International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 2484-2488

Received: 10-07-2019
Accepted: 12-08-2019

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Evaluation of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) on tomato against early blight (*Alternaria* spp), and powdery mildew (*Leveillula taurica*) under field condition

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Abstract
The tomato is the edible, often red, berry of the plant *Solanum lycopersicum*, commonly known as a tomato plant. The species originated in western South America and Central America. Despite botanically being a fruit, it's generally eaten and prepared like a vegetable. Tomatoes are the major dietary source of the antioxidant lycopene, which has been linked to many health benefits, including reduced risk of heart disease and cancer. Early blight caused by *Alternaria solani* and powdery mildew caused by *Leveillula taurica* has become a serious problem for successful cultivation of tomato. Therefore, a field experiment was carried out on the effect of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) on Tomato against early blight (*Alterneria* spp), and Powdery mildew (*Leveillula taurica*) during 2016-17 and 2017-18, at College of Horticulture, Hiriyur. Experimental results revealed that all the treatments significantly reduced the early blight and powdery mildew disease severity over untreated control. Amongst all the treatments in both seasons significantly least disease severity of early blight (6.25 and 5.50%) and Powdery mildew (2.50 and 3.00%) was recorded with foliar application of 1.2 ml of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) with yield of 8.83 and 9.42 t/ha followed by the application of 1 ml of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC).

Keywords: Tomato, early blight, powdery mildew and pydiflumetofen + difenoconazole

Introduction
The Tomato (*Lycoperiscum esculantum* L.) is a diploid species with 2n=24 chromosomes and belongs to the family Solanaceae. It is the world's largest vegetable crop after potato (Maya and Thippanna 2013) [7]. Tomato is one of the most popular warm season fruit vegetable crop grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of cuisines in fresh as well as in preserved form. It is mostly considered as "Protective food" based on its nutritive value, antioxidant molecules such as carotenoids, particularly lycopene, ascorbic acid, vitamin E and phenol compounds, particularly flavonoids (Sepat *et al*., 2013) [13]. Lycopene has important dietetic properties since it reduces the risk of several types of cancers and heart attacks (Clinton, 2005) [3]. Tomato crop is vulnerable to infect by bacterial, viral, nematode and fungal diseases. Among the fungal diseases, Alternaria leaf blight of tomato caused by *Alternaria solani*, is a soil inhabiting air-borne pathogen responsible for leaf blight, collar and fruit rot of tomato disseminated by fungal spores (Datar and Mayee, 1981) [2]. It is an important disease of tropical and sub-tropical areas. Distinctive bulls-eye pattern of leaf spots with concentric rings of spores surrounded by a halo of chlorotic leaf area are common. Leaves turn yellow and dry up when only a few spots are present (Gleason and Edmonds, 2006) [4]. The pathogen causes infection on leaves, stem, petiole, twig and fruits as well as leads to the defoliation, drying of twigs and premature fruit drop which ultimately reduce the yield 30 to 65% in various states (Basu, 1974; Datar and Mayee, 1981; Kamble *et al*., 2009; Saha and Das, 2013) [2, 5, 12]. The disease, if favoured by high temperature and humidity (crowded plantation, high rainfall and extended period of leaf wetness from dew) and plants are more susceptible to the blight infection during fruiting period (Momel and Pemezny, 2006) [9]. Symptoms of powdery mildew caused by *Leveillula taurica* include white lesion on the adaxial leaves surface and on all the other aerial plant parts except on fruits. The fruits are not directly affected but impaired photosynthesis and premature senescence reduces fruit size and nutritional quality leading to diminished yield (Mieslerova and Lebeda, 1999) [8].

In severe out breaks, the lesions coalesce and the disease is debilitating resulting in the death of leaves.

Most of the new generation fungicides are highly specific and single site in mode of action. Thus, a novel fungicide with novel mode of action needs to be identified and evaluated under field conditions. Our objective was to determine the efficacy of different doses of newer generation fungicidal formulations of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) to develop a management module for early blight and powdery mildew of tomato.

Methodology adopted

The field experiment on bio efficacy and phytotoxicity of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) against foliar diseases of tomato was carried out during 2016-17 and 2017-18 at College of Horticulture, Hiriyur, UAHS, Shivamogga. The spray schedule was initiated soon after the disease appearance. The experiments consisted of eight treatments *viz.*, untreated check, Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @0.8, 1.0 and 1.2 ml/lt, Pydiflumetofen 20% SC @ 0.45 ml/lt, Difenoconazole 25% EC (Score 25 EC) 1ml/lt, Tebuconazole 50% + Trifloxystrobin 25% WG @0.7 g/lt and Pyraclostrobin 20% WG 1ml/lt. The experiment was laid out with randomized block design (RBD). The treatment fungicides were sprayed to the tomato plot at the beginning of the disease appearance. Spray schedule was repeated at 14 days interval. The observation of *Alternaria solani*, early blight and *Leveillula taurica* powdery mildew were recorded using 0-5 scale at before and after each spray. Observation are taken at 0, 7 and 14 days after each application. Average of all spray has been given in this and the data was statistically analyzed after suitable transformations. The recorded grade values were converted into Percent Disease Index (PDI) by using following formula proposed by Wheeler (1969) [14].

Pandey & Pandey (2002) [10] reported that rating scale for scoring disease intensity early blight of tomato

Leaf area infected

Grade or Numerical value	Leaf area infected
0	Disease free
1	0-10
2	11-25
3	26-50
4	51-75
5	>76

The percent disease index (PDI) was calculated by the formula:

$$PDI = \frac{\text{Sum of all individual disease ratings}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Max. grade in scale}}$$

For Phytotoxicity studies

Sl. No	Treatment	g. a.i/ha	Formulation (ml/lt of water)
1	Untreated check	-	-
2	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	120 (45+75)	1.2
3	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	240 (90+150)	2.4

Experimental results and discussion

In 2016-17 during the first spray there was not much significant differences among the treatments imposed with respect to the reduction of foliar diseases like early blight and powdery mildew. However the plot sprayed with Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt has recorded lowest Per cent Disease Index (PDI) of early blight (6.25) which is on par with the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt (6.75) and significantly superior over the rest of the treatments. Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt and 1 ml/lt recorded 84.00 and 82.72 per cent disease reduction over check, respectively and were at par with each other (Table 1).

The less disease severity of powdery mildew 2.50% has been observed in treatment treated with Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt which is on par with the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt (2.67). Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt and 1 ml/lt recorded 87.17 and 86.30 per cent disease reduction over check, respectively and were at par with each other. The treatment treated with Pydiflumetofen 20% SC @ 0.45 ml/lt (4.17) Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.7 g/lt (5.00), Pyraclostrobin 20% WG @ 1 ml/lt (5.33) and Difenoconazole 25% EC @1 ml/lt (5.75) and untreated check (19.50) were inferior over the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 and 1 ml/lt (Table- 2).

In the year 2017-18 during the first application there was not much significant difference among the treatments imposed with respect to the reduction of foliar diseases like early blight and powdery mildew. However the plot sprayed with Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt has recorded lowest terminal Per cent Disease Index (PDI) of early blight (5.50) which is on par with the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt (6.00) and significantly superior over the rest of the treatments. Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt and 1 ml/lt recorded 85.57 and 84.26 per cent disease reduction over check, respectively and were at par with each other (Table 3).

The less terminal percent disease index of powdery mildew 3.00 has been observed in treatment treated with Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt which is on par with the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt (3.17) and Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt and 1.0 ml/lt recorded 87.23 and 86.51 per cent disease reduction over check, respectively and were at par with each other. Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 0.8 ml/lt (6.67) is at par with the Pyraclostrobin 20% WG @ 1 ml/lt (6.50) and Difenoconazole 25% EC @ 1 ml/lt (7.00) and inferior over the Tebuconazole 50% + Trifloxystrobin 25% WG@ 0.7 gm/lt (6.12) (Table- 4).

Yield

The comparatively higher fruit yield was recorded in the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt (8.83 t/ha) followed by Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt (8.25 t/ha) during 2016-2017. As per the results the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt and Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt was recorded 29.21 and 24.24 per cent increase in fruit yield in comparison with standard chemical like Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.7 g/lt, Pyraclostrobin 20% WG @ 1 ml/lt and Difenoconazole 25% EC @ 1 ml/lt (Table 5).

During the year 2017-18 a comparative fruit yield was also recorded and the same treatment of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt has recorded the highest fruit yield of 9.42 t/ha followed by Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt (9.08 t/ha). As per the results the Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt and Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1 ml/lt were recorded 23.03 and 20.15 per cent higher fruit yield in comparison with the standard chemical like Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.7 g/lt (15.50), Pyraclostrobin 20% WG@ 1 ml/lt (14.20) and Difenoconazole 25% EC@ 1 ml/lt (10.71) (Table 5). Difenoconazole based fungicide is effective against *Alternaria* and other pathogens related to Ascomycetes fungi in very low concentration. The above results were in agreement with the earlier work of Dahmen and Staub, 1992 [1]; Kopacki and Wagner, 2006 [6]; Pobedinskaya *et al*., 2012 [11]. For the tomato plants difenoconazole based fungicides is traditionally applied against early blight, caused by *Alternaria*. Early blight and late blight in the field often occur at the same time. The application of difenoconazole based fungicide controls the development of *Alternaria* effectively.

Phytotoxicity

There were no phytotoxicity symptoms like epinasty, hyponasty, vein clearing, yellowing, necrosis, leaf margin burning, rossetting and wilting were observed in different concentrations of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) (Table 6).

Conclusions

Based on the experimental results it has been found that, Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) @ 1.2 ml/lt is most effective in management of foliar diseases (early blight and powdery mildew) of tomato which is followed by the same fungicide @ 1 ml/lt when compared to the other treatments.

Acknowledgement

The senior author is grateful to M/s Syngenta, India Ltd, Pune for providing financial assistance to conduct the study.

Table 1: Bio efficacy of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) against early blight of Tomato (2016-17).

Sl. No	Treatment	Dosage G or ml/lt of water	PTO	7 DAA1	14 DAA1	7 DAA2	14 DAA2	% disease reduction
1	Untreated check	--	2.12	6.43	10.53	27.54	39.08	--
2	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	0.8	1.76	3.03	5.43	8.14	11.33	71.00
3	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.0	1.72	2.83	2.96	4.67	6.75	82.72
4	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.2	1.40	2.43	2.63	3.87	6.25	84.00
5	Pydiflumetofen 20% SC	0.45	2.02	3.23	4.06	6.38	9.50	75.69
6	Difenoconazole 25% EC (Score 25 EC)	1.0	2.34	4.96	6.53	9.56	12.50	68.01
7	Tebuconazole 50% + Trifloxystrobin 25% WG	0.7	1.46	3.16	5.76	8.26	11.08	71.64
8	Pyraclostrobin 20% WG	1.0	2.32	4.00	6.16	8.50	11.66	70.16
SEm±			NS	0.23	0.18	0.30	0.66	
CD (0.05%)			NS	0.68	0.42	0.96	1.96	
CV			NS	12.02	5.32	4.76	8.48	

*PTO- Pretreatment observation, DAA1- Days after 1st application, DAA2- Days after 2nd application

Table 2: Bio efficacy of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) against powdery mildew of Tomato (2016-17).

Sl. No	Treatment	Dosage ml/lt	PTO	7 DAA1	14 DAA1	7 DAA2	14 DAA2	% disease reduction
1	Untreated check	--	0.56	2.36	6.66	15.53	19.50	--
2	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	0.8	0.52	0.56	1.06	2.93	5.67	70.92
3	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.0	0.22	0.30	0.46	0.86	2.67	86.30
4	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.2	0.14	0.20	0.23	0.66	2.50	87.17
5	Pydiflumetofen 20% SC	0.45	0.26	0.46	0.96	1.36	4.17	78.61
6	Difenoconazole 25% EC (Score 25 EC)	1.0	0.70	0.90	1.20	2.63	5.75	70.51
7	Tebuconazole 50% + Trifloxystrobin 25% WG	0.7	0.10	0.96	1.06	2.36	5.00	74.35
8	Pyraclostrobin 20% WG	1.0	0.62	1.16	1.76	2.56	5.33	72.66
SEm±			NS	0.22	0.36	0.18	0.26	
CD (0.05%)			NS	0.47	0.98	0.44	0.89	
CV			NS	5.86	10.19	6.54	6.36	

* PTO- Pretreatment observation, DAA1- Days after 1st application, DAA2- Days after 2nd application

Table 3: Bio efficacy of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) against early blight of Tomato (2017-18)

Sl. No	Treatment	Dosage ml/lt	PTO	7 DAA1	14 DAA1	7 DAA2	14 DAA2	% disease reduction
1	Untreated check	--	1.24	5.33	14.66	24.38	38.12	--
2	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	0.8	1.33	2.13	5.36	8.26	11.25	70.48
3	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.0	1.22	1.86	2.60	4.38	6.00	84.26
4	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.2	1.46	1.54	2.36	3.66	5.50	85.57
5	Pydiflumetofen 20% SC	0.45	1.26	2.33	3.60	5.36	9.00	76.39
6	Difenoconazole 25% EC (Score 25 EC)	1.0	1.36	2.66	5.76	8.76	11.75	69.17
7	Tebuconazole 50% + Trifloxystrobin 25% WG	0.7	1.60	2.76	4.36	7.66	10.12	73.45
8	Pyraclostrobin 20% WG	1.0	1.82	3.36	4.86	7.76	10.50	72.45
SEm±			NS	0.33	0.22	0.36	0.66	
CD (0.05%)			NS	0.96	0.64	1.12	2.13	
CV			NS	10.12	8.13	7.56	11.13	

* PTO- Pretreatment observation, DAA1- Days after 1st application, DAA2- Days after 2nd application

Table 4: Bio efficacy of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) against powdery mildew of Tomato. (2017-18)

Sl. No	Treatment	Dosage ml/lt	PTO	7 DAA1	14 DAA1	7 DAA2	14 DAA2	% disease reduction
1	Untreated check	--	0.60	4.66	8.46	18.86	23.50	--
2	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	0.8	0.32	0.46	0.90	5.86	6.67	71.61
3	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.0	0.36	0.40	0.50	1.02	3.17	86.51
4	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.2	0.34	0.30	0.40	0.96	3.00	87.23
5	Pydiflumetofen 20% SC	0.45	0.30	0.50	0.90	2.10	4.97	78.85
6	Difenoconazole 25% EC (Score 25 EC)	1.0	0.36	1.10	2.67	5.96	7.00	70.21
7	Tebuconazole 50% + Trifloxystrobin 25% WG	0.7	0.46	1.66	2.60	5.30	6.12	73.95
8	Pyraclostrobin 20% WG	1.0	0.36	1.36	2.08	5.36	6.50	72.34
SEm±			NS	0.22	0.19	0.26	0.42	
CD (0.05%)			NS	0.77	0.64	0.62	1.28	
CV			NS	5.16	9.76	7.18	9.14	

* PTO- Pretreatment observation, DAA1- Days after 1st application, DAA2- Days after 2nd application

Table 5: Effect of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) on Yield of Tomato during 2016-17 and 2017-18

Sl. No	Treatment	Dosage ml/lt	2016-2017		2017-18	
			Yield (t/ha)	% yield Increase	Yield (t/ha)	% yield Increase
1	Untreated check	--	6.25	--	7.25	--
2	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	0.8	6.92	9.68	8.17	11.26
3	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.0	8.25	24.24	9.08	20.15
4	Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.2	8.83	29.21	9.42	23.03
5	Pydiflumetofen 20% SC	0.45	7.17	12.83	8.88	18.35
6	Difenoconazole 25% EC (Score 25 EC)	1.0	6.88	9.15	8.12	10.71
7	Tebuconazole 50% + Trifloxystrobin 25% WG	0.7	7.98	21.67	8.58	15.50
8	Pyraclostrobin 20% WG	1.0	7.82	20.07	8.45	14.20
SEm±			0.36		0.37	
CD (0.05%)			1.38		1.14	
CV			8.38		10.48	

Table 6: Impact of Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC) on Tomato (mean of two sprays) during 2016-17 and 2017-18

Treatments	Dose (g or ml/lt of water)	Score values on																																	
		0 DAA						1 DAA						3 DAA				5 DAA						7 DAA						10 DAA					
		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pydiflumetofen 7.5% + Difenoconazole 12.5% w/v (200 SC)	2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Untreated check	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

A: Leaf injury on tips and leaf surface; B: Wilting; C: Leaf vein clearing; D: Necrosis; E: Epinasty; F: Hyponasty; DAA: Days after Application.

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