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Efficacy of Novel Fungicides against the *Fusarium oxysporum* f.sp. *cubense* Causing Panama wilt of Banana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Panama wilt of banana caused by *Fusarium oxysporum* f.sp. *cubense* TR4 is considered as most devastating disease of bananas. In Bihar, this disease became a menace to banana growers of Bihar due to introduction of new highly virulent strains *i.e*.TR 4 strain B_2. The objectives of this study were to evaluate newly available fungicides under *in vitro* and *in vivo* conditions for the efficient management of the Panama wilt of banana. Fourteen different fungicides and novel chemicals were tested *in vitro* as well as *in vivo* conditions. Native (tebuconazole 50% + trifloxystrobin 25%) was found to exhibit 100% inhibition over control *in vitro* whereas in pot conditions 86.2% inhibition over control was observed against *Fusarium oxysporum* f.sp. *cubense* TR 4 strain B_2 in cultivar Alpan (AAB).

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1. INTRODUCTION

Bananas are the main stable fruits crops for millions of people in sub-tropical and tropical regions of the world. This plant gives good returns to farmers so it is referred as to "Kalpathru"- a plant of virtues. The banana research in India is completely towards the extension of production and productivity. The production restraints also vary in country from region to region. However, numerous issues are identical in nature across the banana producing states of India and also among the various countries of the world.

"In India, presence of huge genetic diversity, various production systems and their suitability to wide range of agro climatic condition are attributed its large scale adoption. In Bihar state,there are two banana growing region one is old Vaishali belt enriched with a tall group of banana cultivars and second new Koshi belt dominated by dwarf Cavendish group of banana cultivars. Global banana production is intensely threated by the occurrence of a new highly virulent race *i.e.* TR 4. This highly virulent race became more calamitous and devastative due to absence of suitable fungicides, plant products and bio agents for the efficient management.It not only affects Cavendish clones, but many other banana cultivars susceptible to races 1 and race 2" [1]. "This pathogenic variant (TR4) was observed in Taiwan, Malaysia, Inodoneisa, MainlandChina, Philippines, Australia, Oman, Jordan, Mozambique, Lebnan, Pakistan, Laos and Vietnam. In India, first time reported in Bihar after that Uttar Pradesh, Madhya Pradesh and Gujrat" [2]. Earlier, a virulent strain of Foc has been reported in Cavendish group of banana cultivars by Mustafa et al. 2011.

"Recently, a highly virulent strain of Foc TR 4 strain B2 identified which was affecting Cavendish group of banana cv.Grand Naine (AAA) and Robusta(AAA) in Koshi belt of Bihar" [3].

Keeping given the importance of Panama wilt of banana, the present investigation is to screen a range of fungicides including new chemical formulations against the new highly virulent strain.Secondly,the aim is to determine the efficacy of some newly noble chemicals against Panama wilt of banana caused by TR 4 starin B2 under pot conditions.

2. MATERIALS AND METHODS

2.1 Isolation and Purification the Pathogen

The infected plants parts like pseudostem,roots and leaves were collected from the field.These infected parts were cut in to small pieces in 2-3 mm and surface sterilized with 0.1% $Hgcl_2$ solution for 30 seconds after that washed with distilled water to 2-3 times. These pieces were placed aseptically on PDA slants with the help of an inoculating needle and incubated at 28±ºC. The isolates were categorised in to five different groups *viz.,* Iso.M, Iso.A, Iso.K, Iso.G and Iso.R on the based on of host differential of banana cultivars.

2.2 Evaluation of Fungicides and Novel Chemicals against *Fusarium oxysporum* f.sp. *cubense in vitro*

Fourteen fungicides and novel chemicals were evaluated in laboratory against different isolates Foc *in vitro* condition. Their trade name, chemical name and formulation are given in (Table 1). For the investigation of poison food techniques 100 ml sterilized Potato dextrose agar medium was fortified with 5mg(0.005ml), 10mg(0.01ml) and 15 mg(0.015ml) of fungicides or novel chemicals independently to get 50 ppm, 100 ppm and 150 ppm concentrations. Twenty ml of each concentration of medium was poured into each sterilized Petri plate and permitted to solidify in laminar air flow. After solidification, 5 mm disc of seven days old culture of Foc isolates was placed in the centre of the Petri plates and incubated at 28 ± 2ºc. Treatments were replicated thrice along with suitable control in which fungicide was omitted in the medium. The radial growth of different isolates of *Foc* was measured after 24 hrs of inoculation and subsequent observation was recorded at 48 hrs of interval till full growth of the pathogen in control *i.e.* 240 hrs and per cent inhibition were calculated by using following formula as given by Vincent [4].

$$I = \left(\frac{C - T}{C} \right) \times 100$$

Where,

I = Per cent growth inhibition
C = Colony diameter in control Petri plate;
T = Colony diameter in the treated Petri plate.

Table 1. Fungicides and novel chemicals details used against Foc isolates causal agent of Panama wilt of banana

Trade name	Chemical name	Formulation
Bavistin	Carbendazim	50% WP
Tilt	Propiconazole	250 EC
Dithane M-45	Mancozeb	80% WP
Blitox-50	Copper oxychloride	50% WP
Contaf	Hexaconazole	5% EC
Amistar	Azoxystrobin	250 SC
Melody	Iprovalicarb 5.5% + Propineb 61.25%	66.75% WP
Sectin	Fenamidone 10% + Mancozeb 50%	60 WG
Antracol	Propineb	70 %WP
Folicure	Tebuconazole (250 EC)	250 EC
Monceren	Pencycuron	250 SC
Nativo	Tebuconazole 50% +Trifloxystrobin 25%	75WG
Aliette	Fosetyl-Al	80%WP
Luna	Fluopyram 17.7% + Tebuconazole 17.7%	400SC

The per cent inhibition data were analysed statistically using completely randomized design (C.R.D).

2.3 Evaluation of different Novel Chemicals against Foc 4 strain B_2 under Artificial Pot Condition

The effectiveness of different fungicides like iprovalicarb 5.5% + propineb 61.25% (Melody), fenamidone 10% + mancozeb 50% (Sectin), propineb (Antracol), tebuconazol(Folicure), pencycuron(Monceren), tebuconazole 50% + trifloxystrobin 25% (Nativo), fosetyl- Al (Aliette) and fluopyram + tebuconazole(Luna) were tested at 0.2 per cent concentration in Poly house under pot condition against the isolates of Foc TR4 strain B_2. The mass culture of this isolates was prepared as per the method described by Haware [5]. The mass culture of Foc TR 4 strain B_2 isolates were mixed in steam sterilized soil separately @50 g/kg soil having 10 kg sterile loamy soil / plastic pots (50cm diameter). Each fungicide with 0.2% concentration was applied as soil drenching in pathogen inoculated pots after 15 days of transplanting. Inoculation of the pot with sterilized distilled water was served as control. Each treatment was replicated three times in different banana cultivars. The disease incidence (%) was calculated by dividing the total number of transplanted plants showing Panama wilt disease symptoms by the total number of plant transplanted and then multiplying by a hundred. The data on inhibition per cent over control was also recorded in each treatment and data was recorded up to 90 days after transplanting. The data has been analysed by CRD design.

2.4 Per Cent Wilt Index (PWI, External Symptoms)

The intensity of Panama wilt of banana was recorded as per International Musa Testing Program (IMTP) rating in 1-5 scale and per cent wilt index (PWI) was determined in each plot.

Category	Reaction
1	Healthy
2	Slight chlorosis and wilting with no petiole buckling
3	Moderate chlorosis and wilting with some petiole buckling and or splitting of leaf base
4	Severe chlorosis, severe wilting, petiole buckling and dwarfing of newly emerged leaf
5	Dead

Per cent wilt index = (Total sum of numerical rating) / (Total number of plants observed × maximum category in the score chart) × 100

3. RESULTS AND DISCUSSION

3.1 Effectiveness of different Fungicides against Various Isolates of Foc Causing Panama wilt of Banana *In vitro*

Total of six fungicides *viz.,* carbendazim, copper oxychloride, strobilurin, mancozeb, propiconazole and hexaconazole at 50, 100 and 150 ppm concentration were evaluated against different isolates of Foc. The radial growth of these isolates was measured after 24 hrs of

inoculation and subsequent observations were recorded in control *i.e.* 240 hrs and per cent inhibition was calculated based on final observation. The results indicated that all the fungicides at each concentration significantly inhibited the growth of Foc, when compared with control. Data revealed that, the maximum inhibition was recorded in Iso. K (88.9%) followed by Iso. A (88.7%), Iso. M (88.5%) and Iso. R (64.6%). The minimum inhibition was found in Iso. G (63.1%) by the propiconazole, after that hexaconazole Iso. K (85.6%), Iso. A (84.8%), Iso. M (83.5%), Iso. R (52.9%), Iso. G. (52.1%) and fosetyl Al, Iso. K (67.3%), Iso. M (67.2%), Iso. A (67.0%), Iso. R (54.1%) and Iso. G (52.2%) at 150 ppm concentration followed by 100 ppm and 50 ppm concentration over the control. In case of carbendazim, the maximum inhibition was found in Iso. K (83.3%) followed by Iso. A (81.2%), Iso. M (81.1%), Iso. G (44.5%) and Iso. R (44.1%). While, mancozeb, copper oxychloride and strobilurin were found less effective against all the isolates of Foc at 50 ppm, 100 ppm and 150 ppm concentration over the control. Data about inhibition per cent over control revealed that the T_5 was found statistically superior or closely followed by T_6 and the differences between the T_5 and T_6 were recorded as significant at all levels of concentration. However, the differences between T_6 and T_1 were found non significant or efficacy wise T_6 as well as T_1 remained at par against the Iso. M and Iso. K at 150 ppm concentration. The differences between T_7 and T_6 was found non significant or T_7 at par with T_6 with the Iso. G of Foc.

The carbendazim fungicide was found highly effective against the race 1 and race 2 pathogenic variability of Foc but against race 4 (TR 4 strain B_2) was found moderately effective. Data are presented in (Table 2).

3.2 Effectiveness of different Novel Chemicals against Foc TR4 Strain B_2 (Iso G.) Causing Panama Wilt of Banana *in vitro*

This experiment was conducted on evaluation of different novel chemicals against the Iso. G (TR4 strain B_2) of Foc. Because, during earlier experimentation it was found that carbendazim showed moderately effectiveness against this isolate. Total of nine novel chemicals at 50, 100 and 150 ppm concentrations were evaluated against the Iso. G (TR4 strain B_2). The result indicated that all the novel chemicals at each concentration significantly inhibited the growth of Iso. G (TR 4 strain B_2) of *Fusarium oxysporum* f. sp. *cubense* when compared with control.

Among the novel chemicals, tebuconazole 50% + trifloxystrobin 25% was found significantly superior with 100% growth inhibition at all concentration levels. While the inhibitory effect of tebuconazole (250 EC) and fluopyram 17.7% + tebuconazole 17.7% were also showed a higher levels of inhibition per cent over control. Data revealed that the maximum inhibition was recorded in tebuconazole 50% + trifloxystrobin 25%, tebuconazole (250EC) and fluopyram 17.7% + tebuconazole 17.7% with 100% inhibition over control followed by fenamidone 10% + mancozeb 50% (60WG) with 61.1% inhibition, iprovalicarb 5.5% + propineb 51.25% (66.75WP) with 59.8% inhibition and pencycuron 250 SC with 58.3% inhibition. The minimum inhibition percentage was found in the Propineb (70% WP) with 39.8% inhibition over control at 150 ppm concentration followed by 100 ppm and 50 ppm. Data about inhibition per cent over control showed that the T_7 was statistically highly superior to other treatments and T_1 was closely followed by T_5 or varied significantly at 150 ppm concentration. Data are presented in (Table 3).

The radial growth was inhibited 100% in each tebuconazole 50% + trifloxystrobin 25% concentration followed by 100 ppm tebuconazole (250 EC) with an inhibition of 100% which was statistically higher than 50 ppm tebuconazole (250 EC).

3.3 Effectiveness of different Novel Chemicals against the Iso. M (race 1) and Iso. K (race 2) of Foc Causing Panama Wilt of Banana *in vitro*

The tebuconazole 50% + trifloxystrobin 25% was found significantly superior with 100% growth inhibition against the Iso. M (race 1) and Iso. K (race 2) of Foc at all concentration levels. While inhibitory effect of tebuconazole (250 EC) and fluopyram 17.7% + tebuconazole 17.7% was also showed higher level of inhibition per cent over control. Data revealed that the maximum inhibition was recorded in tebuconazole 50% + trifloxystrobin 25%, tebuconazole (250EC) and fluopyram 17.7% + tebuconazole 17.7% with 100% inhibition over control at 150 ppm concentration. After that, fenamidone 10% + mancozeb 50% (60WG), iprovalicarb 5.5% + propineb 51.25% (66.75WP) and pencycuron (250 SC). The minimum inhibition percentage was found in the propineb (70% WP) at 150 ppm

concentration followed by 100 ppm and 50 ppm. Data pertaining to inhibition per cent over control revealed that the T_1 and T_8 was found non significant and remained significantly at par against the Iso. M (race 1) at 150 ppm concentration. Similarly, the differences between T_2 and T_1 at 50 ppm concentration was found non significant or T_2 at par with T_1 against the Iso. K (race 2). Data are presented in (Table 4).

3.4 Effectiveness of different novel chemicals against Foc TR4 strain B_2 (Iso. G) under pot condition

Different novel chemicals were tested at 0.2% concentration against the incidence of Panama wilt of banana under artificial pot conditions. Mass culture of Foc TR4 strain B_2 was multiplied on sand maize medium and added to steam sterilized soil (15 psi for 30 minutes) in pots @ 5% (w/w). Soil mixture without inoculums served as control. Each pot was planted with one-month old banana sucker of different cultivars *viz.,* Malbhog (AAB), Alpan (AAB), Kothia (ABB), Robusta (AAA) and Grand Naine (AAA). The observation was recorded based on the first appearance of symptoms of the disease, per cent incidence of the disease and per cent inhibition over control.

Results showed that all the novel chemicals, significantly inhibited Panama wilt disease incidence in bananas caused by Foc TR4 strain B_2.

Among the novel chemicals, tebuconazole 50% + trifloxystrobin 25% was found most effective against TR4 strain B_2, Panama wilt symptom was not observed up to 80 days in cv. Grand Naine followed by cv. Robusta (79 DAT), cv. Kothia (77 DAT), cv. Alpan (76 DAT) and Malbhog (74 DAT).

The tebuconazole 50% + trifloxystrobin 50% was found highly superior over all the tested novel chemicals, this novel chemical was showed maximum inhibition per cent of disease incidence over control in the cv. Alpan (86.2%) followed by Malbhog (85.6%), Kothia (83.8%), Robusta (81.3%) and Grand Naine (79.4%). This novel chemical was found excellent in disease suppression against the isolate TR4 strain B_2. Data about to inhibition per cent over control under pot condition revealed that the T_4 at par with T_6 in cultivar Malbhog (AAB). In Alpan (AAB), T4 was found non significant and remained at par with T_9 and T_6. But in case of cultivar Kothia (ABB), the T_9 were found at par with T_4, while in cultivar Grand Naine (AAA) T_4 and T_9 also found non significant and remained significantly at par. Results are presented in (Table 5).

These novel chemicals *viz.,* tebuconazole (250 EC), carbendazim and fluopyram 17.7% + tebuconazole 17.7% (400 SC) were found moderately effective against the Foc TR 4 strain B_2. While, some novel chemicals like fosetyl AL (80% WP), iprovalicarb 5.5% + propineb 61.25% (66.75 WP), fenamidone 10% + mancozeb 50% (60 WG) and propineb (70% WP) were found less effective against the Iso. G of *Fusarium oxysporum* f.sp. *cubense* TR 4 strain B_2.

Li chi et al. [6] experimented with “9 fungicides, including 45% Sportak (carbendazim+prochloraz), 50% Sporgon (prochloraz), 50% Ipredine, 50% thiram, 50% carbendazim, 15% Omiral, 2.5% Tilt (propiconazole) etc”. “Results demonstrated that the 45% Sportak, 2.5% Tilt and 50% Sporgon had the highest effectiveness in greatly reducing the pathogen, their EC_{50}/mg/L values were 0.00094, 0.039 and 0.4895 respectively. Carbendazim at 0.01% and 0.02% inhibited fungus at 1.66mm and 1.16mm of mycelial growth respectively after 72 hours of treatment, while at 0.03% concentration, it repressed the fungus growth at 0.99mm after 48 hours only” [7].

Somu et al. [8] assessed “six fungicides *In vitro* conditions against *Fusarium oxysporum* f.sp. *cubense*, carbendazim, carboxin, propiconazole and benomyl showed total inhibition of the fungal growth at the concentrations of 500, 1000 and 2000 ppm. In any case, difenconazole showed total inhibition of the fungal growth at 2000 ppm concentration”. Mengal et al. [9] evaluated “five fungicides against *Fusarium oxysporum. Among* all of them, Nativo was found more effective in reducing the linear colony growth of fungus(3.3mm) followed by Alliete (8.66mm) and Cabriotop (19.00mm)”. Keerio et al. [10] reported that “Nativo was found more effective in reducing the linear colony growth of the fungus at its highest and lowest doses (7.00mm), followed by Alliete (16.1 mm), whereas, Cabriotop and Romeo found less effective as compared to Nativo and Alliete. Dragon was found very less effective as compared to other four fungicides which reduce the linear colony growth of the tested fungi, at its highest dose (64.467 mm)” [11].

Table 2. Effectiveness of different fungicides against various isolates of *Fusarium oxysporum* f.sp. *cubense* causing Panama wilt of Banana *in vitro*

	Treatments	Cons. (ppm)	Radial growth*(mm)									
			Iso. M (race 1)		Iso. A (race 1)		Iso. K (race 2)		Iso. G (race 4)		Iso. R (race 4) **	
			240 hrs.	Inhibition over control (%)	240 hrs.	Inhibition over control (%)	240 hrs.	Inhibition over control (%)	240 hrs.	Inhibition over control (%)	240 hrs.	Inhibition over control (%)
T_1	Carbendazim	50	24.9	71.4	24.2	72.3	23.9	72.6	57.0	35.6	56.3	36.0
		100	20.4	76.6	19.3	77.8	18.4	78.9	53.3	39.7	52.7	40.0
		150	16.4	81.1	16.4	81.2	14.6	83.3	49.0	44.5	49.1	44.1
T_2	Copper oxychloride	50	74.5	14.5	73.4	15.9	72.6	16.7	78.4	11.4	77.3	12.1
		100	70.3	19.2	69.2	20.7	67.8	22.3	74.4	15.9	72.6	17.4
		150	58.8	32.5	58.6	32.9	58.2	33.2	70.1	20.7	69.6	20.8
T_3	Strobilurin	50	29.7	65.9	28.5	67.3	28.2	67.7	54.7	38.1	53.3	39.3
		100	26.3	69.8	24.1	72.3	26.0	70.2	49.8	43.6	47.7	45.7
		150	23.2	73.3	22.5	74.3	22.3	74.4	44.4	49.8	43.1	50.9
T_4	Mancozeb	50	75.6	13.2	74.5	14.6	72.3	17.1	77.2	12.6	76.4	13.1
		100	70.2	19.4	69.3	20.6	68.5	21.4	74.2	16.0	72.6	17.4
		150	63.4	27.2	62.4	28.5	62.2	28.7	69.4	21.5	67.7	23.0
T_5	Propiconazole	50	16.4	81.1	14.3	83.3	14.3	83.6	36.4	58.9	35.1	60.0
		100	13.3	84.7	12.9	85.3	12.4	85.7	34.2	61.3	32.6	63.0
		150	10.1	88.5	9.8	88.7	9.7	88.9	32.6	63.1	31.1	64.6
T_6	Hexaconazole	50	21.2	75.6	19.5	77.7	19.5	77.7	48.3	45.3	47.3	46.2
		100	17.2	80.2	16.6	80.9	16.6	81.0	44.3	49.9	43.3	50.8
		150	14.3	83.5	13.3	84.8	12.6	85.6	42.3	52.1	41.4	52.9
T_7	Fosetyl-Al	50	33.0	62.2	32.9	62.3	32.8	62.4	50.3	43.1	49.1	44.1
		100	29.1	66.6	31.0	64.5	30.4	65.1	46.6	47.3	46.2	47.4
		150	28.6	67.2	28.8	67.0	28.5	67.3	42.2	52.2	40.4	54.1
T_8	Control		87.1		87.3		87.5		88.4		87.9	
CD at 5%			3.28	3.88	2.73	3.25	2.88	3.28	0.94	1.05	1.17	1.38
S.Em. (±)			1.15	1.35	0.95	1.14	1.01	1.15	0.33	0.37	0.41	0.48
C.V. (%)			5.30	3.93	4.50	3.24	4.81	1.62	1.04	1.63	1.31	2.08

**Mean of three replications*

*** Iso. M: Isolate of Malbhog (AAB), Iso. K: isolate of Kothia (ABB), Iso. A: Isolate of Alpan (AAB), Iso. G: Isolate of Grand Naine, Iso. R: Isolate of Robusta (AAA)*

Table 3. Effectiveness of different novel chemicals against *Fusarium oxysporum* f.sp. *cubense* TR4 strain B_2(Iso G.) causing Panama wilt of banana *in vitro*

Treatments		Cons. (ppm)	Radial growth(mm)* at different hrs						
			24 hrs	72 hrs	120 hrs	168 hrs	216 hrs	240 hrs	Inhibition over control (%)
T_1	Iprovalicarb 5.5% + Propineb 61.25% w/w WP (66.75 WP)	50	8.6	24.3	32.5	40.1	43.4	50.4	43.1
		100	7.0	22.6	27.2	32.4	36.2	47.9	46.0
		150	4.8	19.3	22.3	28.0	29.6	35.6	59.8
T_2	Fenamidone 10% + Mancozeb 50% w/w WG (60 WG)	50	9.1	25.2	32.4	40.0	42.4	51.4	42.0
		100	6.2	21.2	29.4	30.2	33.6	39.5	55.4
		150	5.6	18.4	26.5	26.3	29.6	34.5	61.1
T_3	Propineb 70% WP	50	10.9	26.7	49.2	48.6	58.5	69.3	21.8
		100	9.2	23.3	43.2	43.5	49.2	58.1	34.4
		150	6.4	22.3	39.2	39.5	44.4	53.3	39.8
T_4	Tebuconazole 250 EC (25.9% w/w)	50	0.1	0.1	0.4	0.5	0.8	1.2	98.6
		100	0	0	0.0	0.0	0.0	0.0	100.0
		150	0	0	0.0	0.0	0.0	0.0	100.0
T_5	Pencycuron 22.9%	50	10.8	28.2	49.4	49.3	57.4	64.4	27.4
		100	9.2	23.5	35.5	36.5	45.8	58.8	33.7
		150	5.8	16.3	20.4	26.2	32.4	37.0	58.3
T_6	Carbendazim	50	4.1	14.7	26.0	34.6	46.2	57.3	35.5
		100	2.6	10.3	24.0	30.4	44.4	53.5	39.7
		150	1.1	8.1	19.3	24.3	39.3	49.7	44.0
T_7	Tabuconazole50%+ Trifloxystrobin 25%	50	0.0	0.0	0.0	0.0	0.0	0.0	100.0
		100	0.0	0.0	0.0	0.0	0.0	0.0	100.0
		150	0.0	0.0	0.0	0.0	0.0	0.0	100.0
T_8	Fosetyl-Al80% WP	50	6.3	12.0	25.7	32.4	37.5	48.2	45.6
		100	5.5	8.8	23.6	28.3	34.4	44.7	49.6
		150	2.1	5.8	14.4	23.2	31.4	42.2	52.4
T_9	Fluopyram 17.7%+ Tebuconazole17.7% w/w SC (400 SC)	50	4.0	10.5	23.1	26.7	30.3	38.4	56.7
		100	0.1	0.2	0.3	0.4	0.6	1.2	98.7
		150	0.0	0.0	0.0	0.0	0.0	0	100.0
T_{10}	Control		12.8	20.6	38.7	54.7	76.6	88.6	
CD at 5%			1.09	2.35	1.89	1.51	2.44	0.93	1.05
S.Em. (±)			0.38	0.83	0.67	0.53	0.86	0.33	0.37
C.V. (%)			11.67	9.05	4.84	3.32	4.68	1.54	1.05

**Mean of three replications*

Table 4. Effectiveness of different novel chemicals against the Iso. M (race 1) and Iso. K (race 2) of *Fusarium oxysporum* f.sp. *cubense* causing Panama wilt of banana *in vitro*

Treatments		Cons. (ppm)	Radial growth(mm)* at different hrs					
			Iso. M (race 1)			Iso. K (race 2)		
			120 hrs	240 hrs	Inhibition over control (%)	120 hrs	240 hrs	Inhibition over control (%)
T_1	Iprovalicarb 5.5% + Propineb 61.25% w/w WP (66.75 WP)	50	26.2	42.1	52.4	25.5	42.4	52.0
		100	21.5	36.2	59.1	20.7	35.7	59.6
		150	15.4	27.2	68.2	14.7	26.9	69.5
T_2	Fenamidone 10% + Mancozeb 50% w/w WG (60 WG)	50	25.6	42.6	52.1	24.7	41.4	53.2
		100	20.5	28.5	67.8	19.1	27.7	68.7
		150	17.7	26.6	69.9	16.9	25.5	71.2
T_3	Propineb 70% WP	50	36.4	59.6	32.7	33.6	59.7	32.4
		100	32.4	47.4	47.3	30.9	46.6	47.2
		150	19.7	40.3	52.1	18.6	39.7	55.1
T_4	Tebuconazole 250 EC (25.9% w/w)	50	0.0	0.0	100.0	0.0	0.0	100.0
		100	0.0	0.0	100.0	0.0	0.0	100.0
		150	0.0	0.0	100.0	0.0	0.0	100.0
T_5	Pencycuron 22.9%	50	38.8	55.3	38.0	38.6	54.7	38.1
		100	25.6	48.3	45.5	25.5	47.5	46.3
		150	14.4	27.5	69.0	14.3	26.4	70.1
T_6	Carbendazim	50	30.7	25.1	71.6	29.5	23.5	73.4
		100	26.1	21.3	76.0	25.7	19.5	78.0
		150	22.8	17.2	80.6	22.6	16.2	81.7
T_7	Tebuconazole50%+ Trifloxystrobin 25%	50	0.0	0.0	100.0	0.0	0.0	100.0
		100	0.0	0.0	100.0	0.0	0.0	100.0
		150	0.0	0.0	100.0	0.0	0.0	100.0
T_8	Fosetyl-Al80% WP	50	37.8	33.3	62.4	37.7	32.6	63.2
		100	33.6	30.4	65.6	32.0	30.3	65.7
		150	30.6	28.2	68.1	29.6	28.7	67.6
T_9	Fluopyram 17.7%+ Tebuconazole17.7% w/w SC (400 SC)	50	14.4	29.5	65.4	14.3	28.4	67.9
		100	0.0	0.0	100.0	0.0	0.0	100.0
		150	0.0	0.0	100.0	0.0	0.0	100.0
T_{10}	Control		40.5	88.6		40.6	88.4	
CD at 5%			1.73	1.59	1.31	1.62	1.31	1.50
S.Em. (±)			0.72	0.560	0.461	0.57	0.46	0.53
C.V. (%)			1.87	3.59	1.12	0.80	3.02	1.26

**Mean of three replications*

Table 5. Effectiveness of different novel chemicals against *Fusarium oxysporum* f.sp. *cubense* TR4 strain B_2 (Iso. G) under pot condition

Fungicides		Malbhog* (Silk Group)			Alpan* (Mysore Group)			Kothia* (Bluggoe group)			Grand Naine* (Dwarf Cavendish Group)			Robusta* (Dwarf Cavendish Group)		
		First appearance of disease (DAT)	Incidence (%)	Inhibition over control (%)	First appearance of disease (DAT)	Incidence (%)	Inhibition over control (%)	First appearance of disease (DAT)	Incidence (%)	Inhibition over control (%)	First appearance of disease (DAT)	Incidence (%)	Inhibition over control (%)	First appearance of disease (DAT)	Incidence (%)	Inhibition over control (%)
T_1	Iprovalicarb 5.5% + Propineb 61.25% w/w WP (66.75 WP)	46	87	10.3	47	80	80	45	74	7.5	36	86	11.3	37	86	10.4
T_2	Fenamidone 10% + Mancozeb 50% w/w WG (60 WG)	41	80	17.5	43	73	16.1	42	65	18.8	34	80	17.5	35	80	16.7
T_3	Propineb 70% WP	36	93	4.1	37	87	0	38	80	0	32	93	4.1	35	93	3.1
T_4	Tebuconazole 250 EC (25.9% w/w)	54	46	52.6	56	32	63.2	57	40	50.0	54	46	52.6	54	50	47.9
T_5	Pencycuron 22.9%	57	66	32.0	58	60	31.0	59	70	12.5	49	73	24.7	50	66	31.3
T_6	Carbendazim	63	47	51.5	64	34	60.9	58	46	42.5	50	53	45.5	51	60	37.5
T_7	Tebuconazole50%+ Trifloxystrobin 25%	74	14	85.6	76	12	86.2	77	13	83.8	80	20	79.4	79	18	81.3
T_8	Fosetyl-Al80% WP	59	60	38.1	57	54	37.9	54	26	67.5	48	66	32.0	49	40	58.3
T_9	Fluopyram 17.7%+ Tebuconazole17.7% w/w SC (400 SC)	61	40	58.8	63	33	62.2	64	38	52.5	49	47	51.5	52	44	52.0
T_{10}	Control	26	97		27	87		29	80		22	97		26	24	
CD at 5%			3.02	4.34		3.00	4.38		3.09	4.56		3.24	4.93		3.06	4.02
S.Em. (±)			1.02	1.44		1.01	1.46		1.04	1.52		1.09	1.65		1.03	1.34
C.V. (%)			2.78	6.44		3.13	6.35		3.36	7.14		2.82	8.22		2.83	6.07

**Mean of three replications*

4. CONCLUSION

Among the fungicides, propiconazole and carbendazim were found highly effective against the Iso. M (race 1), Iso. A (race 1) and Iso. K (race 2). While, these fungicides were showed low efficacy against the Iso. G (TR 4 stain B_2) and Iso. R of Foc. Due to less effectiveness of carbendazim against the Iso. G of Foc TR4 strain B_2 under *in vitro* condition, some novel chemicals were tested under *In vitro* as well as *In vivo* conditions against this isolate. Among all the novel chemicals, the nativo (tebuconazole 50% + trifloxystrobin 25%) was found to exhibit 100% inhibition over control *In vitro* while in pot condition 86.2% inhibition over control was observed against the Foc TR4 strain B_2.

Similarly, these novel chemicals were also effectives against the Iso. M (race 1) and Iso. K(race 2). The novel chemical *i.e.* Nativo (tebuconazole 50% + trifloxystrobin 25%) was found statistically highly significant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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