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Research Article

Eco-friendly management of papaya collar rot: A biocontrol approach in nurseries using antagonistic bioagents

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ABSTRACT: Collar rot, a devastating nursery disease in papaya (*Carica papaya*), caused by *Pythium aphanidermatum*, severely compromises seedling establishment and crop productivity. This study, conducted at Sylhet Agricultural University, Bangladesh, evaluated the biocontrol potential of three antagonistic bioagents—*Trichoderma* solid (T2), Bioderma solid (T1), and Bioderma powder (T3)—against the pathogen, compared to an untreated control (T0). Morphological characterisation confirmed *P. aphanidermatum* as the causal agent. Trichoderma solid (T2) emerged as the most effective treatment, achieving 84.8% disease suppression, the highest seedling vigour index (1592.2), and superior germination (88.9%), alongside enhanced shoot (9.1 cm) and root growth (8.8 cm). Bioderma solid (T1) ranked second in efficacy, while Bioderma powder (T3) significantly reduced disease incidence and promoted vegetative development. In contrast, the control (T0) exhibited severe collar rot (70.1% incidence) and the lowest vigour (321.4). The results demonstrate that Trichoderma-based formulations act as potent antagonists against *P. aphanidermatum*, offering a sustainable alternative to synthetic fungicides. This study underscores the integration of biocontrol agents into papaya nursery management to mitigate soil-borne pathogens, reduce agrochemical dependency, and enhance seedling resilience. These findings advocate for scaling biocontrol strategies to safeguard papaya cultivation, a critical crop for tropical agro-economies and nutrition security.

KEYWORDS: Biocontrol agents, papaya, collar rot, *Trichoderma*, soil-borne pathogens

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INTRODUCTION

Papaya (*Carica papaya* L.) is a tropical fruit crop of significant economic importance, appreciated for its nutritional richness and diverse culinary applications (Kaysar *et al.*, 2019). A high demand for papaya fruits exists in both domestic and overseas markets. In Bangladesh, the post-harvest loss of papaya fruits was estimated to be 39.9 per cent, with a value of taka 132.1 crore, which is approximately 10.9 million USD, for which fungal diseases were one of the major reasons (Hamim *et al.*, 2014). However, the cultivation of papaya faces numerous challenges, with collar rot emerging as a prominent threat to seedling health and overall crop productivity. Collar rot of papaya caused by *Pythium aphanidermatum* is one of the most devastating diseases of papaya seedlings. *P. aphanidermatum* is a soil-borne fungus, and it is highly adaptive (Arora *et al.*, 2021). Mild stunting to severe wilting, root rot, and mortality are all symptoms of the disease (Lookabaugh, 2013). The emergence of soft, watery sores in the collar region, as well as wilting of leaves as the disease progresses, are the first signs of collar rot. Severe collar rot, on the other hand, causes full wilting and plant collapse (Rodriguez-Alvarado *et al.*, 2001). Collar rot disease has caused up to a 30% loss in this crop, according to many researchers (Mahato *et al.*, 2017).

The common chemicals that are used to control the pathogen are Ridomil Gold 25G, Ridomil Gold 450EC, and Potassium phosphonate (Male & Vawdrey, 2010). But most of the chemicals are phytotoxic and prone to resistance in *Pythium aphanidermatum*. Moreover, in recent years, there has been a growing emphasis on sustainable and environmentally friendly approaches to pest and disease management in agriculture. To control this soil-borne pathogen like *Pythium aphanidermatum*, the use of microbial biopesticides could be an eco-friendly and sustainable management option. However, various *Trichoderma* species, *Lysobacter enzymogenes*, and Bacillus species are effective against the pathogen. (Yang *et al.*, 2004; Postma *et al.*, 2009; Zagade *et al.*, 2012). In addition, *Trichoderma*

spp. can inhibit pathogens and promote plant growth. Based on the foregoing, this study aimed to investigate the efficacy of selected commercial microbial biopesticides in the management of collar rot in papaya seedlings and identify the pathogen causing collar rot of papaya.

MATERIALS AND METHODS

Experimental site preparation

The study was conducted in the net house and laboratory of the Plant Pathology and Seed Science Department, Sylhet Agricultural University, Bangladesh (24.89°N, 91.87°E; elevation: 33.53 m). The site lies within Agro-ecological Zone-20 (AEZ-20), characterised by non-calcareous grey floodplain soils with moderate organic matter (pH: acidic to neutral) (Bari *et al.*, 2015). The region experiences a warm, humid subtropical climate with an annual average temperature of 23.6°C and rainfall of 5,048 mm. The experiment spanned August-October 2020, coinciding with peak monsoon conditions (June-September). The field experiment spanned from August to October 2020, utilising Lal Teer Bikrom Papaya seeds procured from a local market in Bandar Bazar, Sylhet. A Completely Randomised Design (CRD) with three replications was employed to evaluate three biopesticides against *Pythium aphanidermatum*-induced collar rot in papaya (*Carica papaya* cv. Lal Teer Bikrom). Seeds (sourced locally from Bandar Bazar, Sylhet) were sown in metallic trays (0.5 m × 1.0 m) filled with a soil:cow dung (2:1) mixture, pre-treated for 15 days under polythene sheets (Figure 1). Four treatments were applied:

T0: Untreated control

T1: Bioderma solid (20 g/kg soil; ISPAHANI Agro, Ltd.)



Figure 1. seed bed after seed sowing.

T2: Trichoderma solid (20 g/kg soil; IPM Lab, Bangladesh Agricultural University)

T3: Bioderma powder (5 g/kg soil; ISPAHANI Agro Ltd.)

Biopesticides were incorporated into the soil 4 days prior to sowing. Thirty pre-soaked (12 h) seeds were sown per tray on September 1, 2020, with germination observed by September 8, 2020. Data collection encompassed parameters such as germination percentage, leaf count, shoot and root lengths, seedling vigour, infected leaves per tray, disease incidence and severity percentages, and disease inhibition percentage. Statistical analysis employed DMRT and LSD through R software (Agricola package).

Specimen preparation and sample placement

Papaya seedlings with infected roots were collected from the seedbed and washed with clean running water. With a sterile blade, the infected and healthy parts were cut into small pieces. The specimen was then dipped in Clorox (1%) for 30 s before being rinsed with sterile water for nearly 1-2 min. The sterilised portion was then transferred (Figure 2 (a) and (b)) to a petri dish containing PDA media under laminar flow. After that, the Petri dish was placed in an incubation chamber at room temperature. The specimen was prepared on September 21, 2020.

Incubation and fungal identification

After 7 days, a white cotton-like colony was visible in the incubated petri dish (Figure 3). A portion of the colony was transferred to the slide for preparation. The sample was then examined under a compound microscope until the expected pathogen was discovered.

RESULTS

Identification of causal agent

During studies, three commercial biopesticides, viz, Bioderma solid, Trichoderma solid, and Bioderma Powder, were tested against papaya collar rot. The collar rot of papaya (Figure 4) is caused by several organisms, viz, *Pythium aphanidermatum, Sclerotium rolfsiii,* and *Rhizoctonia solani* (Lookabaugh, 2013). From this study, *Pythium aphanidermatum* was confirmed as the causal agent of papaya collar rot, having the following characteristics: Hyphae are hyaline, no cross walls on mycelium, oospores are aplerotic illustrated in Figure 5 (Ashwathi *et al.*, 2017). Koch's postulate was proved to show the pathogenicity of the fungus.

Effect of treatments on germination and seedling growth

Biopesticide treatments significantly influenced germination and growth parameters (Table 1). Trichoderma (solid) treatment (T2) recorded the highest germination rate (88.9%) and improved seedling vigour (1592.2), followed



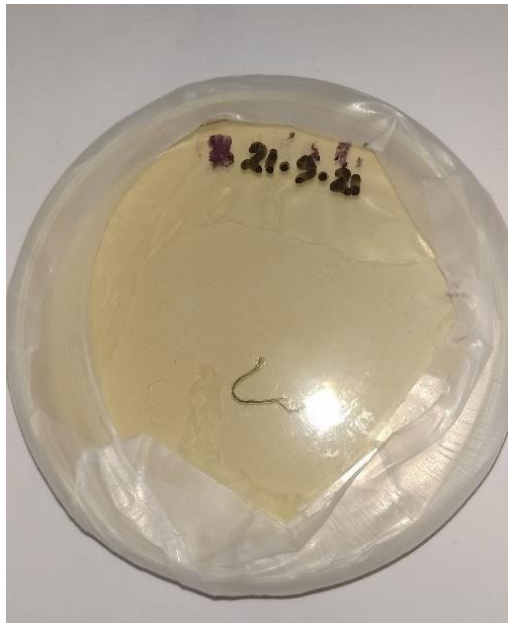


Figure 2. Placement of specimen in the petri dish containing PDA media.

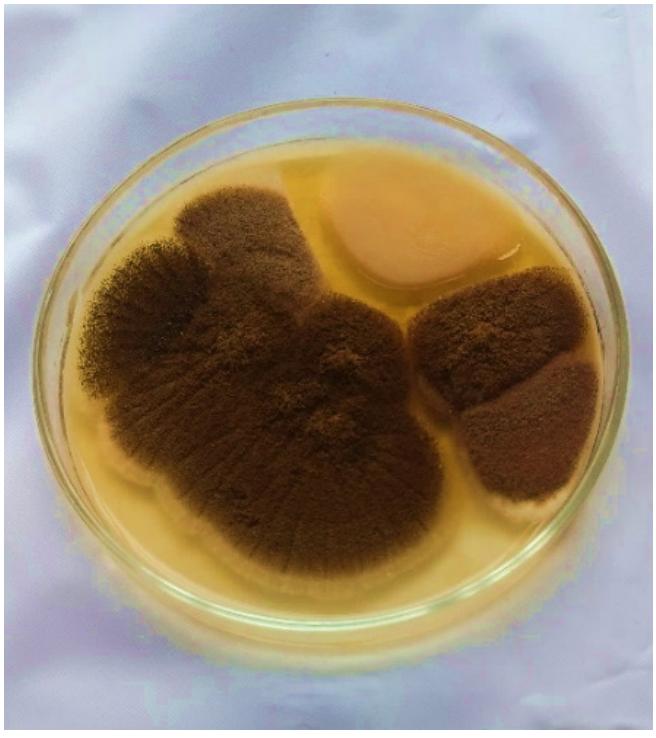


Figure 3. Fungal growth after 7 days of incubation.



Figure 4. Typical Collar rot symptoms of papaya seedlings.

by Bioderma (solid) (T1). In contrast, the untreated control (T0) consistently showed the lowest performance across all parameters.

Shoot and root lengths were also significantly enhanced in T2 (9.07 cm and 8.83 cm, respectively), while T0 had the shortest measurements (4.10 cm and 3.63 cm). Similar trends were observed in leaf number, with T2 recording the highest (7.67) and T0 the lowest (3.33).

Disease suppression by treatments

Disease metrics varied significantly across treatments. Trichoderma (T2) exhibited superior disease management, with the lowest disease incidence (11.1%), severity (12.4%), and infected seedlings per tray (3.33). In contrast, the control (T0) had the highest disease incidence (71.1%) and severity (77.7%). Disease inhibition followed a similar trend, with T2

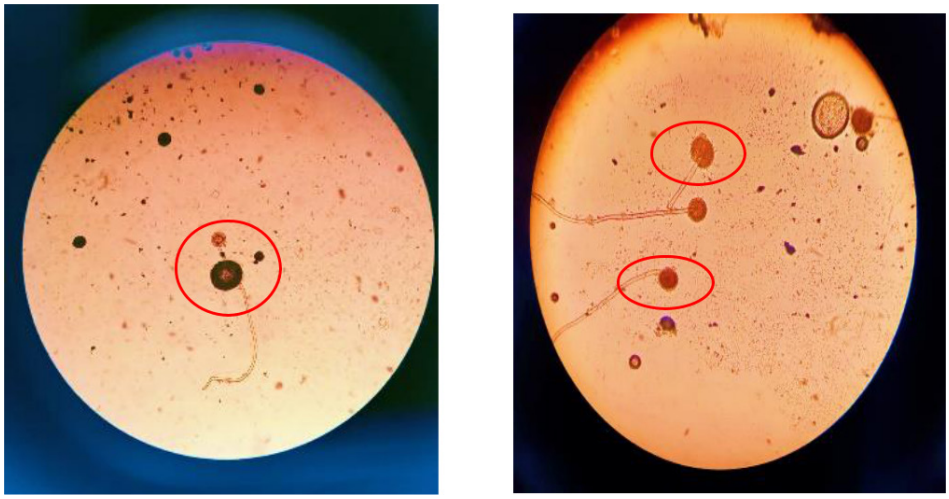


Figure 5. Oospores identification of *Pythium aphanidermatum* under compound microscope.

Table 1. Effect of treatments on germination, shoot/root length, seedling vigour, and number of leaves

Treatment	Germination (%)	Shoot length (cm)	Root length (cm)	Leaves/plant	Seedling vigour
T0	41.1 ± 8.40 c	4.10 ± 0.36 c	3.63	3.33	321.2 ± 93.8 d
T1	75.5 ± 6.93 a	6.10 ± 0.36 b	6.83	5.67	979.8 ± 140.8 b
T2	88.9 ± 5.10 a	9.07 ± 0.55 a	8.83	7.67	1592.2 ± 128.4 a
T3	61.1 ± 5.08 b	4.97 ± 0.45 c	5.00	4.67	607.7 ± 34.1 c

achieving the highest inhibition rate (84.8%), followed by T1 (63.8%) and T3 (42.3%) (Table 2).

Overall, Trichoderma (solid application) proved to be the most effective in promoting seedling growth and suppressing collar rot caused by *Pythium aphanidermatum*. This highlights the potential of eco-friendly biopesticides as viable alternatives to chemical fungicides in nursery management.

DISCUSSION

Trichoderma-treated seeds exhibited the highest germination rates, likely due to the production of growth-promoting compounds such as auxins and cytokinins (Campos *et al.*, 2020). Desai *et al.* (2022) also reported that *T. harzianum* enhanced papaya seed germination by 89% and expedited seedling emergence within 6 days. Similar effects were noted in okra by Mukhtar (2008, where different *Trichoderma* species improved seed germination.

Significant improvement in shoot and root length was observed with Trichoderma (solid) treatment (Table 2, Figure 4), which may be attributed to its role in regulating plant hormones and enhancing nutrient uptake (Stewart & Hill, 2014). These results align with findings by Sánchez-Rangel *et al.* (2016), where Trico-SP6 increased papaya height and managed disease incidence effectively. Lo and Lin (2002) also reported growth enhancement in cucurbitaceous crops due to specific *Trichoderma* strains.

Table 2. Disease incidence, severity, and inhibition by treatment

Treatment	Disease Incidence (%)	Disease Severity (%)	Disease Inhibition (%)
T0	71.1 ± 10.2 a	77.7	0.00
T1	25.5 ± 6.93 bc	29.4	63.8 ± 4.28 b
T2	11.1 ± 1.91 c	12.4	84.8 ± 2.03 a
T3	40.0 ± 6.70 b	46.9	42.3 ± 6.47 c

Seedling vigour was maximised with Trichoderma (solid) treatment (Table 1), supporting the hypothesis that Trichoderma-based biopesticides positively influence physiological and biological functions El-Mohamedy (2004). Zin and Badaluddin (2020) further validated this, showing a direct correlation between Trichoderma application and enhanced seedling vigour.

Regarding disease suppression, Trichoderma (solid) proved to be the most effective among the biopesticides tested. It showed the lowest disease severity and incidence, likely due to the production of antifungal metabolites and lytic enzymes that inhibit pathogen growth (Cook, 2000; Dennis & Webster, 1971; Lee *et al.*, 2016).

Trichoderma (solid) also recorded the highest disease inhibition rate (Table 2), consistent with previous studies that demonstrated its antagonistic activity against *Pythium aphanidermatum* (Jayaseelan *et al.*, 2012). Additional research by Datta and Das (2002), Sharma and Sain (2003), and Muthukumar *et al.* (2011) confirmed the effectiveness of Trichoderma species in managing pathogens like *Sclerotium rolfsii* and *Pythium aphanidermatum.*

CONCLUSION

This study demonstrates the effectiveness of biocontrol agents in managing papaya collar rot, with *Trichoderma* solid (T2) showing the highest disease suppression and growth promotion. The results highlight microbial antagonists as sustainable alternatives to chemical fungicides, enhancing seedling resilience and reducing agrochemical use. Further research is needed to clarify the mechanisms of *Trichoderma* spp. and their broader role in controlling seedling diseases, which holds great potential for sustainable tropical horticulture and food security.

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