

Original Research Article

Efficacy of novel fungicides against the *Fusariumoxysporumf.sp. cubense* causing Panama wilt of Banana

Abstract

Panama wilt of banana caused by *Fusarium oxysporumf.sp. cubense* TR4 is considered as most devastating disease of banana. In Bihar, this disease became menace to banana growers of Bihar due to introduction of new highly virulent strains *i.e.* TR 4 strain B₂. The objectives of this study were to evaluate newly available fungicides under *in vitro* and *in vivo* conditions for the efficient management of Panama wilt of banana. Fourteen different fungicide 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* where in pot conditions 86.2% inhibition over control was observed against *Fusarium oxysporumf.sp. cubense* TR 4 strain B₂ in cultivar Alpan (AAB).

Key word:-*Fusarium*,Nativo

INTRODUCTION

Bananas are the main stable fruits crops for millions of people in sub-tropical and tropical region of the world. This plant gives good returns to farmers so it is referred as “Kalpathru”- a plant of virtues. The banana research in India is completely towards the extension in 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 system and its 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 tall group of banana cultivars and second new Koshi belt dominated with dwarf Cavendish group of banana cultivars. Global banana production is intensely threatened by the occurrence of new highly virulent race *i.e.* TR 4. This highly virulent race became more calamitous and devastating 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 (Ploetz, 2015). This pathogenic variant (TR4) was observed in

Taiwan, Malaysia, Indonesia, Mainland China, Philippines, Australia, Oman, Jordan, Mozambique, Lebanon, Pakistan, Laos and Vietnam. In India, first time reported in Bihar after that Uttar Pradesh, Madhya Pradesh and Gujarat (Thangavelu *et al.*, 2019). Earlier, a virulent strain of *Fusarium oxysporum* f.sp. *cubense* has been reported in Cavendish group of banana cultivars by Mustafa *et al.*, 2011.

Recently, a highly virulent strain of *Fusarium oxysporum* f.sp. *cubense* TR 4 strain B2 identified which was affecting Cavendish group of banana cv. Grand Naine (AAA) and Robusta (AAA) in Koshi belt of Bihar (Shukla and Singh, 2019).

Keeping in view of 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 strain B2 under pot conditions.

MATERIAL AND METHOD

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% HgCl₂ solution for 30 seconds after that washing with distilled water to 2-3 times. These pieces were placed aseptically on PDA slants with the help of inoculating needle and incubated at 28±°C. All the isolates were categorised in to five different groups viz., Iso.M, Iso.A, Iso.K, Iso.G and Iso.R on the basis of host differential of banana cultivars.

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 *Fusarium oxysporum* f.sp. *cubense* 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 in each sterilized

Petri plate and permitted to solidify in laminar air flow. After solidification, 5 mm disc of seven days old culture of *Fusarium oxysporum* f.sp. *cubense* isolates was placed in the centre of the Petri plates and incubated at $28 \pm 2^{\circ}\text{C}$. Treatments were replicated thrice along with suitable control in which fungicide was omitted in the medium. The radial growth of different isolates of *Fusarium oxysporum* f.sp. *cubense* 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 (1927).

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

Where,

I = Per cent growth inhibition

C = Colony diameter in control Petri plate;

T = Colony diameter in the treated Petri plate.

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

Table 1. Fungicides and novel chemicals details used against *Fusarium oxysporum*f.sp. *cube*nseisolates 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

Evaluation of different novel chemicals against *Fusarium oxysporum*f.sp. *cube*nseTR 4 strain B₂ 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 theisolates of *Fusarium oxysporum*f.sp. *cube*nseTR4 strain B₂. The mass culture of thisisolates was prepared as per method described by Haware (1980). The mass culture of *Fusarium oxysporum*f.sp. *cube*nseTR 4 strain B₂isolates was 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 pot with sterilized distilled water was served as control. Each treatment was replicated three times in different banana cultivar. The disease incidence (%) was calculated by dividing the total number of transplanted plants showing Panama wilt disease symptoms by the total plant transplanted and then multiplied by hundred. The data on inhibition per cent over control also recorded in each treatment and data was recorded up to 90 days after transplanting. The data has been analysed by CRD design.

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

$$\text{Per cent wilt index} = \frac{\text{Total sum of numerical rating}}{\text{Total number of plants observed} \times \text{maximum category in the score chart}} \times 100$$

RESULT AND DISCUSSION

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

Total six fungicides viz., carbendazim, copper oxychloride, strobilurin, mancozeb, propiconazole and hexaconazole at 50, 100 and 150 ppm concentration were evaluated against different isolates of *Fusarium oxysporum*f.sp. *cubense*. The radial growth of these isolates was

measured after 24 hrs of inoculation and subsequent observations was recorded at three days interval till full growth of the pathogen in control *i.e.* 240 hrs and per cent inhibition was calculated on the basis of final observation. The results indicated that all the fungicides at each concentration significantly inhibited the growth of *Fusarium oxysporum*f.sp. *cubense*, 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 *Fusarium oxysporum*f.sp. *cubense* at 50 ppm, 100 ppm and 150 ppm concentration over the control. Data pertaining to inhibition per cent over control revealed that the T₅ was found statistically superior or closely followed by T₆ and the differences between the T₅ and T₆ was recorded significant at all level of concentration. However, the differences between T₆ and T₁ was found non significant or efficacy wise T₆ as well as T₁ remained at par against the Iso. M and Iso. K at 150 ppm concentration. The differences between T₇ and T₆was found non significant or T₇ at par with T₆ against the Iso. G of *Fusarium oxysporum*f.sp. *cubense*.

The carbendazim fungicide was found highly effective against the race 1 and race 2 pathogenic variability of *Fusarium oxysporum* f. sp. *cubense* but against race 4 (TR 4 strain B₂) was found moderately effective. Data are presented in (Table 2).

Effectiveness of different novel chemicals against *Fusarium oxysporum*f.sp. *cubense* TR4 strain B₂ (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 B₂) of *Fusarium oxysporum* f. sp. *cubense*. Because, during earlier experimentation it was found that carbendazim showed moderately effectiveness against this isolate. Total nine novel chemicals at 50, 100 and 150 ppm concentrations were evaluated against the Iso. G (TR4 strain B₂). The result indicated that all the novel chemicals at each

concentration significantly inhibited the growth of Iso. G (TR 4 strain B₂) 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 inhibitory effect of tebuconazole (250 EC) and fluopyram 17.7% + tebuconazole 17.7% were 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 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 pertaining to inhibition per cent over control showed that the T₇ was statistically highly superior to other treatments and T₁ closely followed by T₅ 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).

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*

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 *Fusarium oxysporum* f. sp. *cubense* at all concentration levels. While inhibitory effect of tebuconazole (250 EC) and fluopyram 17.7% + tebuconazole 17.7% were 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 T₁ and T₈ was found non significant and remained significantly at par against the Iso. M (race 1) at 150 ppm concentration. Similarly, the differences between T₂ and T₁ at 50 ppm

concentration was found non significant or T₂ at par with T₁ against the Iso. K (race 2). Data are presented in (Table 4).

Effectiveness of different novel chemicals against *Fusarium oxysporum*f.sp. *cubense* TR4 strain B₂ (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 condition. Mass culture of *Fusarium oxysporum*f.sp. *cubense* TR4 strain B₂ was multiplied on sand maize medium 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 symptom of the disease, per cent incidence of the disease and per cent inhibition over control.

Result showed that all the novel chemicals were significantly inhibited Panama wilt disease incidence on banana caused by *Fusarium oxysporum*f.sp. *cubense* TR4 strain B₂.

Among the novel chemicals, tebuconazole 50% + trifloxystrobin 25% was found most effective against TR4 strain B₂, 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 B₂. Data pertaining to inhibition per cent over control under pot condition revealed that the T₄ at par with T₆ in cultivar Malbhog (AAB). In Alpan (AAB), T₄ was found non significant and remained at par with T₉ and T₆. But in case of cultivar Kothia (ABB), the T₉ was found at par with T₄, while in cultivar Grand Naine (AAA) T₄ and T₉ 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 *Fusarium oxysporum*f.sp. *cubense* TR 4 strain B₂. 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 B₂.

Li chi *et al.*, (2008) conducted an experiment 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 greatly reducing the pathogen, their EC₅₀/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 (Kumari *et al.*, 2014).

Somu *et al.*, (2014) 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.*, (2016) 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). Keerioet *et al.*, (2017) 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).

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 B₂) and Iso. R of *Fusarium oxysporum*f.sp. *cubense*. Due to less effectiveness of carbendazim against the Iso. G of *Fusarium oxysporum*f.sp. *cubense* TR4 strain B₂ 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 native (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 *Fusarium oxysporum* f. sp. *cubense* TR4 strain B₂.

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

REFERENCE

Haware, M P. (1980). Methods of artificial inoculation and disease rating of root pathogens in *Phyto Pathological techniques ed: Chand J N and Sharma G. S.* 32-35 pp.

Li, chi., Yu, Li., Chen-YongQin and Xing-Shanshan (2008). Examination of the effectiveness of Fungicides for killing the pathogen of banana wilt disease in laboratory. *South China Fruits.* (2):44-45.

Kumar Sanjeev, Balabaskar P and Muthukumar A. (2010). Occurrence of wilt of banana and variability in pathogen *Fusarium oxysporum* f. sp. *cubense* in Cuddalore district of Tamil Nadu. *Journal of Mycology and Plant Pathology.* 40(3): 473-475.

Keerio, Azizullah., Nizamani, Ahmed Zubair., Hussain, Shahid., Rafiq, Muhammad., Iqbal Sohail., Keerio, Azhauddin (2017). Efficacy of some chemical fungicides against fusarial wilt of sunflower *in vitro* condition. *Int. J. of botany Studied.* Vol: 2(5) pp:80-85.

Mengal S.A., Hussain S., Ali M.A., Nisa T., Khetran R., Dahar G.Y., Zaib U., Mushwani N.S., Keerio A., Maari S.A. 2016. Investigations on *Fusarium* wilt disease of mango nursery and Its *In-Vitro* control by applying different fungicides on the linear colony growth of *Fusarium oxysporium*. *International Journal of Fauna and Biological Studies* 2016; 3(3): 107-112.

Ploetz, R. C. (2015). Management of *Fusarium* wilt of banana: A review with special reference to TR 4. *Crop Protectio.* (73)7 –15.

Shukla, D.N. and Singh, S.K. (2019). First ever report of TR 4 of *Fusarium oxysporum* f. sp. *cubense* in Dwarf Cavendish group of bananas in Bihar state of India. National symposium on Recent challenges and opportunity in sustainable plant health management. February 26-28, 2019, organized by Indian Phyto pathological Society, New Delhi at Institute of Agricultural Sciences, BHU, Varanasi, UP.

Somu R., Thammaiah N., Swamy GSK., Kulkarni M.S. and Devappa V. (2014). In vitro evaluation of fungicides against *Fusarium oxysporum* f. sp. *cubense*. *International Journal of Plant Protection*. 7(1): 221-224.

Thangavelu, R., Mostert, D., Gopi, M., Ganga Devi P., Padmanaban B., Molina A. B. and A. Viljoen (2019). First detection of *Fusarium oxysporum* f. sp. *cubense* TR4 on Cavendish banana in India. *Eur. J. Plant Pathol.* <https://doi.org/10.1007/s10658-019-01701-6>.

Vincent, J. M. (1927). Determination of per cent inhibition *in vitro*. *Nature*. 159:850.

UNDER PEER REVIEW

Table 2. Effectiveness of different fungicides against various isolates of *Fusarium oxysporum* sp. *cubense* causing Panama wilt of Bananain 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. *cabense* TR4 strain B₂(Iso G.) causing Panama wilt of banana *in vitro*

Treatments		Cons. (ppm)	Radial growth(mm)* at different hrs						Inhibition over control (%)
			24 hrs	72 hrs	120 hrs	168 hrs	216 hrs	240 hrs	
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-AI80% 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*.sp. cubense TR4 strain B₂ (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 (%)
T₁	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
T₂	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
T₃	Propineb 70% WP	36	93	4.1	37	87	0	38	80	0	32	93	4.1	35	93	3.1
T₄	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
T₅	Pencycuron 22.9%	57	66	32.0	58	60	31.0	59	70	12.5	49	73	24.7	50	66	31.3
T₆	Carbendazim	63	47	51.5	64	34	60.9	58	46	42.5	50	53	45.5	51	60	37.5
T₇	Tebuconazole 50% + Trifloxystrobin 25%	74	14	85.6	76	12	86.2	77	13	83.8	80	20	79.4	79	18	81.3
T₈	Fosetyl-Al 80% WP	59	60	38.1	57	54	37.9	54	26	67.5	48	66	32.0	49	40	58.3
T₉	Fluopyram 17.7% + Tebuconazole 17.7% 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
T₁₀	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