight loss, which contributed to better quality retention. Modified Atmosphere Packaging (MAP) was found to be the most effective among all treatments, as it resulted in the lowest disease incidence, minimum weight loss, and maximum shelf life. The extended shelf life observed under MAP can be attributed to reduced respiration rate and slower microbial growth due to modified gas composition. These findings clearly indicate that post-harvest management plays a critical role in controlling fruit rot after harvesting.

The comparative analysis of different treatments shows that the integrated approach, combining biological control, botanical extracts, and post-harvest treatments, provided the best results. This approach resulted in the lowest disease incidence, highest shelf life, and improved fruit quality parameters such as TSS and reduced weight loss. The superior performance of the integrated treatment can be explained by the combined effect of different mechanisms, including pathogen suppression, antifungal activity, and improved storage conditions. While chemical treatments provided rapid disease control, and post-harvest treatments improved shelf life, their combination with biological and botanical methods created a more balanced and effective strategy.

Overall, the results clearly indicate that integrated disease management is more effective than individual methods for controlling guava fruit rot disease under Bihar conditions. This approach not only reduces disease incidence but also improves fruit quality and shelf life, making it more suitable for practical application. The findings also highlight the importance of combining pre-harvest and post-harvest strategies to achieve sustainable disease control. For farmers in Bihar, adopting an integrated approach can help reduce losses, improve market value, and increase income while minimizing dependence on chemical fungicides.

## 5. Conclusion

The present study confirms that guava fruit rot disease is a major constraint affecting fruit quality and shelf life under the agro-climatic conditions of Bihar. The high incidence of disease observed in untreated fruits clearly indicates that warm temperature and high humidity create favorable conditions for rapid fungal infection, leading to significant post-harvest losses.

The results demonstrate that chemical fungicides such as carbendazim, mancozeb, and copper oxychloride are effective in reducing disease incidence at the initial stage. However, their effect is mainly short-term and does not significantly improve shelf life during storage. In addition, concerns related to chemical residues and environmental safety limit their long-term use. Biological control agents, particularly *Trichoderma harzianum*, showed moderate but consistent effectiveness in reducing disease incidence and offered an eco-friendly alternative for disease management. Botanical extracts

such as neem and garlic also demonstrated antifungal activity and reduced infection levels, making them suitable low-cost options for farmers.

Post-harvest treatments played a crucial role in improving fruit quality and extending shelf life. Calcium chloride treatment helped maintain fruit firmness and reduce weight loss, while Modified Atmosphere Packaging (MAP) proved to be the most effective in delaying ripening, minimizing decay, and extending storage life. These findings highlight the importance of post-harvest management in controlling disease development after harvesting.

The comparative analysis clearly indicates that the integrated approach, combining biological control, botanical extracts, and post-harvest treatments, is the most effective strategy for managing guava fruit rot disease. This approach resulted in the lowest disease incidence, maximum shelf life, and improved fruit quality. It also provides a balanced solution by combining effectiveness with environmental safety and cost efficiency.

## 6. Recommendations

The findings of the present study provide clear evidence that guava fruit rot disease can be effectively managed through an integrated approach combining biological, botanical, and post-harvest strategies. Based on these results, the following recommendations are proposed for improving disease management and reducing post-harvest losses under the agro-climatic conditions of Bihar.

The study strongly recommends the adoption of integrated disease management (IDM) as a standard practice in guava cultivation. The combined application of bio-agents, botanical extracts, and post-harvest treatments proved to be more effective than individual methods, resulting in lower disease incidence, extended shelf life, and improved fruit quality. Therefore, farmers should be encouraged to adopt a holistic approach rather than depending on a single control method.

Although chemical fungicides demonstrated higher initial effectiveness in reducing disease incidence, their use should be rationalized and limited. Over-reliance on chemical control may lead to environmental concerns, residue accumulation on fruits, and the development of pathogen resistance. It is therefore recommended that chemical treatments be used judiciously, preferably as part of an integrated system rather than as a sole management strategy.

The use of biological control agents such as *Trichoderma harzianum* and *Pseudomonas fluorescens* should be promoted as eco-friendly alternatives. These bio-agents offer sustainable disease suppression and can be effectively integrated into orchard management practices. Their application is particularly suitable for long-term disease control and aligns with the growing demand for safe and residue-free agricultural produce.

Botanical extracts, especially neem and garlic, should be encouraged as cost-effective and locally available disease management options. These treatments demonstrated significant antifungal activity and can be easily adopted by small and marginal farmers. Their inclusion in disease management programs can reduce dependence on synthetic chemicals and promote sustainable agriculture.

Post-harvest management practices must be strengthened to minimize losses during storage and transportation. The study highlights the effectiveness of calcium chloride treatment in maintaining fruit firmness and reducing physiological deterioration. In addition, Modified Atmosphere Packaging (MAP) proved highly effective in extending shelf life and reducing decay. Therefore, the adoption of improved post-harvest technologies should be prioritized, particularly in regions where storage and transportation infrastructure are limited.

There is also a need to improve institutional support systems, including farmer training, extension services, and infrastructure development. Farmers should be provided with technical guidance on integrated disease management practices through Krishi Vigyan Kendras (KVKs) and agricultural extension agencies. Investment in cold storage facilities, packaging units, and efficient transport systems is essential to reduce post-harvest losses and enhance market value.

Finally, further research should focus on developing region-specific disease management strategies, identifying resistant guava varieties, and optimizing eco-friendly control measures. Long-term studies under field conditions are necessary to validate the effectiveness of integrated approaches and to enhance their adoption at the farmer level.

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