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Cost effective management of early blight disease of potato (*Solanum tuberosum*) caused by *Alternaria solani*

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ABSTRACT

Early blight disease of potato (*Solanum tuberosum* L.) caused by *Alternaria solani* (Ellis and Martin), is one of the most important fungal disease throughout the potato growing areas. Field experiments were conducted during winter (*rabi*) season, 2018–19 and 2019–20 at Vegetable Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand for evaluating fungicides against early blight of potato. All the fungicides (mancozeb, hexaconazole, difenoconazole and chlorothalonil) were evaluated *in vitro* using poison food technique as well as field conditions. *In vitro* study revealed that chlorothalonil 75% WP gave the best results and showed 18.0 mm, 17.67 mm, 16.33 mm, 12.33 mm and 8.33 mm mycelial growth of *Alternaria solani* @25 ppm, 50 ppm, 100 ppm, 150 ppm and 200 ppm concentration at 7 days after inoculation. In field condition, chlorothalonil 75% WP @0.2% applied as foliar sprays at 10 days interval resulted the lowest disease severity i.e. 22.50% with highest tuber yield (317.90 q/ha). The findings regarding the economics of the potato cultivation clearly revealed that the treatment chlorothalonil @0.2% gave the highest benefit cost ratio i.e. 2.96. The early blight disease of potato may be controlled by applying chlorothalonil at a concentration of 0.25 three times at a 10-day interval, which increased production and provided extra benefits to farmers.

Keywords: *Alternaria solani*, Economics, Early blight, Fungicides, Potato

Potato (*Solanum tuberosum* L.) is an important staple vegetable crop, well known as a king of vegetables as well as power house of energy. It is originated from the Andes mountains of South America and belongs to the family Solanaceae. Area wise India ranked 4th under potato cultivation while considered as 2nd largest producer in the world after China, with a total production of 48,529 metric tonnes (FAOSTAT 2020). In terms of human consumption, potato ranks in 3rd place after rice and wheat (Anonymous 2020). About 80–85% of potato is grown during winter (*rabi*) season while 12% of potato is grown during rainy (*kharif*) season in different states of India (Arya and Joshi 2019). A total of 10–16% global losses have been estimated due to various diseases in potato crop (Trebicki and Finlay 2019).

Different bio-stresses, viz. early blight, late blight, wart, black scurf, charcoal rot, cyst nematode and many viral diseases are responsible to cause economic losses. Among them, early blight of potato caused by a fungal pathogen *Alternaria solani* is an important disease which causes economic loss by reducing tuber yield in the field. Average annual yield losses due to early blight were reported approximately 50–75% of production (Murmu *et al*. 2017). Different cultural practices i.e. crop rotation, resistant varieties, field sanitation and disease-free seed are used against early blight disease of potato but due to more yield losses, use of fungicides can be an important option. In this modern and ever-changing scenario in agriculture, the role of fungicides is quite significant. It is very essential to apply fungicides for effective management of early blight. So, keeping in view the importance of disease, the studies were carried out to evaluate the potential of fungicides along with economics for management of early blight disease of potato.

MATERIALS AND METHODS

In vitro *studies of fungicides against* Alternaria solani: Evaluation of fungicides belongs to different group was conducted at different concentration for studying their inhibitory effect on mycelial growth of *Alternaria solani*, a test pathogen by using poisoned food technique (Nene and Thapliyal 1979). The concentration of systemic fungicides was 1.25, 2.5, 5.0, 10 and 20 µg/ml and non-systemic fungicides was tested at 25, 50, 100, 150, 200 µg/ml concentration. Stock solution of fungicides was prepared in distilled sterilized water by dissolving weighted quantity of

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double concentrated fungicide in measured volume sterilized distilled water and added to double concentrated sterilized PDA (Kumar *et al*. 2020).

For each concentration, three replications were maintained. A 15 ml of fungicide amended PDA was poured in each sterilized petri plate. After solidification of medium, each petri plate was centrally inoculated with 6 cm disc cut from edge of culture of *Alternaria solani*. In case of control, 15 ml of sterilized medium was added and inoculated with test pathogen. The radial growth of the fungal mycelium was recorded at 7 days after inoculation. Colony diameters were measured and per cent inhibition over control was calculated by the formula given by Vincent (1947).

Field Studies for the management of early blight of potato

Experimental site: The field trials were conducted during winter (*rabi)* season 2018–19 and 2019–20 at Vegetable research Center, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The experiment was laid out in Randomized Block Design having 4 treatments and 4 replications with plot size 3.6 × 2.4 m^2. The fungicides were applied as foliar sprays at 10 days interval. Normal cultural practices were conducted time to time right from planting to harvesting of the crop.

Treatments: The treatments included T_1, Control; T_2, First spray of mancozeb 75% WP (0.25%), second spray of hexaconazole 5 EC (0.05 %) and third spray of mancozeb 75% WP (0.25%) at 10 days interval; T_3, First spray of mancozeb 75% WP (0.25 %), second spray of difenoconazole 25 EC (0.05%) and third spray of mancozeb 75% WP (0.25%) at 10 days interval and T_4, Spray with chlorothalonil (0.2%) thrice at 10 days interval. Foliar sprays were given just after the first appearance of disease in the field and total three foliar sprays were given at 10 days interval.

Disease rating scale: A 0–9 disease rating scale was used for the assessment of the disease severity which includes 0, No symptoms on the leaf; 1, Small, irregular, brown spot with concentric rings covering 1% of the leaf area; 3, Small, irregular, brown spot with concentric rings covering 1–10% of the leaf area; 5, Lesions coalesce to form irregular brown patches with concentric rings covering 11–25% of the leaf area; 7, Lesions coalesce to form irregular brown patches with concentric rings covering 26–50% of the leaf area, the lesion also on the stem and petiole; 9, Lesions coalescing to form irregular, dark brown patches with concentric rings covering 51% or more of the area. Lesions were seen on the stem and petiole.

In this, 10 plants were tagged from each plot and five leaflets were selected from each plant for scoring in each treatment and each replications, and observations were be taken at 10 days interval after appearance of disease. The data on per cent disease index, tuber yield etc were recorded and statistically analyzed. Percent disease index was calculated as (Wheeler 1969):

$$\text{PDI} = \frac{\text{Sum of numerical ratings}}{\text{Total number of leaves observed} \times \text{Maximum disease score}} \times 100$$

Economics of early blight disease of potato: To know the economics, total man days utilized for production of potato crop on hectare basis, cost of cultivation incurred on fertilizer, plant protection measures etc were also recorded. The seed prices as well as sale price of potato used in the analysis were taken for the crop period of 2019–20.

RESULTS AND DISCUSSION

In vitro *studies through poison food technique*: In present studies, four fungicides including systemic and non-systemic fungicides were evaluated at different concentration to record their effect on radial growth of *Alternaria solani*. The results indicated that the increase in per cent inhibition was invariably proportional to the increase in the concentration of most of the tested fungicides. Fungicide chlorothalonil was found the best at all the concentrations followed by mancozeb. Chlorothalonil inhibited the growth of *Alternaria solani* by 79.78–90.64% and mancozeb inhibited by 65.17–86.15% at different concentration (Table 1). Systemic fungicides i.e. hexaconazole and difenoconazole inhibited the fungal growth by 49.07–88.39% and 37.08–80.90% at different concentration respectively.

Sadana and Diwania (2015) evaluated seven fungicides at three concentrations against *Alternaria solani* and reported that fungicide mancozeb at a concentration of 1500 ppm caused the highest inhibition of mycelial growth (86.4%)

Table 1 Effect of different fungicides on radial growth of *Alternaria solani* at 25 ± 2°C

Fungicide	Concentration (µg/ml)	Average diameter of fungal diameter (mm)	Percent inhibition over check
Mancozeb 75% WP	25 ppm	31.00	65.17
	50 ppm	25.33	71.54
	100 ppm	24.00	73.03
	150 ppm	20.00	77.53
	200 ppm	12.33	86.15
Hexaconazole 5 EC	2.5 ppm	45.33	49.07
	5.0ppm	41.67	53.18
	10ppm	33.67	62.17
	15 ppm	31.33	64.80
	20 ppm	10.33	88.39
Difenoconazole 25 EC	2.5 ppm	56.00	37.08
	5ppm	44.00	50.56
	10ppm	32.67	63.29
	15ppm	24.67	72.28
	20 ppm	17.00	80.90
Chlorothalonil 75% WP	25 ppm	18.00	79.78
	50 ppm	17.67	80.15
	100 ppm	16.33	81.65
	150 ppm	12.33	86.15
	200 ppm	8.33	90.64
Control		89.00	
CD (Treatment)		1.12	
CD		1.44	
(Concentration)		2.50	
CD (T × C)		2.87	

in A1 strain of *Alternaria solani.* Kumar *et al.* (2018) also evaluated five combinations of systemic and contact fungicides under *in vitro* and *in vivo* conditions against early blight (*Alternaria solani*). Fenamidone 10% + mancozeb 50% followed by propiconazole 25% EC showed maximum inhibition of fungal growth and also found the best in field conditions too.

Yadav *et al*. (2018) tested three chemicals, bio-control agents and plant extracts *in vitro* against *Alternaria solani*. Among the chemicals, hexaconazole (3.00 mm) followed by mancozeb (3.16 mm) was found the best. Similar kinds of the result were obtained in field conditions. Ahmad *et al*. (2019) tested efficacy of five fungicides, viz. chlorothalonil, mancozeb, thiophanate-methyl, maneb and ridomil gold *in vitro* and results revealed that chlorothalonil at concentration 1000 ppm was highly effective in reducing mycelial growth (2.1 mm) with 91.45% inhibition percentage. Husain *et al*. (2020) found that propiconazole 25% EC and carbendazim 50% WP at 250 ppm completely inhibit the mycelial growth of *A. solani in vitro* condition. Ten fungicides, including 5 systemic and 5 non-systemic fungicides were evaluated for their efficacy against *Alternaria solani* under *in vitro* conditions. Among non-systemic fungicides, both mancozeb 75 WP and propineb 50 WP proved highly toxic and among systemic fungicides, propiconazole 25 EC and tebuconazole 25 EC proved highly toxic in inhibiting the mycelial growth (Misba *et al.* 2022).

Evaluation of fungicides under field conditions: The data revealed that chlorothalonil 75% WP @0.2% applied as foliar sprays at 10 days interval resulted the lowest disease severity i.e. 22.50% with highest tuber yield i.e. 317.90 q/ha (Table 2). There was 65.90% reduction in disease over control and 34.55% increase in yield over control in chlorothalonil sprayed plots. The treatments T_2 and T_3 at 10 days interval showed 29.50% and 28.50% disease severity with 273.3 q/ha and 271.20 q/ha tuber yield respectively. There was no significant difference between the treatment T_2 and T_3 in respect of disease severity and tuber yield. Control plots showed 66.00% disease severity and 235.5 q/ha tuber yield.

Herle and Kamanna (2014) reported that combination product zineb 68% + hexaconazole 4% at 0.2% concentrations was the best (21.50% PDI) which was on par with treatment tebuconazole 25% EC at 0.1% concentration (22% PDI) and captan 70% + hexaconazole 5% at 0.2% concentrations (24.66 PDI). Murmu *et al.* (2017) evaluated the efficacy of seven fungicides against early blight of potato under *in vivo* and *in vitro* condition and reported that propiconazole sprayed at 1 ml/litre recorded the highest per cent disease reduction (57.88%) and also the highest tuber yield (27.03 t/ha) followed by propineb.

Sharma *et al.* (2020) conducted an experiment to test the efficacy of combined fungicides against early blight of potato. Results revealed that fenamidone 10% + mancozeb 50% WGD (2.5 g/litre) recorded the lowest disease intensity. Sharma *et al*. (2020) also studied the efficacy of 7 fungicides at different concentration against early blight of tomato caused by *Alternaria solani* and the result showed that hexaconazole sprayed at 500 ml/ha recorded the highest per cent disease reduction followed by propiconazole respectively. Among six treatments, seed treatment with mancozeb 75 WP followed by foliar spraying of the mancozeb 75 WP was found most effective for early blight disease management and increased the yield of tomato (Mandal *et al.* 2019). The treatment combination of mancozeb 75 WP @0.3% followed by propiconazole 25 EC @0.05% was found to be most efficient in reducing the early blight disease of tomato incidence and intensity to 7.6 and 4.4% as compared to check (Misba *et al.* 2022). Uttam *et al*. (2020) also reported that indofil M-45 exhibited the most effective followed by indofil Z-78 not only in reducing disease intensity but also increasing tuber yield.

Economics of management of early blight of potato

Total man days utilized: The data indicates that on an average, a total of 120 mandays were required for cultivation of potato in 1 ha area. The distribution of labours in different agricultural activities in potato cultivation revealed that the maximum number of mandays (40 mandays) utilized in harvesting and intercultural operation i.e. hoeing, earthening up etc. Field preparations require 20 mandays, for bed preparation and sowing of potato seed 35 mandays, for fertilizer applications 10 mandays, for fungicidal sprays 7 mandays and for irrigation 8 mandays were utilized.

Cost of cultivation: The total average estimated cost of potato cultivation on per hectare basis was ₹1,03,483.00. The input utilized in potato cultivation showed that the major share of the cost was on potato seed (48.32%), labour mandays (37.46%), field preparation and ridge by tractor (2.4%), fertilizer (10.88%), irrigation (0.9%) etc.

Benefit cost ratio: Treatment control in which potato was grown without fungicidal application against early blight of potato gave the 2.27 benefit cost ratio with ₹1,32,017.00

Table 2 Effect of fungicides on early blight disease intensity and tuber yield

Treatment	Disease intensity*			Reduction in disease over control (%)	Tuber yield* (q/ha)	Per cent increase in yield over control (%)
	10 days	20 days	30 days			
T_1	34.00	52.00	66.00	-	235.5	-
T_2	15.00	24.00	29.50	55.30	273.3	16.05
T_3	12.00	21.50	28.50	56.82	271.2	15.19
T_4	10.00	17.50	22.50	65.90	317.9	34.99
CD (P=0.05)	6.03	4.05	3.51	-	20.4	-

*Pooled data of two years i.e. 2018–19 and 2019–20. Treatment details are given under Materials and Methods.

Table 3 Effect of fungicidal treatment on economics of potato cultivation

Treatment	Cost of fungicide* (market rate × quantity required)	Cost of cultivation (₹/ha)	Tuber yield (t/ha)	Gross return (₹)	Net return (₹)	B:C ratio
T_1	-	1,03,483.00	23.55	2,35,500.00	1,32,017.00	2.27
T_2	₹3075 for mancozeb and ₹495 for hexaconazole	1,07,053.00	27.33	2,73,300.00	1,66,247.00	2.55
T_3	₹3075 for mancozeb and ₹825 for difenoconazole	1,07,383.00	27.12	2,71,200.00	1,63,817.00	2.53
T_4	₹4080.00	1,07,563.00	31.79	3,17,900.00	2,10,337.00	2.96

*Cost of mancozeb@ ₹410/kg, hexaconazole @ ₹660/litre, difenoconazole @₹1100/litre and chlorothalonil @ ₹1360/kg. Treatment details are given under Materials and Methods.

net return while treatment chlorothalonil @0.2% gave the highest benefit cost ratio i.e. 2.96 with ₹2,10,337.00 net return (Table 3). Treatment T2 at 10 days interval gave 2.55 benefit cost ratio and treatment T3 at 10 days interval gave 2.53 benefit cost ratio. Treatment T_2 and T_3 gave ₹1,66,247.00 and ₹1,63,817.00 net return.

It is well known that potato plays a very significant role in agricultural economy. It contributes to the livelihood of thousands of the farmers. It also acts as growing linkages to the potato industry. Quadri *et al*. (2013) estimated 1.73 benefit cost ratio in potato cultivation and reported that potato is remunerative enterprise for the farmers. Mandal *et al*. (2017) tested sequential spraying of fungicides for better management of early blight, enhancement of fruit yield and assurance of high economic return.

The results clearly indicated that three sprays of treatment chlorothalonil @0.2% at 10 days interval is the best treatment with minimum disease intensity (22.50%), the highest tuber yield (317.90 q/ha), maximum net return ₹2,10,337.00 and the highest B:C ratio (2.96), and can be effectively used by the farmers for management of early blight of potato.

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