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Effective Management Strategy against Potato Late Blight Incited by *Phytophthora infestans*

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A B S T R A C T

The study was conducted to develop an effective management strategy against the devastating potato late blight. Of the three management modules tested in the field conditions for two consecutive growing seasons, *rabi* 2014-15 and *rabi* 2015-16, the module T3 consisting of soil application of bio-agents (1 kg each talc formulation of *Trichoderma harzianum* and *Pseudomonas fluorescens* enriched in 100 kg well decomposed FYM) 15 days before planting, tuber treatment with Mancozeb @ 0.25%, prophylactic spray with Mancozeb @ 0.2% twice at weekly interval before onset of the disease followed by curative sprays with Cymoxanil + Mancozeb @ 0.3%, Dimethomorph @ 1.0% + Mancozeb @ 0.2%, and Fenamidone + Mancozeb @ 0.3% at weekly interval at onset of the disease was found most effective and recorded least disease severity and higher yield compared to other modules. Hence, this module serves as effective management strategy against the disease under field conditions.

Introduction

Potato, *Solanum tuberosum* L., is one of the most important starchy edible tuber crops in the world (Desjardins *et al.*, 1995; Chycoski and Punja, 1996). In India, potato is a major vegetable crop grown in an area of 1.9 million hectare, with a total annual production of 45.3 million tones with the productivity of 22.70 t/ha (Anon., 2012). The potato crop is unfortunately susceptible to many plant diseases. Of the various diseases occurring in potato, the late blight caused by *Phytophthora infestans* (Mont.) de Bary is one of the most destructive disease affecting potato production world-wide including India (Chycoski and Punja, 1996; Fry and Goodwin, 1997) and has been considered a threat to global food security (Cooke *et al.*, 2012).

The 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 (Chowdappa *et al.*, 2011). Post 2008, severe late blight occurrence has started occurring in major potato growing regions in south-west India including Karnataka, sometimes leading to cent per cent crop loss and it might be due emergence of A2 mating type (Chowdappa *et al.*, 2013). In existence of new mating type under prevalence of

congenial environmental conditions management of late blight has become increasingly difficult under field and storage conditions (Fry *et al.,* 1992). The fungicidal management has played a vital role in curbing the late blight menace but under epidemic 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 (Siddiqui *et al.,* 2016).

From the above facts it is understood that, management of late blight is most challenging in successful potato production. Hence, it is necessary to develop eco-friendly and cost-effective alternative management strategy 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) and Prasad *et al.,* (2018). Further, most of the researchers have explored the possibility of using antagonistic bio-agents for suppression of *P. infestans,* further bio-control agents alone is not sufficient to provide complete protection under variable environment factors in field conditions (Yao *et al.,* 2015). Therefore, the present study was conducted to evolve effective management strategy by taking into account the diverse strategies like soil application of bio-agents, fungicidal tuber treatment and need based prophylactic and curative fungicidal application.

Materials and Methods

The field experiment was conducted during *Rabi* crop season for two consecutive years, 2014-15 and 2015-16 by ICAR-Krishi Vigyan Kendra, Kolar, Karnataka, India (The experiments were 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 late blight susceptible potato cultivar 'Kufri Jyoti'. 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 - Tuber treatment with Mancozeb (@0.25%), prophylactic spray with Mancozeb @ 0.2% twice at weekly interval before onset of the disease, curative sprays with Metalaxyl + Mancozeb @ 0.2% and Cymoxanil + Mancozeb @ 0.3% at weekly interval at onset of the disease.

T3 - Soil application of bio-agents (*Trichoderma harzianum* and *Pseudomonas fluorescens*), Tuber treatment with Mancozeb (@0.25%), prophylactic spray with Mancozeb @ 0.2% twice at weekly interval before onset of the disease, curative sprays with Cymoxanil + Mancozeb @ 0.3%, Dimethomorph @ 1.0% + Mancozeb @ 0.2%, and Fenamidone + Mancozeb @ 0.3% 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). This enriched FYM was applied to the field 15 days before planting. The tuber treatment was performed on the day of planting by dipping the potato seed tubers in Mancozeb (@0.25%) fungicidal solution for 5 minutes later on shade dried and planted in the field. The prophylactic foliar sprays with fungicides were applied at the time of canopy closure *i.e.*, 5th week after planting before onset of disease whereas the curative foliar sprays at onset of disease.

The late blight disease severity assessments were made by following 1-9 severity scale (Malcolmson, 1976) and details of which are given in table 1.

The disease index (%) was computed using the following formula (McKinney, 1923).

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

About 20 plants in each treatment block were selected and disease severity observations were recorded at ten days intervals after first notice of disease. At harvest (90 days after planting) observations on blighted tubers and tuber yield (t/ha) were also recorded. 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. The data were statistically analyzed by using Genstat 14th edition developed by the Rothamsted research station, England.

Results and Discussion

The study was conducted to design the effective management strategy against potato late blight. To devise the same, different management modules were formulated by combining the various components *viz.*, soil application of bio-agents, fungicidal tuber treatment, prophylactic and curative fungicidal sprays (Treatment details are mentioned in materials and methods section) and efficacy of these modules were tested in field condition for two consecutive years (*Rabi* 2014-15 and *Rabi* 2015-16). The disease severity (%) data was recorded at 10 days interval starting from 45 days after planting (DAP) up to 85 DAP.

During the *Rabi* 2014-15, the module T3 (soil application of bio-agents, fungicidal tuber treatment, prophylactic and curative fungicidal sprays) recorded significantly least disease severity (7.29%) followed by T2 (fungicidal tuber treatment, prophylactic and curative fungicidal sprays) (14.93%) and significantly highest disease severity of 18.75 % was noted in T1 (Indiscriminate curative fungicidal sprays) at 45 DAP.

The similar trend was observed at 55, 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 11.82 per cent was recorded with T3 followed by T2 (18.71%) and the module T1 was found least effective and exhibited the significantly highest mean disease severity (24.94%) (Table 2).

The effect of these modules in management of potato late blight followed the similar trend even during *Rabi* 2014-15 as well. Wherein, T3 was found significantly superior with least mean disease severity (15.61%) followed by T2 (22.54%) and T1 was found significantly least effective (28.14%). Additionally, the progress in disease severity in T3 from 45 to 85 DAP was very slow compared to other modules (Table 3). Interestingly the similar trend was noted in pooled data, in which T3

was found most effective followed by T2. Further, T1 was noted to be least effective in managing the potato late blight (Table 4).

These modules were also found effective in controlling the progression of the disease to tubers wherein the T3 recorded least quantity of blighted tubers (0.14 t/ha) at harvest followed by T2 (0.24 t/ha) and T1 was found significantly least effective (0.45 t/ha) during *rabi* 2014-15. Similar trend was noticed during *rabi* 2015-16 and even in pooled data. Further, these modules had positive effect on tuber yield and economics. During *rabi* 2014-15, T3 recorded significantly highest yield (24.32 t/ha) and B: C ratio (1.54). Whereas T1 recorded significantly lowest yield of 20.10 t/ha and B: C ratio of 1.22. Similar trend was noticed during *rabi* 2015-16 and even in pooled data (Table 5).

The current study demonstrates that, the T3 module was found significantly most effective in controlling potato late blight under field conditions. The results are in conformity with the findings of Manjunath *et al.*, (2017) who demonstrated the additive effect between various components of IDM *viz.*, soil application of bio-agents, fungicidal tuber treatment, prophylactic fungicidal spray followed by curative fungicidal sprays in potato late blight management compared to individual components. Similarly, Chakraborty and Banerjee (2016) reported the greatest reduction in potato late blight severity in treatment having prophylactic spray with mancozeb @ 0.2% followed by curative spray with fenamidone + manozeb @ 0.3% thrice at weekly intervals. Further, Sharma and Saikia (2013) were of similar opinion that, prophylactic spray with Mancozeb @0.25% followed by curative sprays with Cymoxanil + Mancozeb @ 0.3% and Dimethomorph @ 0.1% resulted in effective management of the potato late blight disease.

In the present study, soil application of *Trichoderma harzianum* and *Pseudomonas fluorescens* lead to better management of the disease in terms of reduced disease severity and least amount of blighted tubers. This is in agreement with the report of Yao *et al.*, (2015), who demonstrated the field efficacy of *Trichoderma* isolate HNA14 in management of potato late blight. Similarly, El-Naggar *et al.,* (2016) also noted the cumulative effect of *B. subtilis*, *P. fluorescens*, *T. harzianum* and *T. viride* in reducing the potato late blight severity. The presence of *P. fluorescens* and *T. harzianum* in the rhizosphere, the mycelium and other propogules of pathogen present in the tuber and rhizospheric region seemed to be parasitized by the bio-agents (Shanthiyaa *et al.,* 2013). 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).

Table.1 Late blight disease severity assessments scale

Plant area infected (%)	Score
Trace of infection	9
<10	8
11-25	7
26-40	6
41-60	5
61-70	4
71-80	3
81-90	2
Collapsed	1

Table.2 Severity of potato late blight in the field experiment (On farm testing) conducted during *Rabi* 2014-15

Modules	Disease severity (%)					
	45 DAP	55 DAP	65 DAP	75 DAP	85 DAP	Mean
T1	18.75 (25.67)*	24.31 (29.54)	34.86 (36.20)	27.57 (31.68)	19.24 (26.02)	24.94 (29.98)
T2	14.93 (22.74)	18.40 (25.40)	24.44 (29.63)	19.65 (26.32)	16.11 (23.67)	18.71 (25.64)
T3	7.29 (15.56)	14.24 (22.17)	16.25 (23.78)	12.01 (20.28)	9.31 (17.77)	11.82 (20.12)
S.Em.±	0.44	0.38	0.43	0.29	0.21	-
CD (0.05)	1.34	1.14	1.33	0.89	0.63	
CV (%)	10.86	9.14	9.04	8.13	7.62	

*Values in parentheses are arc sine transformed
Treatment details are given in materials and methods section.

Table.3 Severity of potato late blight in the field experiment (On farm testing) conducted during *Rabi* 2015-16

Modules	Disease severity (%)					
	45 DAP	55 DAP	65 DAP	75 DAP	85 DAP	Mean
T1	17.78 (24.95)*	28.19 (32.05)	39.17 (38.76)	33.68 (35.48)	21.88 (27.89)	28.14 (32.05)
T2	16.88 (24.26)	24.79 (29.87)	29.72 (33.04)	21.46 (27.60)	19.86 (26.47)	22.54 (28.36)
T3	10.49 (18.86)	19.17 (25.97)	21.81 (27.84)	15.63 (23.27)	10.97 (19.35)	15.61 (23.28)
S.Em.±	0.32	0.51	0.43	0.40	0.27	-
CD (0.05)	0.98	1.56	1.31	1.22	0.81	
CV (%)	9.03	9.95	8.68	8.97	8.07	

*Values in parentheses are arc sine transformed
Treatment details are given in materials and methods section.

Table.4 Pooled data of potato late blight severity in the field experiments (On farm testing) conducted during *Rabi* 2014-15 and *Rabi* 2015-16

Modules	Disease severity (%)					
	45 DAP	55 DAP	65 DAP	75 DAP	85 DAP	Mean
T1	18.26 (25.31)*	26.25 (30.81)	37.01 (37.49)	30.63 (33.61)	20.56 (26.96)	26.54 (31.02)
T2	15.90 (23.51)	21.60 (27.70)	27.08 (31.36)	20.56 (26.97)	17.99 (25.10)	20.63 (27.03)
T3	8.89 (17.29)	16.70 (24.13)	19.03 (25.87)	13.82 (21.83)	10.14 (18.58)	13.72 (21.75)
S.Em.±	0.35	0.44	0.42	0.31	0.23	-
CD (0.05)	1.07	1.32	1.28	0.94	0.71	
CV (%)	9.55	9.47	8.79	8.18	7.80	

*Values in parentheses are arc sine transformed
Treatment details are given in materials and methods section.

Table.5 Blighted tubers and tuber yield of potato in field experiments conducted during *Rabi* 2014-15 and *Rabi* 2015-16

Modules	Blighted tubers (t/ha)			Yield (t/ha)			B:C ratio		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T1	0.45	0.56	0.51	20.10	16.20	18.15	1.25	1.20	1.22
T2	0.24	0.37	0.31	21.04	17.60	19.32	1.38	1.44	1.41
T3	0.14	0.19	0.16	24.32	19.43	21.87	1.56	1.51	1.54
S.Em.±	0.03	0.06	0.04	0.53	0.45	0.57	-	-	-
CD (0.05)	0.07	0.17	0.11	1.33	1.14	1.43			
CV (%)	5.23	4.57	4.07	8.31	7.16	7.33			

Treatment details are given in materials and methods section.

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 (Harman *et al.*, 2004; Ahmed *et al.*, 2010).

The present investigation further demonstrated that, seed tuber treatment with mancozeb retarded the pathogen present in tuber and even in near vicinity in rhizosphere and hence leads to reduced disease severity. These findings are consistent with Hartill (1980) who recorded reduction in disease incidence and increases in yield in seed tuber treatment plots.

In the study, prophylactic sprays with mancozeb before onset of disease followed by curative sprays with Cymoxanil + Mancozeb, Dimethomorph + Mancozeb, and Fenamidone + Mancozeb at onset of disease proved to be most efficient in reducing the disease severity. These results are in line with findings of Sharma and Saikia (2013); Chakraborty and Banerjee (2016) and Manjunath *et al.*, (2017). 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 (Sobolewski and Robak, 2004) further slows down the development disease epidemic (Sharma and Saikia, 2013). Immediately on onset of disease curative sprays with Cymoxanil + Mancozeb, Dimethomorph + Mancozeb and Fenamidone + Mancozeb at weekly interval effectively check the disease progress. This finding was supported by Muchiri *et al.*, (2009), Alexandrov (2011), Chakraborty and Mazumdar (2012). In this study it was also observed that the curative spray with Metalaxyl + Mancozeb was not found effective. It might be due to its continuous and increased use that might have led to the development of resistant strain of *P. infestans* (Ali and Dey, 1999; Singh *et al.*, 2005).

In the present study, T3 module proved to be most effective as it consist of different approaches of disease management which are likely to be active during the entire crop cycle and turned out to be most efficient management strategy against the deadly potato late blight disease under field conditions.

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