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New Generation Combination Fungicide Famoxadone 16.6 % + Cymoxanil 22.1 % SC for the Management of Tomato Late Blight

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ABSTRACT

The tomato late blight incited by *Phytophthora infestans* is yield limiting disease in tomato which is threatening global food security leading to sudden disease outbreaks and severe crop losses due to distinct evolutionary nature of pathogen. The genetic resistance in host and conventional fungicides resulted in limited management of this disease. Hence, the efforts were made to evaluate newer fungicides against late blight in field conditions for two successive seasons *i.e., kharif* 2019 and *kharif* 2020. Of the various fungicides, the combination fungicide, Famoxadone 16.6 % + Cymoxanil 22.1 % – 38.7 SC @ 1.0 ml/l resulted in least disease severity of 11.06 per cent and 10.68 per cent during first and second season respectively. The Azoxystrobin 8.3 % + Mancozeb 66.7 %, 75 WG @ 3g/l noted with 12.35 per cent and 11.68 per cent of disease severity in first and second season respectively. Consequently, Azoxystrobin 23 % SC @ 1 ml/l exhibited 19.55 per cent and 18.11 per cent of disease severity in first and second season respectively. Hence, the targeted approach ensures that new fungicide molecules with higher efficacy and safer residue levels are effective at managing tomato late blight disease outbreaks, reducing overall fungicides use and costs and improving tomato farming.

Keywords: Disease severity, Fungicides, Late blight, *Phytophthora infestans,* Tomato.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) has 0.81 million hectares area under tomato cultivation with 21.17 million tonnes annual production and productivity of 25.32 Mt (Raiola *et al,* 2014). Tomato late blight incited by *Phytopthora infestans* is a destructive disease of tomato which leads to 78 per cent crop loss in congenial environmental conditions. In field upon occurrence of late blight, the signs and symptoms first appear on leaves leading to necrosis which reduces the chlorophyll content and affect the yield. Eventually symptoms spread to branches, main stem and fruits leading to complete crop loss. The causal organism is primarily air borne and to some extent it acts as soil inhabiting. Further, the disease is prevalent round the year, occurs at all crop stages and characteristically induces severe necrosis of leaf, stem, blossom leading to qualitative and quantitative loss in particular it infects fruits up to 30 per cent. (Panthee *et al,* 2024; Khan *et al,* 2024).

The genetic resistance is vital approach to combat the disease in field but due to the aggressive and diverse virulence nature of *P. infestans* resistance in the varieties is broken within a decade. Further, the fungicides (contact, systemic and translaminar) applied to manage the disease in field resulted in low efficacy due to resistance deployment in pathogen against them. Indicating the necessity of regular evaluation of newer fungicides to curb the disease under field conditions (Lal *et al*, 2018). Hence , the present study was carried out to identify the newer fungicide molecules with higher efficacy and safer residue levels in crop for disease management under field conditions are needed to the utmost level.

MATERIALS AND METHODS

Collection of *Phytopthora infestans* culture

The culture of *Phytopthora infestans,* a pathogen causing late blight of tomato was taken from Plant Pathology department, UHS, Bagalkot for *in-vitro* studies.

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In vitro evaluation of fungicides against *P. infestans*

Four fungicides were obtained from local market and details of them are given in Table 1. The fungicides were evaluated under *in vitro* for their inhibitory potential against pathogen at their recommended dosage through poisoned food technique using PDA medium and the plate without fungicide served as the control. The experiment was carried out in completely randomized design (CRD) with three replications for each fungicide and the whole process was repeated thrice. The mycelia growth inhibition of pathogen was noted as per the formula, I = C-T/C × 100, where, I is inhibition of pathogen mycelial growth (%); C= radial mycelial growth in control; T = radial mycelial growth in treatment (Vincent, 1927).

In vivo evaluation of fungicides against tomato late blight

Experimental location and growth conditions

For assessing the bio-efficacy of fungicides against tomato late blight, the field trials were conducted at ICAR – Krishi Vigyan Kendra, Kolar (Karnataka) for two consecutive seasons (*kharif* 2019 and *kharif* 2020). The experimental plot soil was sandy loam and susceptible tomato hybrid was raised as per the package of practice of University of Horticultural Sciences, Bagalkot (Karnataka).

Treatments

The experiment was conducted using randomized block design (RBD) which consisted of five treatments and in each treatment, four replications were maintained. In each treatment two foliar sprays of fungicides were imposed at 15 days' gap and the first spray was taken up on-set of disease in tomato. The details of treatment were as T_1- foliar application of Famoxadone 16.6 % + Cymoxanil 22.1 % – 38.7 SC @ 1.0 ml/l; T_2 - Azoxystrobin 8.3 % + Mancozeb 66.7 % - 75 WG @ 3g/l; T_3- Azoxystrobin 23 % SC @ 1 ml/l; T_4 - Mancozeb 75 WP @ 3g/l; T_5 – Control.

Disease assessment

Twenty-five plants of each replicate were marked for observations. The late blight severity in each treatment was recorded prior to initiation of experiment and after ten days of each spray. The disease severity was assessed by using 0-5 severity scale, where 0 - No symptoms on the leaf; 1 – up to 11 % infected leaf area covered with spot, no spot on petiole and branches; 2 –12 to 38 % infected leaf area covered with spot, few spots on petiole; 3 –39 to 61 % infected leaf area covered with spot, spots on petiole and branches; 4 –62 to 88 % infected leaf area covered with spot, spots on petiole, branches and stem; 5 – >89 % infected leaf area covered with spot, spots on petiole, branch, stem and fruits (Sandeep *et al*, 2022). The % disease index (PDI) was computed using the formula, Disease index (%) = [Sum of all individual ratings/ (total no. of plants examined x maximum score)] x 100 (Vincent, 1947).

Phytotoxicity assessment of fungicides spray and yield recording

Observations of phytotoxicity evaluation were recorded by visual observations for phytotoxicity symptoms *viz.,* leaf injury on tips/ surface, necrosis, stunting, chlorosis, vein clearing, wilting, epinasty and hyponasty at 1, 3, 5, 7 and 10 days after each spray following 0-10 scale, where: 0 = no phytoxicity, 1 = 1-10%, 2 = 11-20%, 3 = 21-30%, 4 = 31-40%, 5 = 41-50%, 6 = 51-60%, 7=61-70%, 8=71-80%, 9=81-90%, 10=91-100%.Yield of tomato fruit was recorded plot wise at each harvest and pooled data of all pickings have been presented in terms of t/ha (Kabade, 2022).

RESULTS AND DISCUSSION

Late blight caused by *Phytopthora infestan*s, heterothallic fungi with A1 and A2 mating types able to cause up to 78 per cent yield loss under conducive environment is the devastating in tomato production causing severe necrosis of leaf, stem and fruit tissue under favourable field environmental conditions. The level of genetic resistance in tomato to combat the disease is relatively limited (Panthee *et al*, 2024) and hence conventional fungicides are the major means of management of late blight in the field (Saha *et al*, 2017). Thus, the new fungicide molecules with higher efficacy and safer residue levels in tomato to combat the late blight under field conditions are need of the hour. With this need in the present study newer fungicide molecules are evaluated under *in vitro* and field conations against tomato late blight.

Effect of fungicides on growth of *P. infestan*s under *in vitro*

The glance of literature indicated usage of different fungicides for the management of tomato late blight. With these information different fungicides (contact, systemic and combi) were tested against *P. infestans* under *in vitro*. The complete arrest of mycelial growth was seen in combi fungicide, Famoxadone + Cymoxanil and next best was

Table 1: Details of fungicides used.

Common name	Product name	Supplier	Dosage (%)	Mode of action	FRAC code
Famoxadone 16.6 % + Cymoxanil 22.1 % SC	Equation pro 38.7 SC	Corteva	0.10	QoI and Multi -site contact activity	11 27
Azoxystrobin 8.3 %+ Mancozeb 66.7 % WG	Avancer Glow 75 WG	UPL	0.30	QoI inhibition and Multi-site contact activity	11 M 03
Azoxystrobin 23% SC	Amistar 23 SC	Syngenta	0.10	QoI inhibition	11
Mancozeb 75 WP	M-45 75 WP	Indofil	0.30	Multi-site contact activity	M 03

Table 2: Evaluation of fungicides against *Phytophthora infestans* under *in vitro.*

Fungicide	Concentration (%)	Mycelial growth (cm)	Mycelial growth inhibition (%)
Famaxadone + Cymoxanil	0.05	0.00	*100.00 (90.00)
Azoxystrobin + Mancozeb	0.30	0.35	96.11 (78.63)
Azoxystrobin 23% SC	0.10	1.67	81.44 (64.48)
Mancozeb 75 WP	0.30	4.45	50.56 (45.32)
Control	-	9.00	0.00 (0.00)
S.Em±	-	0.07	0.81
CD (0.05)	-	0.21	2.44

*Mean of three replications, and figures in the parenthesis are arcsine transformed values

Table 3: Bio-efficacy of fungicide spray on severity of late blight disease of tomato under field conditions.

Treatment	Dosage	Disease Index (%) at 10 days after different sprays		
		Pre - spray	I spray	II spray
I season (*Kharif* 2019)				
Famaxadone + Cymoxanil	1.0 ml	7.00 (15.34)*	9.88 (18.32)	11.06 (19.42)
Azoxystrobin+Mancozeb	3.0 gm	6.38 (14.63)	9.26 (17.72)	12.35 (20.57)
Azoxystrobin	1.0 ml	7.00 (15.34)	15.64 (23.30)	19.55 (26.25)
Mancozeb	3.0 gm	6.38 (14.63)	23.25 (28.84)	33.13 (35.16)
Control	-	7.00 (15.34)	37.16 (37.56)	58.84 (47.78)
S.em±	-	0.73	0.49	0.36
Cd (0.05)	-	*Ns*	1.51	1.08
II season (*Kharif* 2020)				
Famaxadone + Cymoxanil	1.0 ml	6.58 (14.87)	7.87 (16.30)	10.85 (19.24)
Azoxystrobin+Mancozeb	3.0 gm	5.97 (14.14)	8.49 (16.94)	11.68 (19.99)
Azoxystrobin	1.0 ml	6.69 (14.99)	14.09 (22.05)	18.11 (25.19)
Mancozeb	3.0 gm	5.97 (14.14)	21.40 (27.56)	30.97 (33.83)
Control	-	6.58 (14.87)	34.79 (36.14)	69.91 (56.73)
S.Em±	-	0.48	0.32	0.37
CD (0.05)	-	*NS*	0.82	0.94

*Figures in the parenthesis are arcsine transformed values *NS* – Non significant

Table 4: Effect of fungicide spray on yield of tomato.

Treatment	Yield (t/ha)		Cost: Benefit Ratio (Rs.)	
	Kharif 2019	*Kharif* 2020	*Kharif* 2019	*Kharif* 2020
Famaxadone + Cymoxanil	51.25	45.83	1:2.72	1:2.43
Azoxystrobin + Mancozeb	64.79	59.58	1:3.42	1:3.14
Azoxystrobin	64.17	59.17	1:3.36	1:3.10
Mancozeb	43.33	37.08	1:2.28	1:1.95
Control	18.54	14.38	1:1.01	1:0.78
S.Em ±	0.958	0.376	-	-
CD (0.05)	2.39	0.94	-	-

Table 5: Phytotoxicity assessment of fungicide spray on tomato.

Treatment	Phtotoxicity observations						
	Leaf injury on tips	Stunting	Necrosis	Chlorosis	Vein clearing	Wilting	Epinasty/ Hyponasty
I season (*Kharif* 2019)							
Famaxadone + Cymoxanil	-	-	-	-	-	-	-
Azoxystrobin + Mancozeb	-	-	-	-	-	-	-
Azoxystrobin	-	-	-	-	-	-	-
Mancozeb	-	-	-	-	-	-	-
Control	-	-	-	-	-	-	-
II season (*Kharif* 2020)							
Famaxadone + Cymoxanil	-	-	-	-	-	-	-
Azoxystrobin+Mancozeb	-	-	-	-	-	-	-
Azoxystrobin	-	-	-	-	-	-	-
Mancozeb	-	-	-	-	-	-	-
Control	-	-	-	-	-	-	-

- No phytotoxicity

Azoxystrobin + Mancozeb with 96.11 per cent mycelial inhibition (Table 2). Further, Azoxystrobin exhibited 81.44 per cent mycelial inhibition and least effect was seen with Mancozeb 75 WP @ 3g/l. The complete cessation of mycelial growth of *P. infestans* by Famoxadone + Cymoxanil (oxazolidinedione + cyanoacteamide-oxime group of fungicide) was evidenced by early workers under *in vitro* (Saha *et al,* 2017; Lal *et al,* 2018). Mere on *in vitro* studies the efficacy cannot be confirmed, as the evaluation is done under controlled environment wherein the only pathogen directly interacts with the test fungicide. Further, the test fungicide is not exposed to numerous field factor like variations in temperature, relative humidity and dilution factors (rain and irrigation) *etc.* Thus, to validate the efficacy, the fungicides were further evaluated under field conditions.

Field screening of fungicides against tomato late blight

In the field condition the combi fungicide, Famoxadone + Cymoxanil resulted in lowest disease index (DI) at the end of the experiment in both the seasons (*kharif* 2019 and *kharif* 2020) documenting 9.88 per cent and 11.06 per cent of DI in first and second season, respectively (Table 3). It was also noticed the least increase in severity of disease from beginning till end of the experiment evidencing higher effect of fungicide on pathogen. The same fungicide was noted with higher tomato yield of 51.25 t/ha and 45.83 t/ha in first and second season, respectively as against control recording 18.54 t/ha and 14.38 t/ha. Consequently, higher the cost-benefit ratio was also recorded in the same fungicide (Table 4). Further, combi fungicide Azoxystrobin + Mancozeb was noted

to be next best with respect to enhanced disease control and improved yield which can be employed in management of disease if more than two sprays needed. Interestingly, the individual component fungicides (Azoxystrobin and Mancozeb) were capable to arrest the disease menace in field in both the seasons but, they performed better in combination. None of the fungicides exhibited any visible phytotoxicity symptoms at their recommended dosage in both the seasons (Table 5). The higher efficacy of famoxadone + cymoxanil in managing the late blight of tomato was well documented by early researchers (Saha *et al*, 2017; Lal *et al,* 2018, Supriya *et al,* 2020; Hegde, 2022). Similarly, the higher efficacy of Azoxystrobin in managing the late blight of tomato are in line with findings of Amin *et al* (2013) and Supriya *et al* (2020).

The possible mechanism for higher efficacy Famoxadone against the pathogen is due to its oxazolidinedione group of fungicide belonging to the quinol inhibitor family-QoI (quinol oxidation site of Complex III), which inhibits the mitochondrial respiration of fungi by decreased production of ATP in pathogen there by suppressing the growth and multiplication of the fungi. Similarly, the Cymoxanil is absorbed by the whole plant due to its degrading compound, cyanoacteamide-oxime to glycine within 16-44 h, disrupting the metabolic processes of fungal pathogens, effectively halting their growth and development Comparing to the individual fungicides, the combination proved more effective and reason would be synergetic effect of both oxazolidinedione + cyanoacteamide-oxime groups (NCBI, 2025).

CONCLUSION

The present study highlights the higher bio efficacy of Famoxadone +Cymoxanil, due to its broad-spectrum management adhering to best practices and safety guidelines, while promoting sustainable and environmentally responsible agricultural practices in the pursuit of higher yields and healthier harvests against tomato late blight and hence it may be employed in management of the same under field condition and optimizing resource utilization and mitigating the financial strains on farmers by minimizing the need for multiple fungicide applications throughout the growing season.

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