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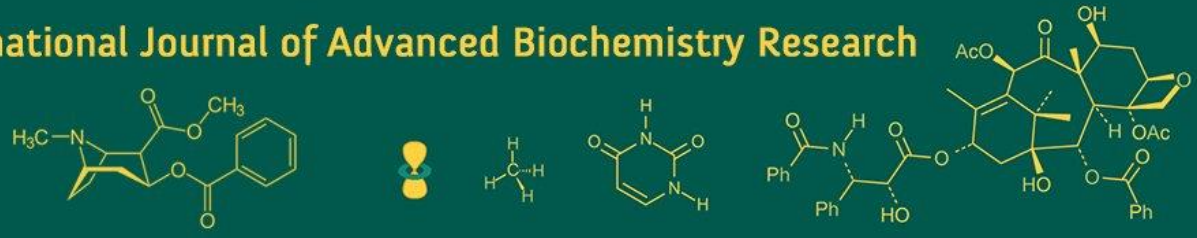

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In vitro efficacy of fungicides against *Fusarium oxysporium* f.sp. *cubense*

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Abstract
The six fungicides, carbendazim, propiconazole, carbendazim + mancozeb, copper oxychloride, tebuconazole and azoxystrobin + tebuconazole in different concentrations were evaluated against mycelia growth of the causal pathogen *Fusarium oxysporum* f.sp. *cubense in vitro* by poisoned food technique. Observations were taken at 2 days intervals up to 7th days for the assessment of their inhibitory effects. Among them, novel fungicide carbendazim, propiconazole and carbendazim + mancozeb with 0.1%,0.05% and 0.25% concentrations were found to be most effective against the pathogen followed by copper oxychloride, tebuconazole and azoxystrobin + tebuconazole 0.25%, 0.05% and 0.1% respectively after 7th days of treatment. The pathogen fungus continued to increase up to 7th days showing a radial growth of 90 mm in control.

Keywords: Fungicide, *Fusarium oxysporum* f.sp. *cubense*, *in vitro*, poisoned food technique

Introduction
Since many diseases infested the banana cultivation, but the most destructive disease of banana plantain is *Fusarium oxysporum* f.sp. *cubense*. *Fusarium oxysporum* f.sp. *cubense* is also known as Panama wilt disease. Panama wilt is soil borne disease, fungus colonizes the roots of rhizomes and pseudostem with characteristic symptoms of wilting before plant eventually dies (Wardlaw, 1961; Stover, 1962) [9, 6]. Panama wilt is most destructive disease-causing heavy losses in banana growing areas. Panama wilt is considered to be originated in Southeast Asia from there was disseminated rapidly throughout the world with infected rhizomes (Stover, 1962) [6]. Panama wilt is major threat in the world for banana cultivation, infected rhizomes and susceptible cultivars play significant role in spread of this disease. Panama wilt of banana is effectively controlled by applying disease-preventive practices such as planting disease-free propagating material. Once infested with the pathogen, the only way of continuing banana production is by means of planting cultivars with resistance to the disease (Deacon, 1984; Ploetz and Pegg, 2000; Viljoen, 2002; Ploetz *et al*., 2003) [1, 4, 7, 5]. Cultivar with resistance to Foc have been identified, but this cultivar are not acceptable in local market by farmers (Viljoen, 2002) [7]. *In vitro* evaluation of fungicides provides preliminary information regarding its efficacy against a pathogen within a shortest period of time and therefore, serves as a guide for further field testing. Hence, the present investigation was undertaken to screen a range of fungicides, including new chemical formulations, for their ability to inhibit the mycelial growth of Foc *in vitro*.

Material and Methods
An experiment was conducted during 2023 at College of Agriculture, Dhule (Maharashtra) to find out the effective fungicide against *Fusarium oxysporum* f.sp. *cubense* in *in vitro*. The experiment was designed in Complete Randomized Design (CRD) with four replications and six treatments. The six fungicides were evaluated against Panama wilt pathogens under laboratory conditions by following poison food technique (Nene and Thapliyal, 1993) [2]. The details of the fungicides used were given below table 1.

Table 1: Details of fungicides

Sl. No.	Common name	Chemical name	Trade name	Dose (in percent)
1.	Propiconazole (25% EC)	1-[[2-(2,4-dichlorophenyl)-4-propyl-1,3-dioxolan-2-yl] methyl]-1H-1,2,4-triazole	Tilt	0.05
2.	Tebuconazole (25.9 EC)	1-(4-chlorophenyl)-4,4-dimethyl-3-(1H-1,2,4-triazol-1-ylmethyl) pentan-3-ol	Folicure	0.05
3.	Carbendazim (50% WP)	Methyl benzimidazol-2-ylcarbamate	Bavistin	0.1
4.	Copper Oxychloride (50% WP)	Di-Copper Chloride Trihydroxide	Blitox	0.25
5.	Carbendazim 12% + Mancozeb 63%	(1H-1,3-benzimidazol-2-yl)carbamate + manganese ethylenebis(dithiocarbamate)	SAAF	0.25
6.	Azoxystrobin 11% + Tebuconazole 18.3% SC	(methyl (E)-2-(2-(6-(2-cyanophenoxy)pyrimidin-4-yloxy)phenyl)-3-methoxyacrylate) + (4-chloro-N-(1-(4-chlorophenyl)-2-propoxyethyl)-1H-1,2,4-triazol-3-amine).	Custodia	0.1

The fungicides suspension was made by adding required quantity of fungicides to the melted PDA medium to obtain the desired concentration. 20 ml of poisoned medium was poured in each sterilized Petri plates. Mycelial disc of 5 mm size from actively growing zone of seven days old culture was cut by a sterile cork borer and one such disc was placed at the centre of each agar plate. Control treatment was maintained without adding any fungicide to the medium. Four replications were maintained for each concentration. Then such plates were incubated at room temperature and radial growth was measured when fungus attained maximum growth in control plates. percent inhibition of mycelial growth over control was calculated by using the formula given by Vincent (1947) [8].

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

Where,
PI = percent inhibition.
C = Radial growth of test fungus in control plate
T = Radial growth of test fungus in treated plate

Results and Discussion

The efficacy of various fungicidal treatments against *Fusarium oxysporum* f.sp. *cubense* was evaluated *in vitro* based on the radial mycelial growth inhibition. The results clearly revealed that significant variation in the degree of fungal suppression depending on the chemical used. The highest inhibition (100%) of fungal growth was recorded in the treatments Propiconazole 25% EC @ 0.5 ml/L, Carbendazim 50% WP @ 1 g/L and Carbendazim 12% + Mancozeb 63% WP @ 2.5 g/L all of which completely suppressed the radial growth of the fungus, with a mean colony diameter of 0.00 mm. Treatment Tebuconazole 25.9% EC also showed very high efficacy with 99.14% inhibition and a minimal colony diameter of 0.50 mm. Moderate inhibition was recorded with Copper Oxychloride 50% WP @ 2.5 g/L and Azoxystrobin 11% + Tebuconazole 18.3% SC @ 1 ml/L, which resulted in mean colony diameters of 22.31 mm and 29.63 mm, corresponding to 75.21% and 67.07% inhibition over control, respectively (Table 2). The untreated control showed maximum fungal growth with a colony diameter of 90.00 mm, confirming the virulence of the pathogen in the absence of any fungicidal interference (Figure 1).

Overall, the study suggests that Propiconazole, Carbendazim, and Carbendazim + Mancozeb are the most promising fungicides for managing *F. oxysporum* f. sp. *cubense* under *in vitro* conditions, and their field evaluation under natural conditions would be necessary to confirm their practical utility in disease management programs. Similar study was carried out by Niwas *et al*., (2020) [3] which found that among the three fungicides tested, (carbendazim, azoxystrobin and propiconazole), carbendazim @ 500 ppm and 750 ppm completely inhibited the growth of *Fusarium oxysporum* f. sp. *cubense* followed by azoxystrobin (32.96, 11.30, 8.12 and 7.16 mm in 100, 250, 500 and 750 ppm, respectively). The maximum mycelial growth was recorded in propiconazole, the similar result, it shows strong support to current finding.

Table 2: Efficacy of different chemicals against radial growth of *Fusarium oxysporum* f.sp *cubense in vitro*.

Treatments	Chemicals	Concentration (%)	Dose (gm or ml/l)	Mean Colony diameter (mm)	Percent inhibition over control
T_1	Propiconazole 25% EC	0.05	0.5 ml/L	0	100
T_2	Tebuconazole 25.9% EC	0.05	0.5 ml/L	0.50	99.44
T_3	Carbendazim (50% WP)	0.1	1g	0.00	100
T_4	Copper Oxychloride (50% WP)	0.25	2.5g	22.31	75.21
T_5	Carbendazim 12% + Mancozeb 63% WP	0.25	2.5g	0.00	100
T_6	Azoxystrobin 11% + Tebuconazole 18.3% SC	0.1	1 ml/L	29.63	67.07
T_7	Control	0	0	90.00	0
S Em±				0.45	-
CD at 1%				1.79	

*Figure in the parentheses indicate corresponding √(x + 0.5) transformed mean.

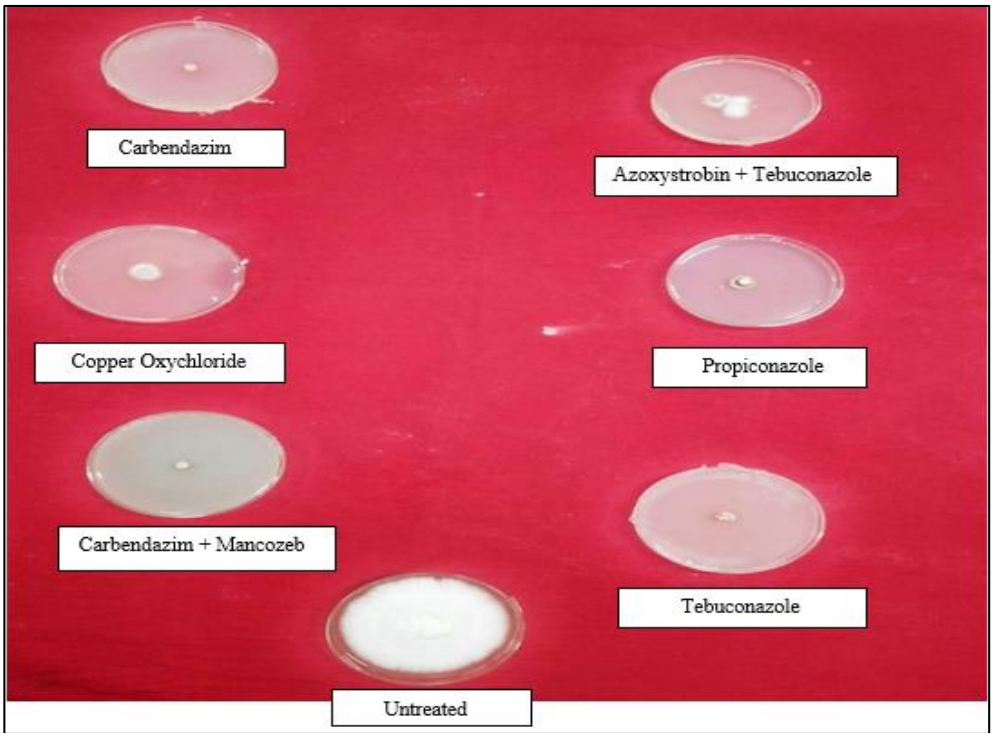

Fig 1: Efficacy of different chemicals against radial growth of *Fusarium oxysporum* f.sp *cubense in vitro*

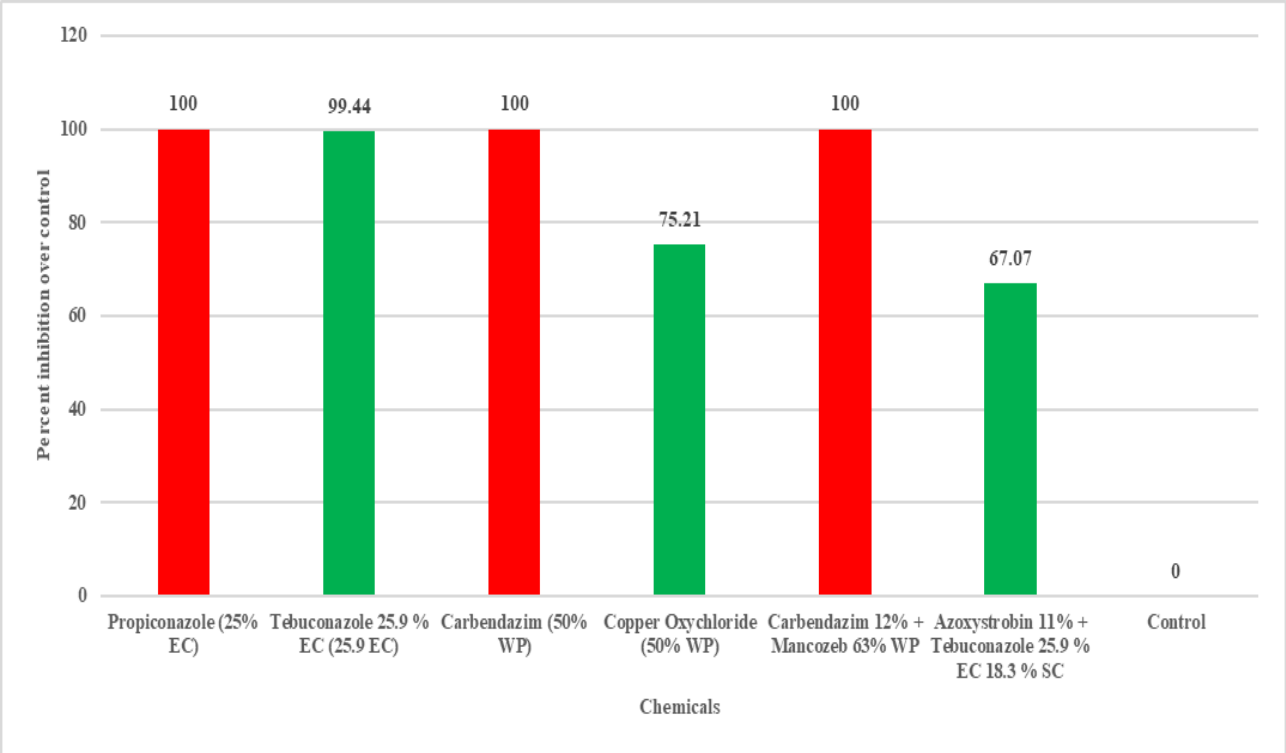

Fig 2: Efficacy of different chemicals against radial growth of *Fusarium oxysporum* f.sp *cubense in vitro*.

Conclusion

In this experimentation, among six different fungicides evaluated against FOC TR1, complete inhibition over control was observed in propiconazole, carbendazim and carbendazim + Mancozeb, respectively. While the tebuconazole, copper oxychloride and azoxystrobin + tebuconazole show moderate inhibition over control.

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