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Integrated management of late blight of potato

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Abstract: Late blight of potato is the major biotic constraint responsible for reduction in yield and quality of the potato crop. Globally, late blight is managed through application of multiple fungicidal chemical sprays affecting both human health and environment.Now a days, methods of biological control are gaining importance as these are non-toxic and also environment friendly. However, *Phytophthora infestans* multiplies very fast; therefore, biological control method alone is not a viable option to manage late blight. Hence, integration of both methods is essential. Eleven treatments consisting of biocontrol agents and fungicides were evaluated against the late bight in three consecutive seasons (2011-12, 2012-13, 2013-14) at ICAR-CPRIC, Modipuram. Meerut. The results revealed that the treatments (T1 to T10) are effective for managing the disease up to certain level; however, lowest average disease severity (27.89%) was recorded in treatment when *Bacillus subtilis* (B5-0.25%) + *Trichoderma viride* (TV-0.7%) was applied before disease appearance followed by cymoxanil8+mancozeb 64%WP (0.3%) at onset of late blight and one more spray of B5+ TV after seven days. The next best treatment was application of B5+ TV before appearance of disease followed by metalaxyl 8+mancozeb 64%WP (0.25%) at onset of late blight and one more spray of B5+ TV against control (average disease severity 91.94%) with higher yield also except the treatment of three spray of mancozeb 75% WP (0.2%). These treatments could be integrated in farmer practices.

Keywords: *Bacillus*, Fungicides, Late blight, Potato, *Trichoderma*

INTRODUCTION

Late blight of potato caused by an oomycete *Phytophthora infestans* (Mont.) de Bary is the most destructive disease of potato in hills and plain regions of India and caused yield losses up to 95% in epidemic conditions (Lal *et al.,* 2015). Recently, reduction in 10-15% yield of potato was estimated due to occurrence of late blight in India on over all basis (Lal *et al.,* 2016). Management strategies for its effective control include use of host resistance, chemicals, biocontrol, forecasting, sanitation and even disease escape (Wastie, 1991; Singh and Sharma, 2013). It is observed that within a decade host resistance is broken down with subsequent increase in level of susceptibility to late blight. Generally, no such cultivar allows the commercial cultivation of potato without fungicides protection. The most commonly used fungicides by farmers are mancozeb 75 WP (0.2%), cymoxanil8+mancozeb64 WP (0.3%), metalxayl 8+64 WP (0.25%),dimethmorph 50 %WP (0.2%) and fenomidon10+mancozeb 50 WG (0.3%). Amongst these, mancozeb comes under group of EBDC (Ethylenebisdithiocarbamate) which break down into ethylenethiourea (ETU), which is a type IIB carcinogen and antithyriod compound (Panganiban *et al*.,2004). Moreover, development of metalaxyl resistance in *P. infestans* races globally had made this systemic fungicide redundant and so far farmers are waiting for its apt replacement. The indiscriminate use of these chemicals not only poses a serious threat to the environment but also to the human health. Biological control by antagonists has attracted much attention because of being eco-friendly to environment and the crop (Harmendez *et al.,* 2005). Recent years have witnessed the increasing popularity of biological control agents as an alternative to fungicides (Glare *et al.,* 2012). Many bio-agents i.e. *Trichoderma viride*, *Penicillium virdicatum*, *P. aurantiogiseum, Chetomium brasilense* (Gupta *et al.,* 2004), *Acremonium strictum* (CPRI, 1999), *Myrothecium varrucaria* and *P. aurantiogriseum* (Roy *et al.,* 1991) showed antagonistic effect against *P. infestans* in lab studies. The antagonistic activities of *Pseudomonas fluorescens, Pseudomonas* sp. *Aspergillus flavus, A. niger, Penicillium* sp., *T. virens* and *T. harzianum* showed positive inhibition of mycelial growth of *P. infestans, Fusarium* spp and *Rhizoctonia solani* under *in vitro* conditions (Lal *et al.*, 2013). *Bacillus* species were used for managing late blight disease of potato *in vitro* (Sunaina *et al.*, 2005;). Different species of *Trichoderma* were also evaluated and reported effective against late blight of potato under field condition (Yuan-Hang *et al*., 2014; Yao *et*

al., 2016). The effectiveness of bio-agents viz, *Trichoderma*, *Bacillus* and *Pseudomonas* were also reported against *P. infestans* under field condition (Basu, 2009; EI-Naggar *et al*., 2016).

Since late blight spreads very fast in the fields when the environmental conditions are conducive, therefore, management of late blight through bioagents only may not be effective. Therefore, present studies were conducted for three consecutive years (2011-12, 2012-13, and 2013-14) in combination of bio-agent with fungicides against late blight with the objective to reduce the number of fungicidal sprays without compromising the economic yield.

MATERIALS AND METHODS

The experiments were conducted on cv. Kufri Bahar which is popular with farmers but highly susceptible to late blight. Eleven following treatments were selected:

T1: (*Bacillus subtilis-B5*- 0.25% +*Trichoderma viride*-TV- 0.7%)-3 spray

T2: (*B. subtilis*+ *T.viride*)-2 spray

T3: (*B. subtilis*+ *T.viride*)-1 spray

T4: Spray of (B5+ TV) before appearance of disease followed by metalaxyl 8+mancozeb 64% WP (0.25%) at onset of late blight and one more spray of B5+ TV.

T5: Spray of (B5+ TV) before appearance of disease followed by cymoxanil8 +mancozeb 64% WP (0.3%) at onset of late blight followed by one more spray of B5+ TV.

T6: Spray of (B5+ TV) before appearance of disease followed by mancozeb 75% WP (0.2%) at onset of late blight followed by one more spray of B5+ TV.

T7: Spray of (B5+ TV) before appearance of disease followed by before- Neem oil based azadirechtin 0.15% (10%) at onset of late blight followed by one more spray of B5+ TV

T8: Mancozeb75% WP (0.2%) spray before appearance of disease followed by mancozeb75% WP (0.2%) at onset of late blight followed by one more spray of mancozeb75% WP (0.2%).

T9: *B. subtilis* spray before appearance of disease followed by *B. subtilis* (0.25%) at onset of late blight followed by one more spray of *B. subtilis* (0.25%).

T10: T V (0.7%) before appearance of disease followed by TV (0.7%) at onset of late blight followed by one more spray of TV (0.7%) spray before, onset and 7 days after second spray.

T11: Control without any spray.

Treatments T1 to T3 were purely bacterial and fungal antagonist, whereas T9 and T10 were purely bacterial and fungal antagonist respectively. These treatments could be applied in organic potato production system also. Treatments T4, T5, T6 used for reducing number of fungicides spray, as only one spray was used and two spray of the combination of bacterial and fungal antagonist. In treatment T7, neem formulation was used at appearance of disease instead of fungicides.

The experiments were conducted in Randomized Block Design with three replications at ICAR-CPRIC, Modipuram Meerut (29.1^{o}N, 77.92^{o}E, 300 msl) during three consecutive rabi seasons i.e. 2011-12, 2012-13, 2013-14. Tubers were planted in second week of November and crop was raised as per recommended practices of the regions. Infector rows were planted as borders of the experimental field to ensure smooth spread of late blight across the treatments. The disease was initiated by putting 0.3cm^2 filter paper discs on the lower side of leaves in infector rows in the evening. These paper discs were dipped in zoospores suspension of *P. infestans* having a concentration of 6 x 10^4 per ml.Sprinklers were used to maintain the humidity in the experimental fields. The tubers of K. Bahar were planted in a standard plot of 9 m^2 size having five rows of three meters length was used per treatment keeping 60 x 20 cms Row x Plant spacing .Spraying was started before one week initiation and the appearance of disease and in total three sprays were given at 7 days interval. Terminal disease severity was recorded after 10 days of 3rd sprays as per the method of Henfling (1987). Data on tuber yield were also recorded at the time of harvesting. The data were subjected to standard statistical analysis using IRRISTAT software.

RESULTS AND DISCUSSION

The results revealed that the treatment T5[*B. Subtilis* + *T. viride* applied before disease appearance followed by cymoxanil 8+mancozeb 64% WP (0.3%) at onset of late blight and one more spray of *B. subtilis* + *T viride*] resulted in less disease severity 14.5, 37.50 and 31.67% along with tuber yield 34.30, 26.61and 21.46 t/ha during 2011, 2012 and 2013, respectively except the treatment T8,where three spray with mancozeb 75 % WP (Table 1) were applied. This treatment was at par with T4[*B. subtilis* (B5) + *T. viride* before disease appearance followed by metalaxyl 8 + mancozeb 64% WP (0.25%) at onset of late blight and one more spray of *B. subtilis* (B5) + *T. viride* (TV)]. On the basis of pooled data, these treatments performed better in both reducing disease severity and increasing tuber yield. These treatments could be used for management of late blight without affecting economic yield and using less chemical sprays. The remaining eight treatments (T1, T2, T3, T6, T7, T8, T9 and T10) were also effective for reducing disease severity (39.95-76.83%) against control (91.94%). Many researchers have demonstrated the effectiveness of biocontrol agents alone and in combination with fungicides in management of late blight of potato and tomato both in the lab studies and under field conditions. *B.subtilis* and *Rahnella aqatilis* both strongly inhibited *P.infestans* on media *in- vitro* and provided the best rate of local protection on whole plants test and among the best rate of systemic protection (Daayf *et al*., 2003). Ajay and Sunaina (2005) reported 46.83-91.15% inhibition of *P. infestans* over

Table 1. Integrated management of late blight of potato.

Treatments	2011-12			2012-13			2013-14			Average		
	Terminal disease severity (%)	Disease con-trolled (%)	Yield (T/ha)	Terminal disease severity (%)	Disease con-trolled (%)	Yield (T/ha)	Terminal disease severity (%)	Disease con-trolled (%)	Yield (T/ha)	Terminal disease severity (%)	Disease con-trolled (%)	Yield (T/ha)
T1: *Bacillus subtilis* (B5-0.25%)+*Trichoderma viride* (TV-0.7%)-3 spray	32.5	62.86	26.93	64.22	34.69	19.11	53.33	40.74	20.32	50.02	46.10	22.12
T2: *Bacillus subtilis* (B5-0.25%)+*Trichoderma viride* (TV-0.7%)- 2 spray	30.5	65.14	25.93	72.22	26.55	17.52	58.33	35.19	20.29	53.68	42.29	21.25
T3: *Bacillus subtilis* (B5-0.25%)+*Trichoderma viride* (TV-0.7%)-1 spray	35.0	60.00	29.16	73.33	25.42	16.34	66.67	25.93	19.81	58.33	37.12	21.77
T4: *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV-0.7%) - metalaxyl8+ mancozeb 64% WP (0.25) - *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV-0.7%)	16.5	81.14	30.91	45.00	54.24	20.92	38.33	57.41	21.34	33.28	64.26	24.39
T5: *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV-0.7%) - cymoxanil 8+ mancozeb 64% WP (0.3%) - *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV -0.7%)	14.5	83.43	34.30	37.50	61.86	26.61	31.67	64.81	21.46	27.89	70.03	27.46
T6: *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (*TV*-0.7%) - mancozeb 75% WP (0.2%) - *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV-0.7%)	22.5	74.29	33.67	53.89	45.20	22.17	46.67	48.15	20.89	41.02	55.88	25.58
T7: *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV-0.7%) - Neem oil based azadirechtin 0.15% (10.0%) - *Bacillus subtilis* (B5-0.25%) +*Trichoderma viride* (TV-0.7%)	35.0	60.00	31.58	71.67	27.12	23.12	53.00	41.11	20.17	53.22	42.74	24.96
T8: Mancozeb 75% WP (0.2%) - mancozeb 75% WP (0.2%) - mancozeb 75% WP (0.2%)	16.5	81.14	30.56	22.50	77.12	24.15	25.00	72.22	24.19	21.33	76.83	26.30
T9: *Bacillus subtilis* (B5-0.25%) - *Bacillus subtilis* (B5-0.25%) - *Bacillus subtilis* (B5-0.25%)	33.5	61.71	31.63	77.50	21.18	19.51	60.00	33.33	19.99	57.00	38.74	23.71
T10: *Trichoderma viride* (TV-0.7%) - *Trichoderma viride* (TV-0.7%) - *Trichoderma viride* (TV-0.7%)	33.0	62.29	30.07	77.22	21.47	17.91	58.33	35.19	19.90	56.18	39.65	22.63
T11:Control (without spray)	87.5		22.83	98.33		14.31	90.00		18.12	91.94	0.00	18.42
CD (0.05)	10.43		4.19	8.07		4.92	12.97		2.22			

control with *B. subtilis*. *Bacillus* sp. inhibited mycelial growth of 7 plant pathogenic fungi *in vitro* and *in vivo* and the same bacterium protected tomato plants against *P. infestans* (Sadlers, 1996). Singh *et al*. (2010) advocated integrated management using *T. viride*+ mancozeb against late blight in tomato. Yao *et al*., 2016 evaluated different isolates of *Trichoderma* against *P. infestans* and found that *Trichoderma* isolates HNA 14 was most effective under both laboratory and field condition . Yuan-Hang *et al*., 2014 also reported that *T. koningiopsis* and *T. asperellum* were effective against *P. infestans* under both laboratory and field conditions.

The systemic/translaminar/contact fungicides are known suppressor of the late blight disease and final application of combination of bioagent at low level of inoculum further suppressed the disease in our experimental fields. Application of *T.viride* and *B. subtilis* before appearance of the disease might have activated some host defense mechanisms that may have delayed the initial establishment and spread of the disease. The defense enzymes viz., chitinase and β.1, 3-glucanase activities of *B. subtilis* and *T. harzianum* are well reported against late blight of potato and early and late blight of tomato (El-Naggar *et al*., 2016; Chowdappa *et al*., 2013). The results of the present study clearly demonstrated that all the treatments are able to provide control of late blight to some extent as against unsprayed control. However, the treatments with only biocontrol agents used individually or together could not provide better control as compared to treatments involving fungicides along with biocontrol agents.

Conclusion

Present finding revealed that the combination of *T. viride* (0.7%) + *B. subtilis* (0.25%) with three sprays, first at before appearance of late blight, second at appearance and third after appearance could be adopted for organic cultivation of potato. Moreover, treatment comprising spray of *T. viride* (0.7%) + *B. subtilis* (0.25%) before late blight appearance and one spray of Cymoxanil8+mancozeb 64% WP at appearance followed by final spray of *T. viride* (0.7%) + *B. subtilis* (0.25%) was highly effective for managing late blight of potato, thus saving two sprays of fungicides and reducing related costs of fungicides and labour without compromising tuber yield of potato.

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