The Pharma Innovation Journal 2021; SP-10(12): 1438-1441

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(12): 1438-1441

www.thepharmajournal.com
Received: 20-10-2021
Accepted: 26-11-2021

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Evaluation of different fungicides, biocontrol agents and botanicals for the management of tomato early blight under field conditions

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Abstract
Early blight caused by *Alternaria solani* (Ellis and Martin) Jones and Grout is one of the most widely spread and destructive disease of tomato. The field efficacy of selected ten treatments was studied for the management of early blight of tomato caused by *A. solani* during late *kharif* 2019-20 and 2020-21. All the treatments reduced the disease intensity as compared to control. Among the treatments [Propiconazole (25%) EC, Mancozeb (75%) WP, Copper oxychloride (50%) WP, Carbendazim (12%) + mancozeb (63%) WP, Tebuconazole (50%) + trifloxystrobin (25%) WG, *Allium sativum* extract, *Azadirachta indica* extract, *Trichoderma harzianum* and *Pseudomonas fluorescens*] three sprays, first at disease initiation, second at 15 days after the first spray and third at 15 days after the second spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent recorded significantly the lowest disease intensity (8.13%, 10.40% and 13.47%) at 45, 60 and 75 days after transplanting, respectively with the highest yield (35.14 t/ha) and was found to be the most effective for the management of early blight disease and increasing fruit yield over control.

Keywords: Early blight, tomato, *alternaria solani*, fungicides, botanicals, biocontrol agents and disease intensity

Introduction
Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crop after potato and is cultivated year-round in tropical and subtropical regions of the world. It is believed to be a native of tropical America (Central and South America), particularly Peru and Mexico. Tomato is extensively consumed in diverse ways as salad, an ingredient in curries and preserved with value addition. It is rich in vitamins and minerals with its anti-cancerous, antiseptic, antioxidant and anti-ageing properties and known to be one of the protective foods for mankind.

In India, it is cultivated in the area of 8.11 lakh ha with 211.73 lakh MT production and 25 MT/ha productivity (Anonymous, 2020a). The major tomato producing states are Gujarat, Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal. In Gujarat, it is extensively cultivated in an area of 49707.00 ha with a production of 1426829 MT of fruits and productivity of 29 tones/ha. The major tomato growing districts of Gujarat are Navsari, Surat, Valsad, the Dangs, Gandhinagar, Mehsana, Sabarkantha, Banaskantha, Patan, Kheda, Dahod, Narmada, Panchmahals, Vadodara and Bhavnagar. In South Gujarat, it is cultivated in an area of 5633 ha with 129906 MT production (Anonymous, 2020b).

Tomato is commonly affected by numerous diseases. Among them, early blight of tomato caused by a necrotrophic fungus, *A. solani* (Ellis & Martin) Jones and Grout, is the world's most catastrophic disease incurring loss both at pre-and post-harvest stages in tomato. The yield losses due to early blight ranged from 48-80 per cent in tomatoes from India, Canada, USA and Nigeria (Mathur and Shekhawat, 1986; Gwary and Nahunnarao, 1998 and Pandey *et al.*, 2003) [6, 4, 7]. The causal organism is air borne and soil-inhabiting and it can also come from other hosts through splashing rain. It causes leaf spots, stem lesions, collar rot and fruit spots which affect most part of the plant. The present studies were therefore, intended to reveal the efficacy of different fungicides, biocontrol agents and botanicals against the early blight of tomato.

Materials and Methods

The experiment was carried out during late *kharif* 2019-20 and 2020-21 at College Farm, N.M. college of Agriculture, NAU, Navsari. The details of experiments are as under.

Evaluation of different fungicides, biocontrol agents and botanicals against the early blight of tomato (Table 1) was carried out in a randomized block design with ten treatments and three replications. Thirty days old seedlings of tomato cv. GAT-5 were transplanted in a plot size of 4.8 m × 3.6 m experimental plots with a raw spacing of 60 cm and plant spacing of 40 cm. The crop was raised as per recommended package of practices and protective irrigation was given as and when required.

A total of three sprayings of all the treatments were undertaken at an interval of 15 days, starting first spraying at first appearance of early blight disease symptoms, second at 15 days after first spray and third at 15 days after second spray were carried out. The efficacy of these treatment was compared with the control plot, which was kept unsprayed with any kind of fungicide, bioagents and botanicals.

Five plants per treatment per replication were selected randomly and tagged; five leaves from each plant were selected for recording observations at 45, 60 and 75 days after transplanting using the following 0-5 scale (Datar and Mayee, 1986) [3] (Table 2).

Table 1: Fungicides, biocontrol agents and botanicals used for the management of the tomato early blight

Sr. No.	Treatments	Conc. (%)	Dose
1	Propiconazole (25%) EC	0.025	1ml/lit.
2	Mancozeb (75%) WP	0.2	2.67g/lit.
3	Copper oxychloride (50%) WP	0.125	2.5g/lit.
4	Carbendazim (12%) + mancozeb (63%) WP	0.2	2.67g/lit.
5	Tebuconazole (50%) + trifloxystrobin (25%) WG	0.05	0.67g/lit.
6	*Allium sativum* L. (Garlic clove extract)	10	100ml in 900ml
7	*Azadirachta indica Juss.* (Neem leaf extract)	10	100ml in 900ml
8	*Trichoderma harzianum* 1×10^8 cfu/gm	0.5	5g/lit.
9	*Pseudomonas fluorescens* 1×10^8 cfu/ml	0.5	5ml/lit.
10	Control	-	-

Table 2: Standard disease rating scale (0-5 grade) for accessing PDI of early blight of tomato

Scale	Description
0	No symptoms on the leaf
1	0-5 per cent leaf area infected and covered by spot, no spot-on petiole and branches
2	6-20 per cent leaf area infected and covered by spots, some spots on the petiole
3	21-40 per cent leaf area infected and covered by spot, spots also seen on petiole, branches
4	41-70 per cent leaf area infected and covered by spot, spots also seen on petiole, branches, stem
5	>71 per cent leaf area infected and covered by spot, spots also seen on petiole, branch, stem, fruits

Per cent Disease Intensity (PDI) was worked out by using the formula given by Wheeler (1969):

$$\text{Per cent disease intensity (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{Total no. of plant examined} \times \text{Maximum no. of disease rating}} \times 100$$

In both, seasons mature and ripened tomato fruits were harvested regularly in all the treatments replicated and cumulative fruit yield for all pickings per plot was recorded and yield in t/ha was calculated.

Results and Discussion

Effect of Fungicides, Biocontrol Agents and Botanicals on the Disease Intensity of Early Blight of Tomato Late *kharif* 2019-20

Results revealed that after first spraying (one day before second spraying- at 45 DAT), minimum disease intensity (9.33%) was recorded in foliar spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent during late *kharif* 2019-20 and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (10.13%), propiconazole (25% EC) at 0.025 per cent (12.27%) and carbendazim (12%) + mancozeb (63%) at 0.2 per cent (13.33%).

After the second spraying (one day before third spraying- at 60 DAT), significantly least disease intensity (11.20%) was recorded with the fungicide spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (13.07%) and propiconazole (25% EC) at 0.025 per cent (14.40%).

The disease intensity recorded at 15 days after 3rd spraying (at 75 DAT) was found that significantly least disease intensity (14.40%) was recorded with the fungicide spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (15.47%) and propiconazole (25% EC) at 0.025 per cent (17.07%).

Late *kharif* 2020-21

Results indicated that after first spraying (one day before second spraying- at 45 DAT), minimum disease intensity (6.93%) was recorded in foliar spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (8.27%).

After second spraying (one day before third spraying- at 60 DAT), significantly least disease intensity (9.60%) was with the fungicide spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (11.20%) and propiconazole (25% EC) at 0.025 per cent (13.33%).

The disease intensity recorded at 15 days after 3rd spraying (at 75 DAT) was found that significantly least disease intensity (12.53%) was recorded with the fungicide spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent

and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (14.13%) and propiconazole (25% EC) at 0.025 per cent (16.27%).

Pooled

Pooled analysis of two year revealed that after first spraying (one day before second spraying- at 45 DAT), minimum disease intensity (8.13%) was recorded in foliar spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (9.20%). Moreover, next best in order of merit were recorded with minimum PDI by the application of propiconazole (25% EC) at 0.025 per cent (11.60%), carbendazim (12%) + mancozeb (63%) at 0.2 per cent (13.20%), copper oxychloride (50% WP) at 0.125 per cent (16.93%), *T. harzianum* at 0.5 per cent (20.93%), *P. fluorescens* at 0.5 per cent (22.67%), *A. sativum* at 10 per cent (24.80%) and *A. indica* at 10 per cent (25.73%).

After second spraying (one day before third spraying- at 60 DAT), significantly least disease intensity (10.40%) was recorded with the fungicide spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (12.13%). Moreover, next best in order of merit were recorded with minimum PDI by the application of propiconazole (25% EC) at 0.025 per cent (13.87%), carbendazim (12%) + mancozeb (63%) at 0.2 per cent (16.67%), copper oxychloride (50% WP) at 0.125 per cent (19.73%), *T. harzianum* at 0.5 per cent (23.33%), *P. fluorescens* at 0.5 per cent (25.07%), *A. sativum* at 10 per cent (28.00%) and *A. indica* at 10 per cent (29.47%).

The disease intensity recorded at 15 days after 3rd spraying (at 75 DAT) was found significantly least disease intensity (13.47%) was recorded with the fungicides spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was statistically at par with mancozeb (75% WP) at 0.2 per cent (14.80%) and propiconazole (25% EC) at 0.025 per cent (16.67%). Moreover, next best in order of merit were recorded minimum PDI with the application of carbendazim (12%) + mancozeb (63%) at 0.2 per cent (20.53%), copper oxychloride (50% WP) at 0.125 per cent (23.73%), T. harzianum at 0.5 per cent (28.93%), P. fluorescens at 0.5 per cent (32.53%), A. sativum at 10 per cent (36.93%) and A. indica at 10 per cent (40.67%).

Table 3: Effect of fungicides, botanicals and bioagents against early blight of tomato

Sr. No.	Treatments	Conc. (%)	PDI								
			45 DAT			60 DAT			75 DAT		
			2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1	Propiconazole (25%) EC	0.025	20.47** (12.27)*	19.26 (10.93)	19.86 (11.60)	22.26 (14.40)	21.40 (13.33)	21.83 (13.87)	24.31 (17.07)	23.72 (16.27)	24.01 (16.67)
2	Mancozeb (75%) WP	0.2	18.45 (10.13)	16.51 (8.27)	17.48 (9.20)	21.13 (13.07)	19.48 (11.20)	20.31 (12.13)	23.13 (15.47)	22.02 (14.13)	22.57 (14.80)
3	Copper oxychloride (50%) WP	0.125	23.89 (16.53)	24.53 (17.33)	24.21 (16.93)	26.07 (19.47)	26.55 (20.00)	26.31 (19.73)	29.30 (24.00)	28.94 (23.47)	29.12 (23.73)
4	Carbendazim (12%) + mancozeb (63%) WP	0.2	21.32 (13.33)	21.13 (13.07)	21.23 (13.20)	24.34 (17.07)	23.75 (16.27)	24.04 (16.67)	27.67 (21.60)	26.15 (19.47)	26.91 (20.53)
5	Tebuconazole (50%) + trifloxystrobin (25%) WG	0.05	17.66 (9.33)	15.07 (6.93)	16.37 (8.13)	19.45 (11.20)	17.82 (9.60)	18.64 (10.40)	22.28 (14.40)	20.61 (12.53)	21.45 (13.47)
6	*Allium sativum* (Garlic clove extract)	10	29.27 (24.00)	30.37 (25.60)	29.82 (24.80)	32.10 (28.57)	31.72 (27.73)	31.91 (28.00)	37.17 (36.53)	37.65 (37.33)	37.41 (36.93)
7	*Azadirachta indica* (Neem leaf extract)	10	30.00 (25.07)	30.91 (26.40)	30.46 (25.73)	33.10 (29.87)	32.59 (29.07)	32.85 (29.47)	39.37 (40.27)	39.85 (41.07)	39.61 (40.67)
8	*Trichoderma harzianum* 1×10^8 cfu/gm	0.5	26.92 (20.53)	27.44 (21.33)	27.18 (20.93)	28.90 (23.47)	28.79 (23.20)	28.85 (23.33)	32.25 (28.53)	32.76 (29.33)	32.51 (28.93)
9	*Pseudomonas fluorescens* 1×10^8 cfu/ml	0.5	28.03 (22.13)	28.75 (23.20)	28.39 (22.67)	30.18 (25.33)	29.85 (24.80)	30.01 (25.07)	34.56 (32.27)	34.90 (32.80)	34.73 (32.53)
10	Control	-	34.09 (31.47)	33.27 (30.13)	33.68 (30.80)	37.80 (37.60)	36.99 (36.27)	37.39 (36.93)	43.08 (46.67)	42.01 (44.80)	42.55 (45.73)
	S.Em.±	-	1.43	1.31	0.97	1.39	1.30	0.95	1.42	1.35	0.98
	C.D. at 5%	-	4.26	3.89	2.79	4.14	3.87	2.73	4.21	4.02	2.81
	C.V.	-	9.94	9.18	9.57	8.76	8.38	8.58	7.83	7.59	7.71

*Figure in parenthesis is original value, **Figures outside parenthesis is arcsine transform value, DAT: Days after transplanting

Effect of Fungicides, Botanicals and Bioagents on Fruit Yield of Tomato Late *kharif* 2019-20

The tomato fruit yield during late *kharif* 2019-20 was found higher in all treatments as compared to control. The highest fruit yield (34.53 t/ha) was obtained in tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent which was statistically at par with mancozeb (75% WP) at 0.2 per cent (33.26 t/ha) and propiconazole (25% EC) at 0.025 per cent (32.30 t/ha).

Late *kharif* 2020-21

Total fruit yield was more (35.74 t/ha) in the treatment sprayed with tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent which was statistically at par with mancozeb (75% WP) at 0.2 per cent (34.46 t/ha), propiconazole (25% EC) at 0.025 per cent (33.42 t/ha) and carbendazim (12%) + mancozeb (63%) at 0.2 per cent (31.26 t/ha).

Pooled

In pooled of two years, total fruit yield was significantly higher in all the treatments over control. However, maximum fruit yield (35.14 t/ha) was obtained in plot sprayed with tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent and it was at par with mancozeb (75% WP) at 0.2 per cent (33.86 t/ha) and propiconazole (25% EC) at 0.025 per cent

(32.86 t/ha). Furthermore, next best order of merit was carbendazim (12%) + mancozeb (63%) at 0.2 per cent (30.68 t/ha). Moreover, next best in order of merit were copper oxychloride (50% WP) at 0.125 per cent (28.47 t/ha), *T. harzianum* at 0.5 per cent (25.32 t/ha), *P. fluorescens* at 0.5 per cent (24.27 t/ha), *A. sativum* at 10 per cent (22.19 t/ha) and *A. indica* at 10 per cent (21.27 t/ha).

The lowest fruit yield was recorded in control 19.46 t/ha, 20.28 t/ha and 19.87 t/ha during late *kharif* 2019-20, 2020-21 and pooled of two years, respectively. All the treatments of fungicides, botanicals and biocontrol agents exerted a significant reduction in the disease intensity and significant increase in yield during the investigation. Three sprays, first at disease initiation, second at 15 days after first spray and third at 15 days after second spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent recorded lowest disease intensity (8.13%, 10.40% and 13.47%) at 45, 60 and 75 days after transplanting, respectively with the highest yield (35.14 t/ha). The findings of present field studies suggested that the three sprays, first at disease initiation, second at 15 days after first spray and third at 15 days after second spray of tebuconazole (50%) + trifloxystrobin (25%) (75% WG) at 0.05 per cent (067g/lit. of water) was effective in reducing the early blight of tomato along with it increased the fruit yield in tomato.

Results obtained in present study were on the same line with the findings of those reported earlier by several workers. Saha *et al.* (2014) showed that spray of tebuconazole (50%) + trifloxystrobin (25%) WG at 350 g/ha resulted in the lowest early blight intensity during 2009-10 (11.1%) and 2010-11 (10.9%). Hegde and Nagaraj (2020) also recorded that two sprays of tebuconazole (50%) + trifloxystrobin (25%) WG @350g/ha and 400g/ha at 15 days interval was found promising in reducing the early blight disease and increasing the fruit yields as compared to the other treatments.

Table 4: Effect of fungicides, botanicals and bioagents on fruit yield of tomato

Sr. No.	Treatments	Yield (t/ha)		
		2019-20	2020-21	Pooled
1	Propiconazole (25%) EC	32.30	33.42	32.86
2	Mancozeb (75%) WP	33.26	34.46	33.86
3	Copper oxychloride (50%) WP	27.93	29.01	28.47
4	Carbendazim (12%) + mancozeb (63%) WP	30.11	31.26	30.68
5	Tebuconazole (50%) + trifloxystrobin (25%) WG	34.53	35.74	35.14
6	*Allium sativum* (Garlic clove extract)	21.61	22.77	22.19
7	*Azadirachta indica* (Neem leaf extract)	20.84	21.70	21.27
8	*Trichoderma harzianum* 1×10^8 cfu/gm	24.72	25.93	25.32
9	*Pseudomonas fluorescens* 1×10^8 cfu/ml	23.54	24.99	24.27
10	Control	19.46	20.28	19.87
	S.Em.±	1.42	1.68	1.10
	C.D. at 5%	4.20	4.99	3.15
	C.V.	9.14	10.41	9.82

Conclusion

The studies of field evaluation (during late kharif 2019-20 and 2020-21) of fungicides, bio-agents and botanicals against early blight disease indicated that the three sprays, first at disease initiation, second at 15 days after first spray and third at 15 days after second spray of tebuconazole (50%) + trifloxystrobin (25%) at 0.05 per cent found most effective for the management of tomato early blight.

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