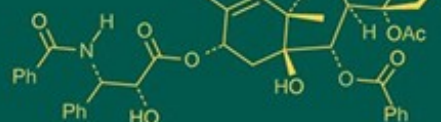
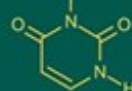


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Efficacy of fungicides against anthracnose of dragon fruit (*Hylocereus* spp.) caused by *Colletotrichum gloeosporioides* under laboratory conditions

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ABSTRACT

Dragon fruit, belonging to the genus *Hylocereus* of the Cactaceae family, is a tropical climbing cactus recognized for its considerable nutritional value and numerous health-promoting properties. Despite its increasing cultivation, the crop is highly susceptible to several fungal diseases, among which anthracnose, Anthracnose caused by *Colletotrichum gloeosporioides* represents a major disease problem, with its development being favored by high humidity and excessive moisture. The present study was conducted during 2024–25 at the Department of Plant Pathology, College of Agriculture, Junagadh Agricultural University, Junagadh, to determine the in vitro efficacy of non-systemic, systemic and ready-mixed fungicides in suppressing the growth of *C. gloeosporioides* using the poisoned food technique. A total of twenty-one fungicides, comprising seven non-systemic, seven systemic and seven ready-mixed formulations, were tested at various concentrations using a Completely Randomized Design with three replications. Among the non-systemic fungicides evaluated, copper oxychloride 50 WP exhibited the highest efficacy, resulting in 82.83% inhibition of mycelial growth, followed by propineb 70 WP and chlorothalonil 75 WP. In the systemic fungicide group, propiconazole 25 EC was the most effective treatment, with 91.28% mycelial growth inhibition, followed by thiophanate methyl 70 WP and difenoconazole 25 EC. Among the ready-mixed fungicides, zineb 68 + hexaconazole 4 WP demonstrated the greatest inhibitory effect (86.65%), followed by tebuconazole 50 + trifloxystrobin 25 WG and captan 70 + hexaconazole 5 WP.

Keywords: Dragon fruit, Anthracnose disease, *Colletotrichum gloeosporioides*, Fungicides, Mycelial inhibition

1. Introduction

Dragon fruit (*Hylocereus* spp.) is a climbing cactus belonging to the family Cactaceae and is widely recognized as a tropical fruit. It is commonly known as pitaya, pitahaya or strawberry pear. In India, it is popularly called Kamalam, owing to the lotus-like appearance of its fruit. The crop originated in South and Central America and is now cultivated extensively in tropical and subtropical regions worldwide. Dragon fruit is regarded as a nutritious fruit because it contains essential vitamins, minerals, complex carbohydrates, dietary fibre and antioxidant compounds. In addition, the fruit promotes the proliferation of beneficial microorganisms in the gut and contains betacyanin, a red-purple pigment known for its potent antioxidant properties. The fruit is also low in calories and cholesterol but provides considerable antioxidant content, which may support cardiovascular health and assist in maintaining normal blood pressure (Patel *et al.*, 2019) [1].

In India, dragon fruit cultivation has expanded considerably, covering approximately 14,640 ha with a production of 55,780 MT during 2024–2025. In India, cultivation of this crop is reported in several states and union territories, namely Andhra Pradesh, Mizoram, Maharashtra, Karnataka, Gujarat, Kerala, Tamil Nadu, Odisha, West Bengal, Tripura, Telangana and the Andaman and Nicobar Islands (Anon., 2023) [2]. Among the important production regions, Kutch district of Gujarat is a major dragon fruit-growing area. In Gujarat, dragon fruit is cultivated over approximately 1,214 ha, with a reported production of 4,079.3 tonnes and with a productivity of about 3.36 tonnes ha⁻¹.

Dragon fruit is vulnerable to infection by numerous fungal pathogens, with around 21 fungal species reported to be associated with various diseases. In India, several important diseases have been reported, including stem canker caused by *Neoscytalidium dimidiatum*, anthracnose caused by *Colletotrichum* spp., fruit rot or blotch caused by *Bipolaris cactivora*, stem rot caused by *Fusarium* spp., stem or brown spot associated with *Botryosphaeria dothidea* and *Alternaria blight* caused by *Alternaria* spp. Environmental conditions such as heavy rainfall, excessive irrigation and waterlogging can favour the development and spread of these fungal diseases. These diseases pose a significant threat to dragon fruit production, especially when en

vironmental conditions favour disease development. Furthermore, red-fleshed dragon fruit cultivars have been reported to exhibit greater susceptibility to anthracnose compared with white-fleshed cultivars.

2. Materials and Methods

The study was carried out under laboratory conditions in the Department of Plant Pathology, College of Agriculture, Junagadh Agricultural University, Junagadh, during 2024–25. A total of seven fungicides, comprising non-systemic, systemic, and ready-mixed formulations, were evaluated at three different concentrations against *Colletotrichum gloeosporioides* using the poisoned food technique described by Bagchi *et al.* (1968) [3]. An experiment was laid out in Completely Randomized Design (factorial concept) with three repetitions.

The study was undertaken to determine the *in vitro* efficacy of various fungicides against *Colletotrichum gloeosporioides*, the pathogen responsible for anthracnose of dragon fruit. The fungicides were classified into three groups based on their mode of action and formulation. The non-systemic group comprised seven fungicides, namely chlorothalonil 75 WP, copper oxychloride 50 WP, mancozeb 75 WP, metiram 70 WG, propineb 70 WP, wettable sulphur 80 WP and zineb 75 WP, which were evaluated at concentrations of 1000, 1500 and 2000 ppm. The systemic group consisted of seven fungicides, viz., carbendazim 50 WP, difenoconazole 25 EC, kresoxim-methyl 44.3 SC, propiconazole 25 EC, hexaconazole 5 EC, fosetyl-Al 80 WP and thiophanate-methyl 70 WP, tested at 100, 250 and 500 ppm.

Furthermore, seven ready-mixed fungicides, namely azoxystrobin 11% + tebuconazole 18.3% SC, mancozeb 40% + azoxystrobin 7% OS, captan 70% + hexaconazole 5% WP, carbendazim 25% + mancozeb 50% WS, fluxapyroxad 250 g/L + pyraclostrobin 250 g/L, hexaconazole 4% + zineb 68% WP and tebuconazole 50% + trifloxystrobin 25% WG, were assessed at 100, 250 and 500 ppm against *C. gloeosporioides* under laboratory conditions.

The poisoned food technique, as described by Grover *et al.* (1962) [4], was employed to determine the efficacy of different fungicides against *Colletotrichum gloeosporioides*. The required quantity of each fungicide was added to 100 ml of autoclaved potato dextrose agar (PDA) medium contained in a 250 ml conical flask before solidification. A digital balance was used for weighing solid formulations, whereas a micropipette was used for measuring liquid formulations. The medium was thoroughly mixed by shaking on a vortex mixer and subsequently dispensed into sterilized Petri plates (90 mm diameter) at a uniform volume of 20 ml per plate. The plates were then allowed to solidify. Following solidification, a 4 mm diameter disc of actively growing mycelium of *C. gloeosporioides* was excised using a sterilized cork borer and placed aseptically at the centre of each Petri plate, with the mycelial surface in direct contact with the PDA medium. The inoculated plates were incubated at 28 ± 1 °C until complete growth was observed in the untreated control plates. Radial mycelial growth of *C. gloeosporioides* was measured in both fungicide-treated and control plates. PDA plates without fungicide served as the untreated control (Grover *et al.*, 1962) [4]. The percentage inhibition of mycelial growth was calculated using the formula proposed by Vincent (1947) [5].

$$I = \frac{C - T}{C} \times 100$$

Where,

I = Per cent inhibition of mycelial growth

C = Mean radial growth of fungus in control plate (mm)

T = Mean radial growth of fungus in treated plate (mm)

2.1 Statistical analysis

The experimental data were subjected to statistical analysis following the standard procedures described by Panse *et al.* (1985) [6]. The percentage values obtained were transformed into angular values before statistical analysis.

3. Results and Discussion

The mycelial growth inhibition caused by non-systemic, systemic and ready-mixed fungicides was assessed nine days after inoculation. The results obtained are presented below.

3.1 Efficacy of Non-Systemic Fungicides Against *C. gloeosporioides*

In vitro

The results presented in Table 1, Figure 1 and Plate I-A indicated that all the non-systemic fungicides exhibited inhibitory effects on the *in vitro* mycelial growth of *C. gloeosporioides* compared with the untreated control.

The tested non-systemic fungicides significantly suppressed the mycelial growth of the pathogen in comparison with the untreated control. Among the fungicides evaluated *in vitro*, copper oxychloride 50 WP exhibited the greatest inhibitory effect, with 82.83 per cent mean inhibition of mycelial growth. This was followed by propineb 70 WP (60.17%) and chlorothalonil 75 WP (55.60%). Mancozeb 75 WP (49.54%) and zineb 75 WP (47.63%) showed comparatively moderate effectiveness.

At concentrations of 1000, 1500 and 2000 ppm, copper oxychloride 50 WP exhibited the highest inhibitory effect against the pathogen, with mycelial growth inhibition of 72.27%, 86.72% and 89.50%, respectively. Propineb 70 WP also demonstrated considerable effectiveness, particularly at 2000 ppm. Overall, copper oxychloride 50 WP and propineb 70 WP were found to be the most promising treatments for suppressing the mycelial growth of *C. gloeosporioides* under *in vitro* conditions.

Chlorothalonil 75 WP and zineb 75 WP exhibited relatively higher inhibitory activity, recording 71.16 and 72.83 per cent inhibition, respectively, at 2000 ppm. Wettable sulphur 80 WP showed comparatively moderate efficacy, with mycelial growth inhibition of 34.10, 48.37 and 52.45 per cent at 1000, 1500 and 2000 ppm, respectively. At 1000 ppm, zineb 75 WP recorded the lowest inhibition (27.24%), indicating comparatively lower effectiveness at this concentration.

The interaction between fungicides and their respective concentrations indicated that copper oxychloride 50 WP performed significantly better at all the tested concentrations, recording an overall mean inhibition of 82.83%. Propineb 70 WP applied at 2000 ppm was the next most effective treatment, producing 80.05% inhibition of mycelial growth. In contrast, wettable sulphur 80 WP at 1000 ppm recorded the lowest inhibition (34.10%), which was statistically at par with chlorothalonil 75 WP at 1000 ppm (35.03%).

The present findings are consistent with the observations reported by Kadlag *et al.* (2023) [7] and Shedge *et al.* (2021) [8], who documented the strong efficacy of copper oxychloride 50 WP in suppressing the mycelial growth of the pathogen.

3.2 Efficacy of systemic fungicides against *C. gloeosporioides* *in vitro*

The findings presented in Table 2, Figure 2 and Plate I-B indicated that all the systemic fungicides tested exhibited inhibitory effects on the *in vitro* mycelial growth of *C. gloeosporioides* compared with the untreated control.

The systemic fungicides assessed in this study demonstrated a marked decrease in the mycelial growth of the target pathogen compared to the untreated control group. Among the fungicides tested, propiconazole 25 EC emerged as the most effective, achieving an impressive average mycelial growth inhibition of 91.28%. This level of inhibition was significantly superior to all other fungicides evaluated, highlighting its robust efficacy in controlling the pathogen in *in vitro* conditions.

Among the fungicides evaluated, thiophanate methyl 70 WP ranked second in efficacy, achieving 79.86% inhibition of mycelial growth. Its pronounced inhibitory activity indicated good antifungal potential; however, its performance was significantly lower than that of propiconazole. Difenoconazole 25 EC was the next most effective treat

ment, exhibiting 76.41% inhibition of mycelial growth and demonstrating appreciable activity against the pathogen.

Carbendazim 50 WP exhibited a comparatively moderate antifungal activity, with 75.11% inhibition of mycelial growth, while hexaconazole 5 EC resulted in 69.92% inhibition. On the other hand, markedly lower inhibitory effects were observed with kresoxim-methyl 44.3 SC and fosetyl-Al 80 WP, which restricted mycelial growth by only 39.97% and 18.71%, respectively, making them the least effective fungicidal treatments.

Propiconazole 25 EC maintained its superior inhibitory effect across the entire concentration range evaluated, with the highest efficacy observed at 100, 250, and 500 ppm. A pronounced inhibitory response was also obtained with thiophanate methyl 70 WP at 500 ppm. The efficacy of carbendazim 50 WP increased progressively with concentration, reaching 81.53% and 86.17% inhibition at 250 and 500 ppm, respectively. Hexaconazole 5 EC likewise performed effectively at the higher concentration, producing 84.49% inhibition of mycelial growth at 500 ppm.

The findings obtained in the present investigation corroborate earlier reports by Rajashree *et al.* (2020) [9] and Gopinath *et al.* (2006) [10]. Both studies highlighted the superior antifungal activity of propiconazole 25 EC and thiophanate methyl 70 WP in restricting the mycelial growth of *Colletotrichum* spp.

3.3 Efficacy of Ready-Mixed Fungicides Against *C. gloeosporioides*

In vitro

The results summarized in Figure 3, and Plate I-C demonstrated that each of the ready-mixed fungicide formulations effectively suppressed the *in vitro* mycelial growth of *C. gloeosporioides* compared with the untreated control.

An *in vitro* evaluation was conducted to determine the efficacy of seven ready-mix fungicides against *C. gloeosporioides* at 100, 250 and 500 ppm concentrations. The fungicides were tested by employing the poisoned food technique and each treatment was replicated three times. Mycelial growth inhibition was assessed and recorded nine days following inoculation.

A significant reduction in mycelial growth was observed with all the ready-mix fungicide treatments when compared with the untreated control. Among the fungicides evaluated, zineb 68 + hexaconazole 4 WP exhibited the highest inhibitory effect, with a mean mycelial growth inhibition of 86.65%. This was followed by tebuconazole 50 + trifloxystrobin 25 WG and captan 70 + hexaconazole 5 WP, which recorded 85.42% and 83.34% inhibition, respectively. Carbendazim 12 + mancozeb 63 WP and azoxystrobin 11 + tebuconazole 18.3 SC exhibited intermediate levels of inhibition, with 78.38% and 72.33%, respectively. In comparison, fluxapyroxad + pyraclostrobin SC and mancozeb 40 + azoxystrobin 7 OS produced comparatively lower inhibition of 69.56% and 66.10%, respectively. Despite their lower efficacy among the tested treatments, both fungicides resulted in greater inhibition of the pathogen than the untreated control.

The present results are consistent with earlier investigations demonstrating the effectiveness of ready-mix fungicides against *Colletotrichum* spp. In particular, Kanase (2018) [11] reported the effective performance of zineb 68 + hexaconazole 4 WP against *Colletotrichum* spp., supporting the superior activity of this combination observed in the present study.

4. Conclusion

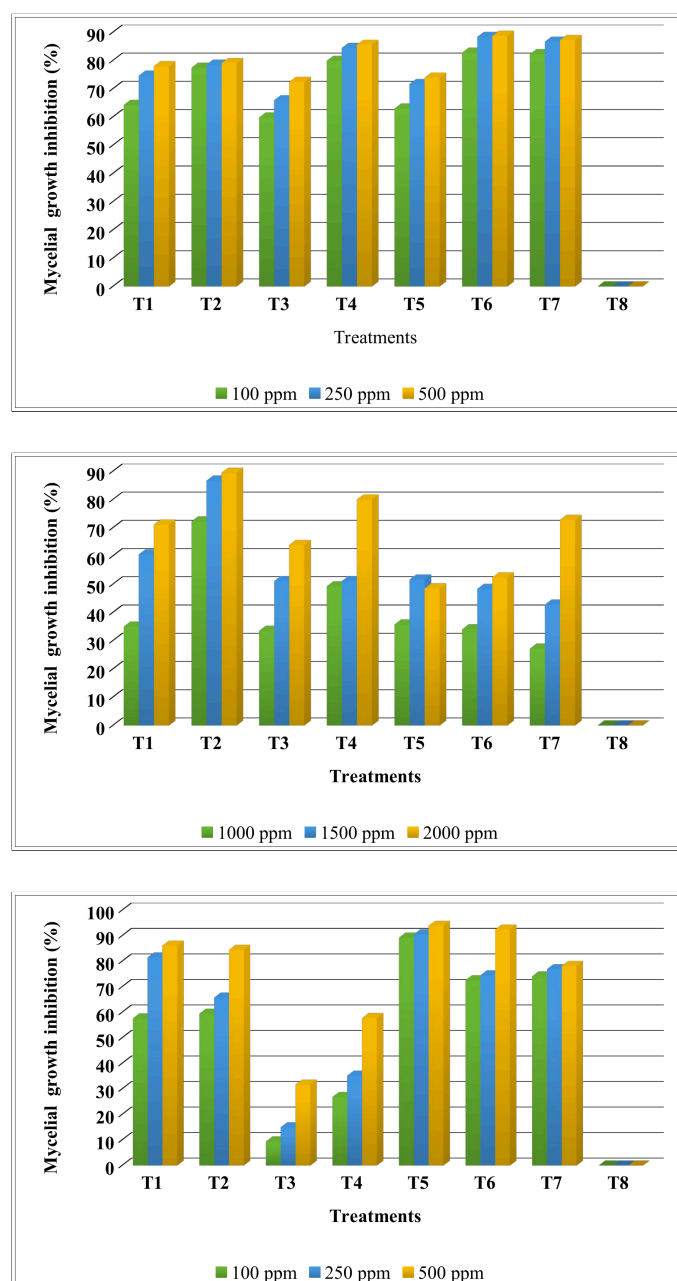
The present investigation demonstrated that both non-systemic and systemic fungicides, along with ready-mix fungicides, were effective in suppressing the *in vitro* mycelial growth of *Colletotrichum gloeosporioides*, the causal agent of anthracnose of dragon fruit

(*Hylocereus* spp.). Among the fungicides evaluated, propiconazole 25 EC was the most effective systemic fungicide, recording the highest mean mycelial growth inhibition of 91.28%. The non-systemic fungicides also exhibited considerable inhibitory activity against the pathogen, while zineb 68 + hexaconazole 4 WP proved to be the most effective ready-mix fungicide. A general increase in mycelial growth inhibition was observed with increasing fungicide concentration. The findings emphasize that appropriate selection of effective fungicides and their application at suitable concentrations can contribute significantly to the management of anthracnose of dragon fruit.

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Figures



1500 ppm
1000 ppm



Treatments**T₁ : Chlorothalonil 75 WP****T₂ : Copper oxychloride 50 WP****T₃ : Mancozeb 75 WP****T₄ : Propineb 70 WP****T₅ : Metiram 70 WG****T₆ : Wettable sulphur 80 WP****T₇ : Zineb 75 WP****T₈ : Control****[A]****250 ppm****500 ppm**

100 ppm

500 ppm
100 ppm
250 ppm



Treatments

T₁ : Azoxystrobin 11 + Tebuconazole 18.3 SC
T₂ : Carbendazim 25 + Mancozeb 50 WS
T₃ : Mancozeb 40 + Azoxystrobin 7 OS
T₄ : Captan 70 + Hexaconazole 5 WP
T₅ : Fluxapyroxad 250g/l + Pyraclostrobin 250g/l
T₆ : Zineb 68 + Hexaconazole 4 WP
T₇ : Tebuconazole 50 + Trifloxystrobin 25 WG

T₈ : Control
Treatments
T₁ : Carbendazim 50 WP
T₂ : Hexaconazole 5 EC
T₃ : Fosetyl AL 80 WP
T₄ : Kresoxim methyl 44.3 SC
T₅ : Propiconazole 25 EC
T₆ : Thiophanate methyl 70 WP
T₇ : Difenconazole 25 EC
T₈ : Control
[C]
[B]

Plate I. Efficacy of non-systemic [A], systemic [B] and ready-mixed [C] fungicides against *A. alternata* in vitro

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12. Mean mycelial growth inhibition (%). 2000 ppm.
13. F x C.
14. Note: * Mean of three repetitions.
15. Data outside the parentheses are arcsine transformed, whereas inside are re-transformed values.
16. Mean mycelial growth inhibition (%).
17. 500 ppm.
18. F x C.
19. Note: * Mean of three repetitions.
20. Data outside the parentheses are arcsine transformed, whereas inside are re-transformed values.
21. Mean mycelial growth inhibition (%).
22. 500 ppm.
23. F x C.
24. Note: * Mean of three repetitions Data outside the parentheses are arcsine transformed, whereas inside are re-transformed values. 2000 ppm.

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