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Management of tomato late blight caused by *Phytophthora infestans*

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Abstract
Late blight, caused by the *Phytophthora infestans*, is one of the most serious and economically important diseases of tomato. The study was conducted to develop an area specific effective intergraded disease management (IDM) module against the tomato late blight by combining the antagonists and need based fungicidal application. Of the three IDM modules tested in the field conditions during *rabi* 2013-14 (On Farm Testing - OFT) by ICAR-KVK, Kolar, Karnataka, the module T3 consisting of soil application of antagonists (1 kg each talc formulation of *Trichoderma harzianum* and *Pseudomonas fluorescens* enriched in 100 kg well decomposed FYM) prior to transplanting, prophylactic spray with Mancozeb (0.2%) twice at weekly interval before onset of the disease (on onset of disease favorable conditions) followed by curative sprays with Metalaxyl + Mancozeb (0.3%), Fosetyl-Al (0.2%) and Dimethomorph (0.1%) + Polyram (0.2%) at weekly interval at onset of the disease was found most effective in managing the disease. Hence, this module will serve as effective IDM against the tomato late blight under field conditions.

Keywords: late blight, *Phytophthora infestans*, antagonists, fungicides and tomato

Introduction

Late blight caused by *Phytophthora infestans*, is one of the most important diseases of tomatoes and potatoes worldwide (Son *et al.*, 2008) [17]. The late blight is known to cause more than $5 billion annual loss worldwide in both the crops and thus the pathogen is regarded as a threat to global food security (Latijnhouwers *et al.*, 2004) [9]. In the past few decades, the frequency and severity of the disease have increased in many parts of the world including India and have been a serious threat to tomato production (Chowdappa *et al.*, 2011) [3].

The tomato and potato growing region in northern parts of India has evidenced the annual and regular severity of late blight but was not the same case in southern parts, especially Karnataka prior to 2006. Post 2008, severe late blight occurrence has started occurring in major tomato and potato growing regions in south-west India including Karnataka, sometimes leading to cent percent crop loss and it might be due emergence of A2 mating type (Chowdappa *et al.*, 2013) [4]. Upon prevalence of congenial environmental conditions and in existence of new mating type the management of late blight becomes increasingly difficult under field conditions (Fry *et al.*, 2016) [6].

The systemic fungicides are playing major role in late blight management but under disease favoring environmental conditions the only curative fungicidal sprays have miserably failed to control the devastating problem. Further, the regular fungicidal use encourages the development of resistance in *P. infestans*, increases the production cost and more important being it is detrimental to the environment (Siddique *et al.*, 2016) [16]. Biological control of crop disease is receiving increased attention as an environmentally safe alternative to chemical pesticides but, bio-control agents alone are not sufficiently potent enough to curb the menace of devastating late blight in field conditions (Ellis *et al.*, 1999) [5].

Looking to the above facts it is imperative to formulate an effective region specific integrated disease management module consisting of diverse strategies against the disease. Effectiveness of prophylactic application of fungicides on onset of favorable environment before disease occurrence followed by curative sprays on disease onset have been reported by Manjunath *et al.* (2017) [10] in tomato. Further, most of the researchers have explored the possibility of using antagonistic bio-agents for suppression of *P. infestans* in tomato (Junior *et al.*, 2006) [8]. Thus, the present study was conducted to evolve effective IDM module by taking into account the diverse strategies like soil application of bio-agents, need based prophylactic and curative fungicidal application.

Materials and Methods

The field experiment was conducted during *Rabi* 2013-14 by ICAR-Krishi Vigyan Kendra, Kolar, Karnataka, India (The experiment was conducted as a part of On Farm Testing - OFT). The experiment was laid out in randomized block design with three treatments and eight replications using the commercial tomato hybrid Indus 1030. The soil of the experimental plot was red sandy loam in texture. The crop was raised as per the agronomic practices recommended by University of Horticultural Sciences, Bagalkot, Karnataka (India). The treatment details are mentioned hereunder,

T1 - Indiscriminate spray of one or combination of two fungicide *viz.*, Mancozeb @ 0.2%, Dimethomorph @ 0.1% + Metiram @ 0.2%, Copper Oxy Chloride @ 0.3%, Fenamidone + Mancozeb @ 0.3%, Metalaxyl + Mancozeb @ 0.2%, Cymoxanil + Mancozeb @ 0.3%, Copper Hydroxide @ 0.2%, Propineb @ 0.2%, Chlorothalonil @ 0.2% at weekly intervals starting from disease onset till completion of crop cycle.

T2 - Prophylactic spray with Mancozeb @ 0.2% twice at weekly interval before onset of the disease, curative sprays with Metalaxyl + Mancozeb @ 0.2% and Fenamidone + Mancozeb @ 0.3% at weekly interval at onset of the disease.

T3 - Soil application of bio-agents (*Trichoderma harzianum* and *Pseudomonas fluorescens*), prophylactic spray with Mancozeb @ 0.2% twice at weekly interval before onset of the disease, curative sprays with Metalaxyl + Mancozeb @ 0.2%, Fosetyl Al @ 0.2%, and Dimethomorph @ 1.0% + Polyram @ 0.2% at weekly interval at onset of the disease.

For soil application of bio-agents, 1 kg each talc formulation of *Trichoderma harzianum* (10^8 cfu/gram) and *Pseudomonas fluorescens* ($2x10^8$cfu/gram) were mixed with 100 kg well decomposed farm yard manure (FYM) and allowed to multiply for 15 days with 25-30% moisture level under proper shade conditions (Shanthiyaa *et al.,* 2013) [12]. This enriched FYM was applied to the field just prior to transplanting. The prophylactic foliar sprays with fungicides were applied before onset of disease but on onset of disease favorable environment, whereas the curative foliar sprays were applied at onset of disease.

The late blight disease severity assessments were made by following 1-9 severity scale (Horneburg and Becker, 2011) [7] and details of which are given in the below table.

Plant area infected (%)	Description	Score
No infections	**No infections/No symptoms**	**1**
1-10	First symptoms as grey-green to brown lesion observed on leaves	2
11-20	Symptoms obvious. Yellowing or browning of some leaves or small lesions 50% of plant height	3
21-30	Increased yellowing or browning, or small lesions to 75% of plant height	4
31-40	Small lesions to 75% of plant height the leaves dead	5
41-50	Yellowing or browning to 50% of plant height	6
51-60	Yellowing or browning to 75% of plant height	7
61-70	Entire plant yellow to brown, all leaves infected	8
>71-100	All leaves dead/collapsed	9

The disease index (%) was computed using the following formula (Wheeler, 1969) [18],

$$\text{Disease index (\%)} = \frac{\text{Sum of all individual ratings}}{\text{Total no. of plants examined x maximum score}} \times 100$$

About 20 plants in each treatment block were selected and disease severity observations were recorded at ten days intervals starting from 45 days after planting (DAP) up to 85 DAP. Each treatment was harvested separately and yield per plot was recorded further, benefit: cost ratio was also calculated. Yield data were pooled from all the harvests of each plot and expressed as t/ha. The original data was arc sine transformed and subjected to analysis of variances (ANOVA) and critical difference (CD) was used to separate the treatment means.

Results and Discussion

The present investigation was carried out to develop region specific efficient integrated disease management (IDM) module against tomato late blight. In the study, three IDM modules were tested in field condition during *Rabi* 2013-14. At 45 days after planting (DAP) significantly least disease severity (11.95%) was recorded in module T3 followed by T2 (15.72%). Whereas T1 was found to be least effective with significantly highest disease severity (25.51%) (Table 1). The disease severity at 55 DAP was slightly increased wherein T1 module recorded significantly highest disease severity (31.85%), on other hand T3 module was found to most effective in management of disease with significantly least disease severity (13.20%). The advancement in disease severity followed the similar trend at 65, 75 and 85 DAP. Additionally, the progress in disease severity in T3 from 45 to 85 DAP was very slow compared to other modules. In total, the significantly lowest mean disease severity of 9.20% was recorded in T3 followed by T2 (13.50%) and the module T1 was found least effective and exhibited the significantly highest mean disease severity of 23.75% (Table 1).

The IDM modules tested were also found effective in enhancing the yield and in-turn increased benefit cost ration (BCR). In this regard, T3 module witnessed significantly highest yield of 59.62 t/ha with a BCR of 4.27 whereas T1 module recorded significantly least yield of 46.87 t/ha with a BCR of 3.39 (Table 2).

The current study demonstrates that, the T3 IDM module consisting of soil application of bio-agents, prophylactic sprays followed by curative sprays with fungicides was found significantly most effective in tomato late blight management under field conditions. The results are in line with the findings of Manjunath *et al*. (2017) [10] who demonstrated the cumulative effect between various IDM components *viz.*, soil application of bio-agents, prophylactic fungicidal spray followed by curative fungicidal sprays in management of tomato late blight compared to individual components. Similarly, Shrestha and Ashley (2007) [14] reported the effectiveness of IDM module against tomato late blight consisting of bio-agents application (*Trichoderma viride*), bio-pesticides spray (*Azadirachta indica, Artemisia vulgaris*) and the fungicidal spray (Metalaxyl + mancozeb and Mancozeb). In addition, Silva *et al.* (2004) [15] evidenced the effective control of tomato late blight severity under field conditions through combined application of *B. cereus* and the fungicide chlorothalonil.

In the study, soil application of bio-agents *Trichoderma harzianum* and *Pseudomonas fluorescens* lead to better management of the disease. This finding is in agreement with Junior *et al.* (2006) [8], who reported the field efficacy of epiphytic antagonists and *Bacillus cereus* in reducing the severity of late blight. They further stated that integration of these biological control agents with fungicides, cultural practices, and other measures can contribute to manage late blight on tomato production systems. In continuation, Zegeye *et al.* (2011) [20] reported the biocontrol potential of *Trichoderma viride* and *Pseudomonas fluorescens* against *Phytophthora infestans* under greenhouse conditions. The abundance of *P. fluorescens* and *T. harzianum* in the rhizosphere, the mycelium and other propogules of pathogen present in crop debris incorporated in soil seemed to be parasitized by the bio-agents (Shanthiyaa *et al.*, 2013) [12]. Further, depletion of essential nutrients at the point of contact, fast and high rate of sporulation and colonization capacity of bio-agents may have suppressed the infection by pathogen (Yao *et al.*, 2015) [19]. Besides, the prior application of bio-agents may have induced the systemic resistance in potato plant which in turn leads to least severity of late blight (Ahmed *et al.*, 2010) [1].

The present study, prophylactic sprays with mancozeb before onset of disease followed by curative sprays with Metalaxyl + Mancozeb, Fosetyl Al, and Dimethomorph + Polyram at onset of disease had additive effect in reducing the late blight severity in field. These results are in line with findings of Meya *et al.* (2014) [11] and Manjunath *et al.* (2017) [10]. Upon onset of congenial weather for late blight development the prophylactic spray with mancozeb serve as protective layer on foliage and destroy the sporangia landed on the foliage thereby delaying in onset of the disease. Due to delay in onset of disease crop may escape most susceptible stage for the disease further slows down the development disease epidemic (Sharma and Saikia, 2013) [13]. Immediately on onset of disease three curative fungicidal sprays at weekly interval effectively check the disease progress. This finding was supported by Chakraborty and Mazumdar (2012) [2].

In conclusion, from the results reported in this study IDM module T3 consisting of diverse disease management strategies (soil application of bio-agents prior to planting, prophylactic fungicidal sprays followed by curative fungicidal sprays) which are likely to be active during the entire crop cycle and found most effective in managing the tomato late blight in field conditions.

Table 1: Tomato late blight severity in the field experiment (On farm testing) conducted during *Rabi* 2013-14

Modules	Disease severity (%)					
	45 DAP	**55 DAP**	**65 DAP**	**75 DAP**	**85 DAP**	**Mean**
T1	25.51 (30.35)*	31.85 (34.38)	25.92 (30.62)	18.92 (25.80)	17.24 (24.55)	23.75 (29.18)
T2	15.72 (23.37)	19.53 (26.24)	13.91 (21.91)	9.85 (18.30)	8.77 (17.23)	13.50 (21.57)
T3	11.95 (20.23)	13.20 (21.31)	8.40 (16.86)	6.82 (15.15)	5.64 (13.75)	9.20 (17.67)
S.Em.±	0.65	0.53	0.31	0.58	0.61	-
CD (0.05)	1.94	1.58	0.93	1.74	1.83	
CV (%)	11.39	12.53	10.57	9.82	7.89	

*Values in parentheses are arc sine transformed

Table 2: Yield and economics of tomato in field experiment conducted during *Rabi* 2013-14

Modules	Yield (t/ha)	B:C ratio
T1	46.87	3.39
T2	54.00	3.91
T3	59.62	4.27
S.Em.±	0.54	-
CD (0.05)	1.63	-
CV (%)	11.93	-

Treatment details are given in materials and methods section.

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