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Early blight caused by *Alternaria solani* (Ellis & G. Martin) L.R. Jones & Grout is a major foliar disease of potato. A field experiment was conducted with potato to compare the disease management provided by conventional fungicides and biofungicides having different inherent efficacy and mode of action, when applied alone or in combination throughout the treatment period. The level of disease control provided by all the treatments was significantly higher than nontreated plots in both years. Considering both year together, Mancozeb @ 2.5 g/l (T2) reduced highest disease severity followed by T6 and T8. Among the *Bacillus subtilis* based treatments, T6 i.e. Tank mix foliar spray of conventional fungicides Mancozeb @ 1.25 g/l and *Bacillus subtilis* formulation @ 370 g/ha at weekly intervals and T8 i.e. Mancozeb @ 2.5g/l alternated with*Bacillus subtilis* formulation @ 370 g/ha at weekly intervals effectively control the Early blight disease and produced good yield in the present investigation.

Key words: *Bacillus subtilis*, Early blight, fungicides, management, potato

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the most important vegetable crop in terms of quantities produced and consumed worldwide. This crop produces more food and nutrition, per unit area per unit time, than any other crops. In India potato production is challenged by several diseases and pest infestation. Besides Late blight, Early blight disease caused by*Alternaria solani* (Ellis & G. Martin) L.R. Jones & Grout is becoming more devastating in potato and tomato. Early blight is widespread in most potato growing area but is most prevalent in tropical and temperate zone. High temperature and humidity during growing season are conducive to disease development. The disease is a potential threat where potatoes are cultivated under irrigation or during times of heavy dew. Disease affects the potato foliage and leads to leaf necrosis and premature defoliation. Symptoms are initially observed on older, senescing leaves. Characteristic symptoms are dark brown or black lesions with concentric rings on leaves which produce a target spot effect. Infected tubers develop a dry rot, characterized by isolated dark irregular sunken lesion on surface.

Fungicides of various chemical groups are extensively used to manage the early blight pathogen in potato due to lack of other durable, effective disease control measure (Gudmestad *et al*. 2013). Early blight is difficult to control because of its capacity to produce huge amounts of secondary inoculums. In order to proper control many farmer use conventional fungicides like mancozeb and chlorothalonil frequently from early in the growing season until the maturity. These fungicides are less expensive and have low risk of resistance development because they affect the function of multiple metabolic pathways. However, these are less effective under intense disease pressure in favorable environmental condition (Pasche and

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Gudmestad, 2008). At present single site specific fungicides which are highly effective are used but have the high risk of fungicides resistance in target population of *Alternaria* spp. (Stevenson *et al*. 2007). This causes concerns about ineffective fungicides usage and indicates a requirement for guidelines for plant protection against early blight which integrate chemical and biofungicides. The aim of this work was to incorporate a reduced fungicides strategy into disease management and to evaluate the efficacy of *Bacillus subtilis* based biofungicides as compared to conventional fungicides having different inherent potentiality and mode of action, when applied alone or in combination throughout the treatment period on Early blight of Potato.

MATERIALS AND METHODS

The field experiment on the effect of *Bacillus subtilis* based biofungicides against Early blight of potato caused by *Alternaria solani* (Ellis and Martin) Jones and Grout was conducted during the *rabi* season of 2014-15 and 2015-16 in randomized block design with three replications in subtropical climatic condition of West Bengal at Regional Research Station (Red and Laterite Zone), Bidhan Chandra Krishi Viswavidyalaya, Jhargram, Paschim Medinipur, West Bengal. The variety, Kufri Jyoti was used as test crop. The treatment schedule against Early blight was used as follows; T1: Untreated control, T2: Foliar spray of Mancozeb 75WP @ 2.5g/l at weekly intervals, T3: Foliar application of*Trichoderma viride* formulation @ 3g/l at weekly intervals, T4: Foliar spray of *Bacillus subtilis* formulation @ 185 g/ha at weekly intervals, T5: Foliar spray of *Bacillus subtilis* formulation @ 370 g/ha at weekly intervals, T6: Tank mix foliar spray of Mancozeb75WP @ 1.25 g/l and *Bacillus subtillis* formulation @ 370g/ha at weekly intervals, T7: Foliar spray of Mancozeb 75WP @ 1.25 g/l at weekly intervals, T8: Foliar spray of Mancozeb 75WP @ 2.5g/l alternated with Foliar spray of *Bacillus subtilis* formulation @ 370 g/ha at weekly intervals, T9: Foliar spray of Mancozeb 75WP @ 2.5 g/l alternated with water spray at weekly interval. The spray schedule was started next day of first appearance of disease symptoms. The observation on disease intensity was recorded from 10 plants in each replicated plot at 7 days after each spraying (Table 1). Percent disease index of Early blight was calculated on the basis of 0-7 scale by using the following formula:

$$PDI = \frac{\text{Sum of all numerical rating}}{\text{Total number of observation x Maximum rating}} X\ 100$$

The area under disease progresscurveof treatments was calculated based on the following equation :

$$A = \sum_{i=1}^{k} \frac{1}{2} (S_i + S_{i-1}) X\ d$$

where, A= AUDPC value, *Si*= disease severity at the end of the week *i* , and *k* = the number of successive evaluation of disease and *d* = interval between two evaluations.

Timing and rates for field operation associated with field trial is presented in Table 1.

RESULTS AND DISCUSSION

A high level of disease severity was present on potato plant leaves in nontreated plots by crop maturity in both field trials with mean values of 47.62 and 63.81% of surface covered with Early blight in 2014-15 and 2015-16, respectively. The level of disease control provided by all the treatments was significantly higher than nontreated plots in both years. Considering both year together, T2 reduced highest disease severity followed by T6 and T8. When *Bacillus subtilis* based biofungicides was applied in alternate week with conventional fungicides (T6) disease intensity reduced 8.81%

Table 1 : Timing and rates for field operation associated with field trial conducted to control Early blight of Potato

Field operation	Field trial 2014-15	Field trial 2015-16
Cultivar	Kufri Jyoti	Kufri Jyoti
Plot size	12 m^2	12 m^2
Spacing	50cm X 20cm	50cm X 20cm
Basal Fertilizer application	24.11.2014	18.11.2015
Date of sowing	26.11.2014	19.11.2015
Date of emergence	06.12.2014	25.11.2015
Fertilizer dose	N: P_2O_5: K_2O – 200:150:150 kg/ha	N: P_2O_5: K_2O – 200:150:150 kg/ha
Date of first top dressing	16.12.2014	10.12.2015
First earthing up	15.12.2014	10.12.2015
Weeding	14.01.2015	23.12.2015
Date of second top dressing	26.12.2014	24.12.2015
Date of first appearance of symptoms	29.12.2014	06.01.2016
Insecticide application	05.01.2015, Imidacloprid 17.8% SL @ 1ml/5l	26.12.2015, 11.01.2016, Imidacloprid 17.8% SL @ 1ml/5l
Fungicide/Biofungicide application	30.01.2015,06.02.2015, 13.02.2015	07.01.2016,14.01. 2016,21.01.2016
Harvesting	25.03.2015	01.03.2016

Table 2 : Effect of different treatments on disease severity of Early blight and yield of Potato

Treatments	Percent disease index			AUDPC	Yield (Kg/plot)		
	2014-15	2015-16	Mean		2014-15	2015-16	Mean
T_1	47.62 (43.61)	63.81 (53.01)	55.72	778.37	18.20	14.77	16.49
T_2	16.67 (24.06)	28.57 (32.28)	22.62	273.32	30.80	26.10	28.45
T_3	32.38 (34.67)	62.38 (52.15)	47.38	643.30	16.87	18.00	17.44
T_4	23.33 (28.86)	48.57 (44.16)	35.95	518.32	26.20	22.60	24.40
T_5	24.29 (29.52)	41.90 (40.32)	33.10	456.72	24.40	23.83	24.12
T_6	22.86 (28.52)	32.38 (34.65)	27.62	375.03	27.77	24.63	26.20
T_7	24.76 (29.80)	48.10 (43.89)	36.43	490.04	27.60	22.70	25.15
T_8	20.00 (26.53)	35.24 (36.38)	27.62	311.71	27.93	25.67	26.80
T_9	21.43 (27.56)	39.05 (38.65)	30.24	406.70	27.19	22.87	25.03
SEM (±)	1.36	1.35			1.22	0.77	
CD at 5%	2.89	2.86			3.76	1.63	

* Values in the parenthesis indicate the arc sine transformed values

more as compared to sole application of conventional fungicides (T7) throughout the season long. According to AUDPC data most fungicides treatments suppressed Early blight and T2 checked the disease progression most efficiently than others. The treatments T6 and T8 reduced same disease severity but disease progression over time was very slow in T8. The highest potato yield was also recorded in T2 followed by T8 . Among the *Bacillus subtilis* based treatments, T6 i.e. Tank mix foliar spray of conventional fungicides Mancozeb @ 1.25 g/l and *Bacillus subtilis* formulation @ 370 g/ha at weekly intervals and T8 i.e. Mancozeb @ 2.5g/l alternated with *Bacillus subtilis* formulation @ 370 g/ha at weekly intervals effectively control the early blight disease and produced good yield in the present investigation. (Table 2).

On the basis of our analysis, disease control provided by standard protectant fungicides significantly reduced the disease severity. Potato grower in West Bengal have been concentrated the standard protectant fungicides before the onset of disease. High disease pressure based on the environmental differences from year to year is one of the reasons that potato growers have incorporated more expensive single site specialty fungicides into their foliar disease management programme (Yellareddygari *et al*. 2016). In the studies reported here superior control of Early blight was obtained with *Bacillus subtilis* based product when applied with in rotation with standard chemical fungicides relative to sole application of *Bacillus subtilis*. The similar type of result was reported by Matheron and Porchas (2013) against powdery mildew of cantaloupe by *Bacillus subtilis* (Serenade MAX) in rotation with triflumizole. However, evaluation of long term effects of partner fungicides on the development of resistance to at risk chemistries is difficult to achieve in field studies, due to complication such as movement of inoculums between plots, interchange of inoculums from source outsides the experimental area, and year to year variation in disease pressure.

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