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Efficacy evaluation of chemical fungicides against *Fusarium oxysporum F.SP. lycopersici* (FOL)

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Abstract
Tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family and is the second most important horticultural product cultivated worldwide. Because of its importance as food, tomato has been bred to improve productivity, fruit quality, and resistance to biotic and abiotic stresses. Tomato has been widely used not only as food, but also as research material. The tomato plant has many interesting features such as fleshy fruit, a sympodial shoot, and compound leaves, which other model plants (e.g., rice and Arabidopsis) do not have. Field experiments were conducted in a private farm in East Godavari district, Andhra Pradesh to evaluate the efficacy of ten chemical fungicides against Fusarium wilt disease under field conditions during the two consecutive seasons (2018-2019 and 2019-2020). Each fungicide and bio fungicide was applied at two rates as foliar spraying 3 times per season. These results revealed that Tebuconzole + Trifloxystrobin completely inhibited growth of Fol, at 1000 ppm.

Keywords: *lycopersicon esculentum,* fusarium wilt, *fusarium oxysporum,* fungicides

Introduction
Tomato (Lycopersicon esculentum L.) is one of the most extensively cultivated and consumable vegetable crops in the world and is supposed to be the second chief vegetable later potato in the world [Costa JM and Heuvelink E (2018) [1]; Saeed *et al*., 2014] [2]. Several management strategies such as biological control, crop rotation, sanitation and judicious use of fungicides have been reported to manage the Fusarium wilt (Sahar *et al*, 2013) [3]. Resistance can be important for vegetables due to self-protection by resistance genes that impart tolerance to disease (Amini & Sidovich, 2010) [4]. Although use of cultivars with genes carrying moderate to high resistance significantly resulting in decreases in pathogen population levels in rhizosphere but different fungicides and biological control agents have been regarded as quick control measure. In recent past the Fusarium wilt has already been controlled at low doses of suitable fungicides (Kumar *et al*., 2001) [5]. Different biocontrol agents compete with fungal pathogens for space and nutrition and perform activities antagonistic to pathogens. Another way of biocontrol activity is through production of certain chemical toxic to pathogen and antidotes which will inhibit the growth and development of fungal pathogens (Agrios, 2005) [5].

Material and Methods
Fungicides mentioned below in table no 1 were evaluated against *Fol*, isolate under *in vitro* conditions by poisoned food technique (Vincent, 1947) [7] at three concentrations i.e. 500, 1000 and 1500 ppm. Three replications were maintained for each treatment with control.

Fungicide Concentration
100 ml of PDA was taken into 250 ml conical flask and was sterilized in an autoclave for 15 to 20 minutes at 120 ^{0}C. To be tested test fungicide was added to the sterilized medium at lukewarm temperature under aseptic conditions and mixed thoroughly by shaking to obtain required concentration. Poisoned medium was equally distributed in the Petri plates and allowed to solidify.
Three replications were maintained for each treatment. Discs of 5 mm diameter of virulent *Fol*, were cut with sterilized cork borer separately and transferred on to centre of Petri plates having poisoned medium. Similarly, control was maintained by placing 5 mm discs of test fungal culture in centre of the Petri Plates containing the PDA medium without fungicide. All Petri plates were incubated at 27 ± 2ºC in BOD incubator. Radial growth fungal colony was measured in each of the treatment till control plate was fully covered with test pathogen. Colony diameter inhibition in fungicide treated plates compared to control was taken as a measure of fungitoxicity. Per cent inhibition over control was calculated as per the formula (Vincent, 1927),

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

Where I = Per cent inhibition of the mycelial growth,
C = mycelial growth of the fungus in control,
T = mycelial growth of the fungus in treatment.

The experiment was done with statistical design CRD and the best effective fungicide observed under *in vitro* was taken for evaluation at field level (*in vivo*).

Results
Efficacy of ten fungicides was evaluated against *Fol*, adopting poisoned food technique. All the tested fungicides were effective in inhibiting radial growth of *Fusarium oxysporum* f.sp. *lycopersici*, and all the treatments were significantly superior over control in reducing radial growth of the *Fol* , at different concentrations. (Table 2)

Table 1: List of tested fungicides

S. No	Name of the fungicide	Trade name (Company Name)	Mode of action
1	Copper oxychloride 50%WP	Blitox (Tata Rallies)	Contact
2	Mancozeb 75% WP	Dithane M-45 (UPL)	Contact
3	Carbendazim 12% + Mancozeb 63% WP	Saaf (UPL)	Systemic + Contact
4	Metalaxyl 4% + Mancozeb 64% WP	Ridomilgold(KrushiKendra)	Systemic + contact
5	Hexaconzole 5 % + Captan 70 % WP	Taqat (Tata Rallis)	Systemic + Contact
6	Thiophanate Methyl 70 % WP	Topsin M WSB (UPL)	Systemic
7	Thiophanate Methyl 45% + Pyraclostrobin 5% FS	Xelero (BASF)	Systemic
8	Tebuconzole 250 E.C	Folicur (Bayer)	Systemic
9	Tebuconzole 50 % + Trifloxystrobin 25 % WP	Nativo (Bayer)	Systemic
10	Azoxystrobulin 23% SC	Amistar (Syngenta)	Systemic

Table 2: Per cent growth inhibition of *Fol*.

S. No	Tested fungicides	Per cent growth inhibition of *Fol* over control		
		500 ppm*	1000 ppm*	1500 ppm*
1	Copper oxychloride 50%WP	61.10	69.56	78.16
2	Mancozeb 75% WP	69.96	77.70	82.56
3	Carbendazim 12% + Mancozeb 63% WP	72.56	83.66	100.00
4	Metalaxyl 4% + Mancozeb 64% WP	67.33	71.10	79.96
5	Hexaconzole 5 % + Captan 70% WP	70.70	78.83	85.86
6	Thiophanate Methyl 70 % WP	67.86	74.56	79.96
7	Thiophanate Methyl 45% + Pyraclostrobin 5%	68.66	70.73	72.93
8	Tebuconzole 250 E.C	79.56	86.23	100.00
9	Tebuconzole 50 % + Trifloxystrobin 25 % WP	86.60	100.00	100.00
10	Azoxystrobulin 23% SC	58.46	69.20	79.96
11	Control	90.00	90.00	90.00
	Se(m)	0.52	0.73	0.55
	CD	1.68	2.27	1.70
	C.V	1.90	2.31	1.54

*-mean of three replications

At 500 ppm

At 500 ppm concentration per cent growth inhibition of *Fol*, varied from 58.46 per cent to 86.60 per cent with maximum per cent growth inhibition in Tebuconzole + Trifloxystrobin and least per cent growth inhibition with azoxystrobulin. (Figure 1)

Fig 1: Efficacy evaluation of chemical Fungicides (poison Food technique) (500 PPM)

At 1000 ppm

At 1000 ppm concentration, per cent growth inhibition of *Fol*, varied from 69.20 per cent to cent per cent (100%) with maximum per cent growth inhibition with Tebuconzole + Trifloxystrobin and least per cent growth inhibition with azoxystrobulin. (Figure 2)

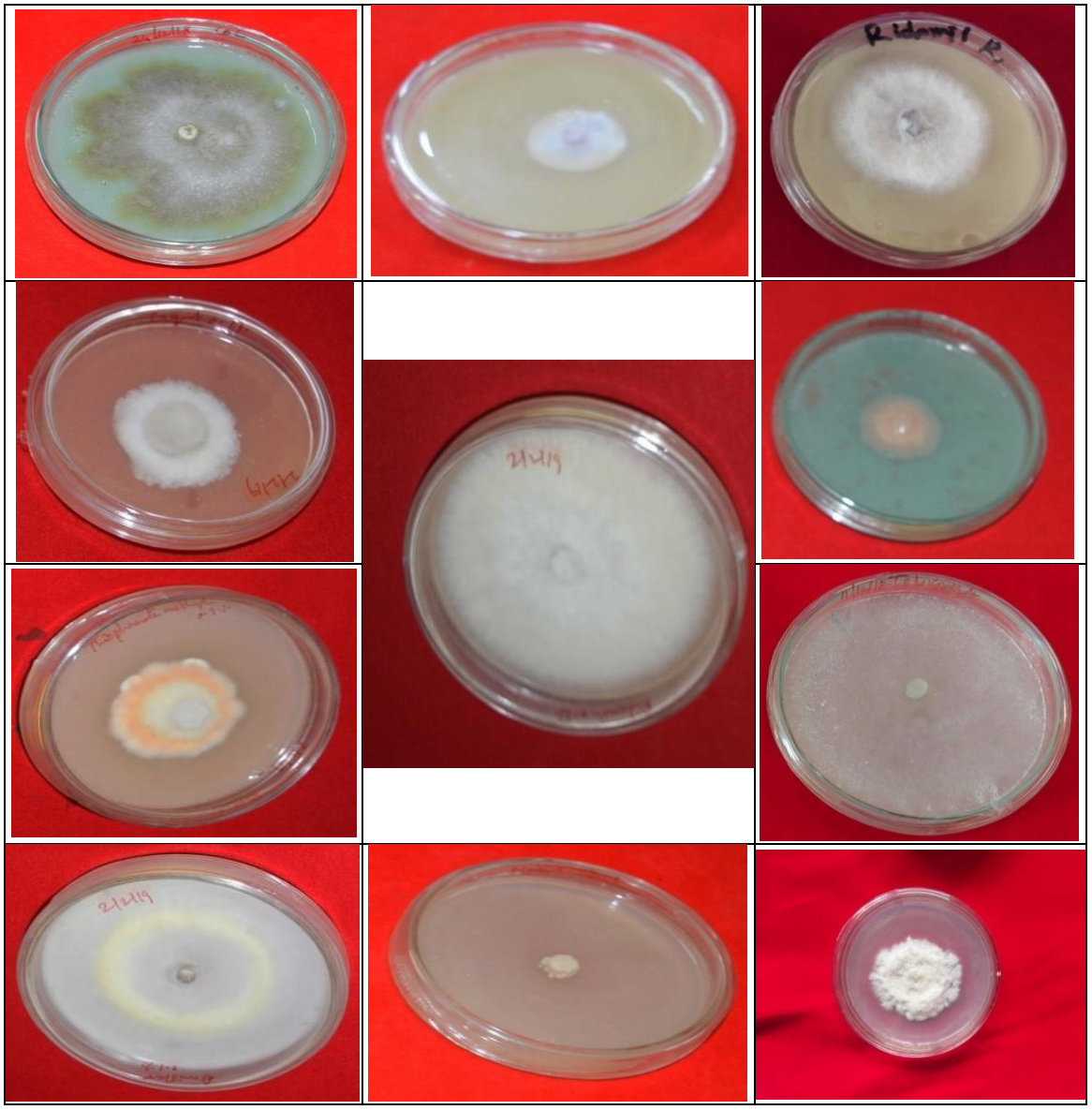

Fig 2: Efficacy evaluation of chemical Fungicides (poison Food technique) (1000 PPM)

At 1500 ppm

At 1500 ppm concentration, per cent growth inhibition of *Fol*, varied from 78.16 per cent to cent per cent with maximum per cent growth inhibition with Carbendazim + Mancozeb, Tebuconzole and Tebuconzole + Trifloxystrobin and least per cent growth inhibition with Thiophanate Methyl + Pyraclostrobin. (Figure 3)

These results revealed that Tebuconzole + Trifloxystrobin completely inhibited growth of *Fol*, at 1000 ppm.

Fig 3: Efficacy evaluation of chemical Fungicides (poison Food technique) (1500 PPM)

Discussion

Similar results were reported by Tazeem Akhtar *et al*. (2017) that Tebuconzole 50 % + Trifloxystrobin 25 % WP (nativo) was found most effective by reducing mycelial growth of *Fusarium oxysporum* f.sp. *lycopersici*, with 0.53cm at 750 ppm over control followed by Ridomil Gold, Antracol and Cordate with 1.44cm, 2.37cm and 2.73c respectively and under *invivo* disease incidence was recorded with 32.75 per cent reduction over control @ 0.1%.

Aroosa Khan *et al*. (2012) also observed similarly that, Fosetyl aluminium (Wisdom) and tebuconazole (Treety) were found significantly effective by suppressing radial growth and with reduction of fungal biomass from 20 to 90 per over control of *FOl*.

Mais Alkbaily *et al*. (2019) also found that thiophanate methyl, quinosol and fosetyl aluminium were effective againt vascular wilt of tomato with disease indicence of 30.7, 35.0 and 27.3 per cent and reduction over control by 67.40, 62.50 and 70.29 per cent respectively.

Han *et al*. (2019) [11] in his findings reported similarly that tebuconazole, bloom and Epic belonging to triazole group caused structural destruction of *F. oxysporum* f. sp. *lycopersici* , and making unavailability of ergo sterol that lead to growth suppression, which was observed with present findings.

Jahanshir Amini (2010) [4] reported similarly that azoxystrobin was least effective at 10 µg/ml against *Fusarium oxysporum* f.sp. *lycopersici*, under *in vitro* and *in vivo* , due to ineffective in ininhibiting ergostol synthesis.

Mukhtar (2008) [13] also reported similarly that folicur, blitox and bavistin were highly effective with maximum reduction of mycelia growth of *Fusarium oxysporum* f.sp.*lycopersici* (*FOL*) along with Contafplus and Cursor.

Poddar *et al*. (2004) [14] found that except thiophanate methyl, carbendazim, Propiconazole, thiophanate methyl and tebuconazole were most effective against *Fusarium oxysporum* , causal organism of chick pea wilt.

Sharma *et al.* (2007) [15] observed under *in vitro* conditions that copper oxy chloride at 1500 ppm inhibited growth and sporulation of *F. oxysporum* f. sp. *li1ni.*

Singh *et al.* (2017) [16] reported similarly that Carbendazim 50% WP and carbendazim 12% + mancozeb 63% had effectively inhibited the mycelial growth and the sporulation from 50 ppm to 1000 ppm and found that propiconazole 25%, captan 70% + hexaconazole 5%, carboxin 37.5% + thiram 37.5% were effective at 1000 ppm, whereas captan 50% was found least effective against Fuarium wilt in chilli caused by *Fusarium oxysporum*.

Salma Begum *et al*. (2015) [17] reported similarl findings that Carbendazim 0.1 per cent, mancozeb 0.2 per cent, thiophenate methyl 0.1 per cent, tricyclazole 0.1 per cent, propiconazole 0.1 per cent, difenconazole 0.1 per cent, hexaconazole 0.1 per cent, and carbendazim 12% + mancozeb 63% 0.2 percent had completely inhibited the growth *Fusarium moniliforme*, whereas ridomil gold (metalaxyl 8% + mancozeb 64%) and copper oxychloride each at 0.2 per cent inhibited 81.11% and 52.22% only.

Pasquali *et al*. (2013) [18] described similarly that, fusarium species are sensitive towards fungicides belonging to the group of DMI such tebuconazol, but are intrinsically resistant towards complex III respiration inhibitors (QoI) such trifloxystrobin and the SDHI which supports the present research results.

Shikha Srivasta (2014) [19] also observed similarly that efficacy of triazole group compared to strobulin group is more as pyraclostrobin suppressed 68% growth of *Fusarium oxysporum*, causal organism of wilt in Orchids at 100 ppm and 50 per cent growth suppression by azoxystrobulin at 100 ppm while triticonzole showed more potency with a reduction of 92% over the control.

Vallabhaneni Tilak Chowdary and SK Biswas (2018) [20] reported similarly that Carbendazim 0.1 per cent was effective against *Fusarium oxysporum* f.sp. *lycopersici,* with mycelia growth reduction of 92.5 per cent followed by Metalaxyl 8% + Mancozeb 74% and Copper oxy chloride 50% WP each at 0.2 per cent with 83.92 per cent reduction over control and Mancozeb and Chlorothalonil as moderately effective Metalaxyl 35% WS as least effective. These results revealed that Tebuconzole + Trifloxystrobin completely inhibited growth of *Fol*, at 1000 ppm.

Conclusion

Based on the results we concluded that the fungicides (Tebuconzole and Trifloxystrobin) were the most effective for controlling *Fusarium oxysporum* f.sp. *lycopersici* than other tested fungicides and increased the yield. This investigation will help the Tomato producers to facilitate the optimal input use of fungicides and plant extracts that assist them to reduce the crop damage and increase the productivity of Tomato in India.

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