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Phytophthora root rot of potato and its management in Kashmir Valley

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Abstract. Potato is an important crop and is grown allover the world. It is a promising food to millions of people especially in developing countries after rice, wheat and corn. Potato tubers are attacked by fungal diseases such as dry rots mostly in storage and soft rots at every stage and cause substantial loss. The present study was therefore carried out to study the incidence of fungal rot of potato in storage. It was revealed from the study that potato tubers in storage are attacked by *Phytophthora infestans* (Mont.) de Bary causing Phytophthora root rot. A study was also carried out for the management of fungal rot of potato with some systemic and non-systemic fungicides. Amongst all the fungicides used carbendazim proved highly effective in reducing the colony diameter and rot severity of *Phytophthora infestans* followed by hexaconozole, bitertanol, myclobutanil, mancozeb, captan and zineb respectively. Higher concentrations of the fungicide proved effective than lower concentrations.

Keywords: Control; Colony diameter; Fungicides; Lesion diameter; *Phytophthora infestans;* Rot severity; Storage.

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Introduction

Potato is an important crop which holds promise food to millions of people especially in developing countries. Major fungal diseases such as late blight, early blight, black scurf, fusarial wilt/dry rot, wart, powdery scab, charcoal rot and major bacterial diseases like soft rot, common scab, bacterial wilt and brown rot cause considerable loss to potato production in field and otherwise. Diseases such as late blight, early blight, Fusarial wilt and black leg primarily affect the crop/foliage where as diseases such as black scurf, wart, powdery scab and common scab disfigure the tubers and reduce their market value (Daradhiyar, 1980; Hooker, 1986; Khurane et al., 1989; Hassan, 1996; Daami-Remadi and Singh, 2006).

In Jammu and Kashmir State, the potato is cultivated under varied environmental conditions from Subtropical Region of Jammu Division to extreme cold hilly terrain of Kashmir Valley occupying an area of 1.8 thousand hectares with a production of 9.0 thousand metric tons per hectare (Anonymous, 1999) which is much less as compared to other states of India. Some tuber diseases such as dry rots appear mostly in storage while others such as soft rot affect potato tubers at every stage *i.e.* in field, storage and in the transit and may cause substantial loss under certain conditions. Full potential of the crop can be realized only if diseases that affect the crop are kept under control. Although fungicides have hazardous effects on environment but certain systemic and non-systemic fungicides have been used at some safer or limited concentrations for the control of fungal rot of vegetable (Kassim, 1985; Torres et al., 1986; Sinha, 1989; Theron, 1989; Khan et al., 1995; Cohen, 1999; Prasad et al., 1999; Dinesh and Thakur, 2005).

Phytophthora root rot of potato affecting potato crop in storage and on standing crop is therefore studied here with respect to their identification, symptoms on potato tubers, nature of the pathogen involved, control with some fungicides.

Materials and methods

To investigate the fungi which cause the decay and rots of potato in Kashmir Valley, diseased fruits were collected in polythene bags from fields, markets, godowns and at storage places of different areas of Kashmir valley. These samples were either used immediately or stored at 10 °C in the laboratory for different pathological studies. Small portions of rotted tissues were isolated aseptically from the potato tubers. The isolated portions were invariably maintained on Potato Dextrose Agar (PDA) medium. Pure colony cultures were obtained by sub-culturing the fungal growth in separate Petri-dishes containing the same medium. The pathogen was identified by their morphological, reproductive and cultural characteristics.

For pathogenicity and mode of infection, pathogens were re-inoculated after isolation onto the healthy potato tubers by different methods as: One set of potato tubers was inoculated by spraying spore suspension on the surface of each potato tuber without injury. Another set of potato tubers was inoculated by introducing the drop of suspension after pricking them with some needles. In all these cases an equal number of potato tubers were kept uninoculated which served as control. Then all the potato tubers were kept in clean polythene bags and incubated at 23$\pm$1 °C for ten days. Disease symptoms were studied or Koch's postulates proved. The different parameters such as symptoms caused by these fungi on the healthy potato tubers, cultural characteristics of the pathogens and Microscopic studies of the pathogens were studied.

Control of *Fusarium* rot of potato caused by *Phytophthora infestans* (Mont.) de Bary

In the present study an attempt was made to study the effect of some fungicides on mycelial growth, lesion diameter of *Phytophthora infestans* (Mont.) de Bary on potato tubers and rot severity as under.

Effect of fungicides on mycelial growth of *Phytophthora infestans* (Mont.) de Bary

For the control of fungus, *Phytophthora infestans* seven fungicides both systemic and non-systemic, viz. carbendazim, myclobutanil, bitertanol, hexaconozole, mancozeb, captan and zineb were evaluated at different concentrations (Table 1) for their efficacy on mycelial growth of *Phytophthora infestans* Mont by food poisoning technique (Falek, 1907; Grower and Moore, 1962). Appropriate quantity of each fungicide was separately dispensed in molten sterilized PDA medium to make desired concentrations for each fungicide. The mycelial discs of 5mm diameter, taken from 10 days old culture of the fungal pathogens were aseptically placed in the center of solidified poisoned PDA. Five replications were maintained for each concentration. The Petri-plates were incubated at 24±2 °C and observations on the mycelial growth of test fungus were recorded after seven days of incubation. The growth of test fungus on non-poisoned PDA served as a control. The percent inhibition in growth due to various fungicidal treatments at different concentrations was computed as given by Vincent (1947).

$$\text{Mycelial growth inhibition (\%)} = \frac{dc - dt}{dt} \times 100$$

Where:
dc = average diameter of fungal colony in control, and
dt= average diameter of fungal colony in treatment group.

Table 1. Different concentration of fungicides used for the control of fungal rot of vegetables.

Fungicides	Concentrations ($mg.L^{-1}$)			
Carbendazim 50WP	125	250	500	1,000
Bitertanol 10WP	125	250	500	1,000
Myclobutanil 25WP	125	250	500	1,000
Hexaconozole 5Ec	125	250	500	1,000
Mancozeb 75WP	500	1,000	1,500	2,000
Captan 50WP	500	1,000	1,500	2,000
Zineb 75WP	500	1,000	1,500	2,000

Effect of fungicides on lesion diameter

Fresh samples of potato tubers were dipped separately in different fungicidal concentrations for 5 min before inoculation of the pathogen by pin prick method as above. Potato tubers were then dried under shade and kept in card board trays and incubated at a temperature of 24±2°C for different duration. The observations were recorded after 4 days to 10 days of incubation by measuring the average diameter of the resultant lesion.

Effect of fungicides on rot severity

Different concentrations of fungicides such as carbendazim, hexaconozole, bitertanol, myclobutanil, mancozeb, captan and zineb were evaluated for their efficacy on rot severity caused by Phytophthora rot of potato on potato tubers under storage conditions. Rot severity was recorded as per the grade scale and formula adopted by Mckinney (1923) and Singh and Singh (1991).

Grade	Extent of rotting	Numerical score (%)
0	No rotting	0
1	Pin head to 10 mm	10
2	Upto 1/4th of the fruit	25
3	Upto 1/2 of fruit	50
4	Upto 3/4th of the fruit	75
5	More than 3/4th of fruit	100

$$\text{Rot severity (\%)} = \frac{\text{Sum of all numerical rotting}}{\text{No. of vegetables examined x maximum grade value}} \times 100$$

Results and observations

It was observed from the study that potato tubers in storage places undergo decay or rotting due to fungus *Phytophthora infestans* Mont thereby resulting in *Phytophthora infestans* Mont The fungus was identified on the basis of symptoms caused by the fungus on stored potato tubers, cultural and microscopic characteristics

Phytophthora root rot of potato

Disease initially starts from the leaf tips or margins and spread inward. The leaf areas first appear as small fade patches which under favorable environmental conditions soon turn into brown spots. The tubers obtained from the blighted crop shows signs of infection. The first sign of tuber infection in storage was observed as brown to purple discoloration of the skin followed by brownish dry rot which extended to about half an inch below the surface of tubers (Figure 1a). The entire infected tubers rapidly decayed completely at the later stage. The causal agent of this disease was successfully isolated from the diseased tubers on Potato dextrose agar medium (PDA). After 4 to 7 days of incubation at 26±1 °C, the fungus produced white, smooth and regular colony (Figure 1b). The microscopic observation revealed that the mycelium is slender about 3.75 µm-7.50 µm in diameter, coenocytic, hyaline and profusely branched, produce slender asepate, hyaline indeterminate sporangiophores about 5.63 µm-7.5 µm diameter with sparse thick walled side branches having bulbous enlargement at intervals that develop into sporangia (Figure 1c, 1d). The sporangiophores were found to produce hyaline, thin walled lemon-shaped sporangia, 30.0 µm × 15 µm-18.75 µm in diameter with terminal papilla. The sex organs, oogonium and anthridium were also produced under culture conditions (Figure 1d).

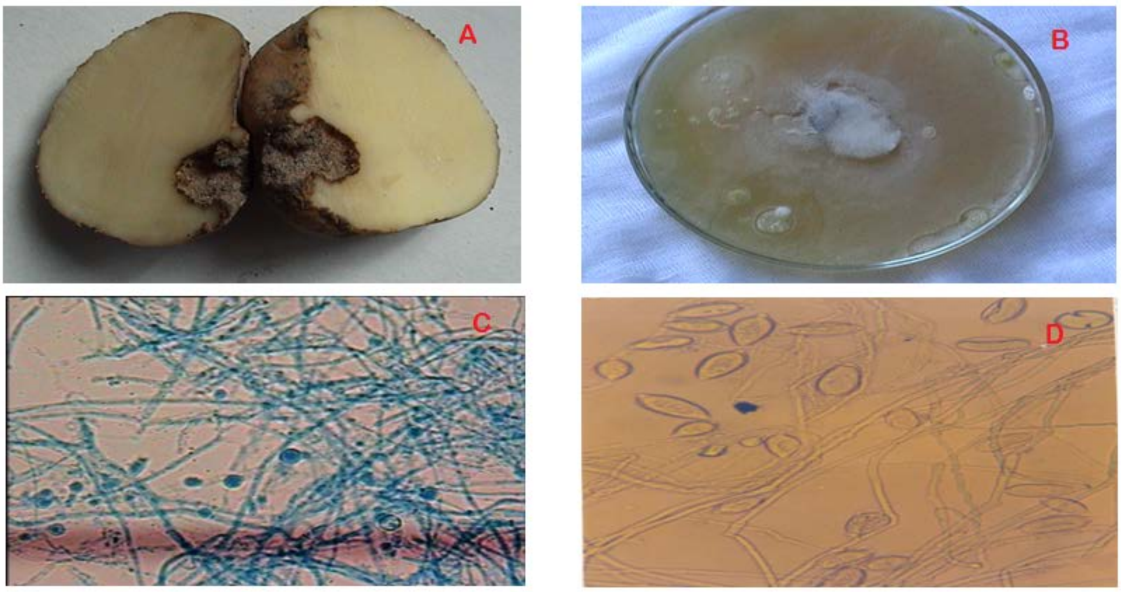

Figure 1. A, Infected potato tuber with *Phytophthora infestans*. B, Culture of *P. infestans* on PDA in Petri plate. C, Mycelium of *P. infestans* with sex organs. D, Lemon shaped sporangia formed on branched sporangiophore.

Control of Phytophthora root rot of potato with fungicides

In the present study systemic and non-systemic fungicides were evaluated for their effect on the inhibition of the mycelial growth of the fungal pathogen causing decaying or rotting of potato in storage. These fungicides were also evaluated for their efficacy on the colony diameter, lesion diameter and severity of Phytophthora root rot of potato and germination of spores of *P. infestans*. Plant extracts of some plants were also evaluated for their effect on the germination of spores of *P. infestans.*

Effect of different concentrations of fungicides on colony diameter of *P. infestans* causing Phytophthora root rot of potato

It was revealed from the results (Table 2) that all systemic fungicides at different concentrations caused significant reduction in colony diameter of *P. infestans*. The maximum reduction in colony diameter was observed at highest concentration of fungicides. It was followed by lower concentration of fungicides. In case of systemic fungicides, the carbendazim, at highest concentration (1,000 mg.L^{-1}) brought about highest reduction in colony diameter (0.0 mm) followed by hexaconozole (0.0 cm), bitertanol (20.40 mm), myclobutanil (26.20 mm), respectively at the same concentration. Other concentrations of systemic fungicides also brought about reduction in colony diameter but to a lesser extent. It was also observed from the study (Table 2) that amongst non-systemic fungicides, the mancozeb was found most effective (0.0 mm) in reducing the colony diameter of *P. infestans* followed by captan (0.0 mm) and zineb (16.80 mm), respectively. Other concentrations of non-systemic fungicides also brought about reduction in colony diameter but to a lesser extent. The least reduction was found in control without treatment.

Table 2 Effect of different concentrations of fungicides on the colony diameter of *Phytophthora infestans* causing Phytophthora root rot of potato.

Treatment	Colony diameter (mm)				
Systemic fungicide	**125 mg.L^{-1}**	**250 mg.L^{-1}**	**500 mg.L^{-1}**	**1,000 mg.L^{-1}**	**Control**
Carbendazim	0.00	0.00	0.00	0.00	69.20
Bitertanol	47.40	40.80	28.60	20.40	67.40
Myclobutanil	50.40	46.00	31.00	26.20	69.80
Hexaconozole	20.00	11.20	0.00	0.00	70.60
Non-systemic fungicide	**500 mg.L^{-1}**	**1,000 mg.L^{-1}**	**1,500 mg.L^{-1}**	**2,000 mg.L^{-1}**	**Control**
Mancozeb	0.00	0.00	0.00	0.00	68.60
Captan	19.80	11.40	0.00	0.00	69.00
Zineb	35.80	29.40	23.20	16.80	70.40

	SE. diff.	C.D (P=0.05)	C.D (P =0.01)
Fungicidse.	0.31	0.98	1.32
Concentration.	1.49	1.93	3.76
Fungicide × Conc.	2.43	3.72	5.11

Mean of five replicates.

Effect of different concentrations of fungicides on the lesion diameter caused by of *P. infestans* on potato

It was revealed from the results (Table 3) that the application of fungicides at different concentrations brought about significant reduction in the lesion diameter caused by *P. infestans* on potato as compared to untreated control which showed least reduction in lesion diameter on the potato. However, there was observed an increase in the lesion diameter on potato tubers with the increase in the incubation period. The highest increase in the lesion diameter was observed after 10 days of incubation.

In case of systemic fungicides, the carbendazim brought about maximum reduction in lesion diameter on potato (100%) followed by hexaconozole (79.17%), myclobutanil (34.73%) and bitertanol (31.95%) (Table 3). In case of non -systemic fungicide, the mancozeb was found most effective (83.05%) in reducing the lesion diameter of *P. infestans* followed by captan (52.77%) and zineb (27.7%) respectively. It was also revealed from the study (Table 3) that lesion diameter on potato tubers increased significantly with the increase in incubation period from 4 days to 10 days. In case of systemic fungicides, the carbendazim proved highly effective in reducing lesion diameter even after increase in incubation period from 4 days to10 days, but in case of myclobutanil, bitertanol and hexaconozole there was found an increase in the lesion diameter on potato tubers with the increase in incubation period from 4 days to 10 days.

Table 3 Effect of different concentration of fungicides on the lesion diameter caused by *Phytophthora infestans* on potato.

Treatment	Concentration	Lesion diameter (cm) after incubation				Mean	%age diameter of rot over control	% age of reduction of rot over control
		4 days	6 days	8 days	10 days			
Carbendazim	1,000 mg.L^{-1}	0.0	0.0	0.0	0.0	0.0	0.00	100.00
Bitertanol	1,000 mg.L^{-1}	1.3	4.3	6.2	7.9	4.9	68.05	31.95
Hexaconozole	1,000 mg.L^{-1}	0.0	0.7	1.3	4.0	1.5	20.83	79.17
Myclobutanil	1,000 mg.L^{-1}	1.9	3.4	5.5	8.0	4.7	65.27	34.73
Mancozeb	2,000 mg.L^{-1}	0.0	0.0	0.0	0.0	0.0	0.00	100.00
Zineb	2,000 mg.L^{-1}	2.4	4.0	5.7	7.5	4.9	74.24	25.76
Captan	2,000 mg.L^{-1}	2.4	3.1	5.7	6.9	4.5	62.50	37.50
Control		4.3	6.5	8.2	10.0	7.2		

	SE. diff.	C.D (P=0.05)	C.D (P =0.01)
Fungicide.	0.76	0.84	1.52
Concentration.	1.52	1.93	3.76
Fungicide × Concentration	2.43	3.65	6.05

Mean of five replicates.

Table 4. Effect of fungicidal dips applied as pre-inoculation treatments on the severity of Phytophthora root rot of potato caused by *Phytophthora infestans.*

Treatment	**Concentration**	**Rot severity (%) after incubation**			
		4 days	**8 days**	**12 days**	**16 days**
Carbendazim	1,000 mg.L^{-1}	0.00	0.00	1.45 (6.92)	9.16 (17.62)
	500 mg.L^{-1}	0.87 (5.38)**	3.79 (11.23)	9.13 (17.59)	(21.68)
	250 mg.L^{-1}	4.13 (11.73)	10.83 (19.22)	17.54 (24.76)	24.02 (29.35)
Hexaconozole	1,000 mg.L^{-1}	1.74 (7.60)	5.18 (13.16)	11.02 (19.39)	17.78 (25.09)
	500 mg.L^{-1}	6.48 (14.75)	10.89 (19.27)	20.35 (26.82)	33.14 (35.15)
	250 mg.L^{-1}	11.50 (19.83)	19.95 (26.53)	26.71 (31.12)	35.13 (36.35)
Myclobutanil	1,000 mg.L^{-1}	10.85 (19.24)	17.35 (24.62)	24.45 (29.65)	35.73 (36.71)
	500 mg.L^{-1}	17.44 (24.69)	25.00 (30.00)	35.73 (36.71)	41.30 (39.99)
	250 mg.L^{-1}	31.88 (34.38)	40.81 (39.71)	49.45 (44.69)	58.20 (49.72)
Bitertanol	1,000 mg.L^{-1}	8.78 (17.24)	13.15 (21.27)	24.42 (29.62)	31.65 (34.24)
	500 mg.L^{-1}	11.66 (19.97)	15.63 (23.29)	24.57 (29.72)	33.54 (35.39)
	250 mg.L^{-1}	14.91 (22.72)	20.34 (26.81)	29.10 (32.65)	41.26 (39.97)
Mancozeb	2,000 mg.L^{-1}	0.00	0.00	0.00	0.00
	1,500 mg.L^{-1}	0.00	0.00	0.00	0.00
	1,000 mg.L^{-1}	0.00	1.36 (6.71)	3.45 (10.72)	4.58 (12.36)
Captan	2,000 mg.L^{-1}	0.00	8.94 (17.40)	13.01 (21.15)	20.25 (26.75)
	1,500 mg.L^{-1}	7.14 (15.91)	12.50 (20.71)	24.02 (29.35)	31.73 (34.29)
	1,000 mg.L^{-1}	12.97 (21.11)	23.14 (28.76)	40.20 (39.35)	44.35 (41.76)
Zineb	2,000 mg.L^{-1}	10.26 (18.69)	14.83 (22.65)	28.31 (32.15)	41.31 (40.00)
	1,500 mg.L^{-1}	13.47 (21.54)	21.88 (27.89)	30.30 (33.40)	48.65 (44.23)
	1,000 mg.L^{-1}	21.57 (27.68)	25.00 (30.00)	35.49 (36.57)	51.30 (45.75)
Control		34.15 (35.76)	49.51 (44.72)	62.31 (52.12)	80.17 (63.55)

	SE. diff.	**C.D (P=0.05)**	**C.D (P =0.01)**
Fungicide	0.89	0.99	1.69
Concentration.	1.65	1.87	2.69
Fungicide x Conc.	2.64	3.17	4.25

Mean of five replicates; **Figures in parentheses are arc Sin√%age transformed value and are statistically identical.

Similarly in case of non-systemic fungicides, the mancozeb proved highly effective in reducing the lesion diameter even after increase in incubation period from 4 days to 10 days. But lesion diameter increased with the increase in the incubation period from 4 days to 10 days in case of captan and zineb respectively.

Effect of fungicidal dips applied as pre-inoculation treatments on the severity of Phytophthora root rot of potato caused by *Phytophthora infestans*

It was revealed from the results (Table 4) that the severity of Phytophthora root rot of potato reduced significantly after dip treatment in all the concentrations of fungicides as compared to untreated control. However, the severity of the rot increased with the increase in the incubation period from 4 days to 10 days. Highest reduction in the severity of Phytophthora root rot of potato was found at highest concentration (1,000 mg.L^{-1}) followed by lower concentrations i.e. 500 mg.L^{-1} and 250 mg.L^{-1}, respectively. Amongst all the fungicides, the carbendazim proved highly effective in reducing the severity of potato rot caused by *P. infestans* followed by hexaconozole, bitertanol, myclobutanil, mancozeb, captan and zineb, respectively.

In case of systemic fungicides, the carbendazim at highest concentration (1,000 mg.L^{-1}) proved highly effective in reducing the severity of rot followed by, hexaconozole, bitertanol and myclobutanil at the same concentration (Table 4). Other concentrations also proved effective in reducing the severity of rot but to a lesser extent. In case of carbendazim, the reduction in the severity of Phytophthora root rot of potato in its different concentrations was from 4.13% to 0.00% after 4 days of incubation, from 10.83% to 0.00% after 6 days of incubation, from 17.54% to 1.45% after 8 days of incubation and from 24.35% to 9.16% after 10 days of incubation period respectively. The severity of Phytophthora root rot of potato was more after 10 days of incubation. Similar trend was found in other systemic fungicides hexaconozole, bitertanol, and myclobutanil, respectively.

In case of non-systemic fungicides, the mancozeb at highest concentration (2000 mg.L^{-1}) proved highly effective in reducing the severity of rot caused by *P. infestans* on potato followed by captan and zineb respectively at the same concentration (Table 4). Other concentrations also proved effective in reducing the severity of rot but to a lesser extent. In case of mancozeb the reduction in the severity of Phytophthora root rot of potato in its different concentrations was from 0.00% after 4 days of incubation, from 1.36% to 0.00% after 6 days of incubation, from 3.45% to 0.0% after 8 days of incubation and from 4.58% to 0.00% after 10 days of incubation period. However, the severity of Phytophthora root rot of potato was high after 10 days of incubation. Similar trend was observed in other systemic fungicides, captan and zineb, respectively.

Discussion

It was clear from the results that potato tubers in storage are attacked by fungus, *Phytophthora infestans* and this fungus was responsible rot of potatoes under storage conditions and in the field conditions. Such study on fungal rot of potatoes have been carried out for the first time in Kashmir Valley. However, some study has been carried out on the fungal rot of potato in India and all over the world. This fungus was identified on the basis of symptoms cause by the fungus on potato tubers under storage and in the field conditions. Similar finding were reported in relation to fungal rot of potato caused by similar or other fungi (Kasim, 1980; Miller et al., 1995; Lambert and Currier, 1997; Schmitthenner, 1999; Sharma and Chaudhary, 2004; Ali et al., 2005; Miller et al., 2006). Wani and Wani (2010) also used cultural, morphological and reproductive characteristics for the identification of causal fungus of fungal rots of some vegetables and fruits.

In the present study fungicides were used for the management of Phytophthora root rot of potato. All the tested fungicides were found to reduce mycelia growth, lesion diameter on potato tubers. In a similar study, the fungicides have been shown to completely inhibit the mycelial growth of *Phytophthora infestans* Mont in Richards medium (Khan et al., 1995). Patel et al. (2005) evaluated five different fungicides such as mancozeb, carbendazim, copper-oxychloride and potassium permagnate *in vitro* for their efficacy on the mycelial growth of *Alternaria* sp. and observed that all tested fungicides at different concentrations brought about significant reduction in the colony diameter as compared to control. Fludioxonil has been observed to show higher efficacy and totally inhibited the mycelial growth of all tested *Fusarium* isolates, even those of *F. sambucinum* which are shown to be resistant to benzimidazoles in previous studies (Daami-Remadi and El-Mahjoub, 2006; Thirumala Rao and Sitaramaiah, 2000; Vijaya and Rahman, 2004; Khurana et al., 2005).

There was a significant reduction in the lesion diameter after dip treatment in different concentration of fungicides. The highest reduction in lesion diameter was observed at maximum concentration, it was followed by lower concentration of fungicides. The highest reduction in lesion diameter was observed in different concentration of hexaconozole followed by carbendazim, myclobutanil and bitertanol respectively, whereas in non-systemic fungicides, the highest reduction in lesion diameter was observed in different concentration of mancozeb followed by captan and zineb, respectively. However, the present study revealed that the lesion diameter increased with the increase in the incubation period from 4 days to 10 days. The highest increase in lesion diameter was observed after 10 days of incubation followed by 8 days, 6 days and 4 days of incubation respectively. The decrease in the lesion diameter may be due to effect of fungicides on the mycelial growth of fungal pathogens responsible for rotting of these vegetables in storage. Similar findings were observed by Patel et al. (2005). They observed that fungicides such as mancozeb, carbendazim, copper-oxychloride, and potassium permanganate caused reduced in mycelial growth and lesion diameter of *Alternaria* rot of tomato. Singh et al. (1997) and Kumar et al. (2005) also revealed that fungicides and plant extracts inhibited the mycelial growth of *A. flavus* on chilli fruits. Suryavanshi and Deokar (2001) noticed maximum inhibition of mycelial growth of *A. niger* by captan on some vegetables.

It was clear from the study that different concentrations of all the tested systemic and non-systemic fungicides when applied as pre-inculcation treatments brought about significant reduction in the severity of *Fusarium* rot of Potato. However, the highest reduction in the severity was observed at highest concentration of fungicides followed by lower concentrations of fungicides. Amongst systemic fungicides, the carbendazim mostly proved highly effective in reducing the severity of fungal rot, it was followed by hexaconozole, bitertanol and myclobutanil respectively, whereas amongst non-systemic fungicides, the mancozeb was found highly effective in reducing the fungal rot of vegetables followed by captan and zineb respectively. However, it was also revealed from the study that severity of fungal rot of vegetables increased with the increase in the incubation period from 4 days to 10 days of and highest severity was observed after 10 days of incubation. The reduction in the severity of fungal rot of vegetables may be due to inhibition in growth of causal fungus by different concentrations of fungicides. The present findings are in agreement with those of Nagaraju and Urs (1998). Gambhir and Khainar (1986) found that *Penicilliun brefeldianum* was unable to tolerate even 500 $mg.L^{-1}$ of copper oxychloride (Bilitox.). Onions when tested with benomyl + thiram and mancozeb at two doses were effective in controlling severity of *Penicillium* sp. (Tylkowska et al., 1998). Maheshwari et al. (1988) reported that carbendazim remained effective against black mold of onion. Sinha et al. (1994), Cohen (1999), Prasad et al. (1999), Thirumala Rao and Sitaramaiah (2000), Vijaya and Rahman (2004), Miller et al. (2006), Dinesh and Thakur (2005), and Shahnaz et al. (2007) also reported effect of fungicides on the severity of fungal rot of different vegetables.

The present study also indicates that systemic fungicides and non-systemic fungicides at different concentrations proved highly effective in reducing the severity of fungal rot of potato after different incubation periods. Such finding were also reported by Kumar (2005) who also revealed that carbendazim at 1,000 mg.L^{-1} significantly proved effective at par with penconazole (1,000 mg.L^{-1}) followed by carbendazim (500 mg.L^{-1}) after 8 days of inoculation in post inoculation treatments. Amongst systemic fungicides, SAFF was most effective in inhibiting the radial growth of onion caused by *Aspergillus niger* and *Penicillium. digitatum* followed by benomyl and carbendazim (Raju and Naik, 2006). Shahnaz et al. (2007) reported that carbendazim remained most effective when applied as pre-harvest spray on severity of black mold of onion. Banyal et al. (2008) evaluated ten fungicides such as carbendazim, mancozeb, captan, chlorothalonil, thiabendazole, carboxin, campanion, propineb, tebuconazole and indofil M-45 for the control of collar rot of tomato caused by *Sclerotium rolfsii.*

References

Ali, S.; Rivera, V. V.; Secor, G. A. First report of *Fusarium graminearum* causing dry rot of potato in North Dakota. **Plant Disease**, v. 89, No. 1, p. 105, 2005. https://dx.doi.org/10.1094/PD-89-0105B

Anonymous. **Potato in India**. Simla: Central Potato Research Institute, 1999.

Banyal, D. K.; Mankotia, V.; Sugha, S. K. Integrated management of tomato collar rot caused by *Sclerotium rolfsii*. **Journal of Mycology and Plant Pathology**, v. 38, p. 165-167, 2008.

Cohen, E. The post harvest treatment in citrus fruits in Isreal. Proc. Int. Symp. Citriculture, Nov. 23-27, NRC for Citrus. p. 1081-1087, 1999.

Daami-Remadi, M.; Singh, J. P. Presence in Tunisia of *Fusarium sambucum* isolates resistant to Benzidmadazoles: *in vitro* growth and aggressiveness on potato tuber. **Biotechnology Agronomy Society and Environment**, v. 10, p. 7-16, 2006.

Daradhiyar, P. K. Studies on some post harvest disease of tomato and their control. **Journal of Botanical Control**, v. 59, p. 230-233, 1980.

Dinesh, S.; Thakur, A. K. Effect of fungicides on spoilage caused by mycoflora in Kinnow (*Citrus reticulate* Blanco) fruits during storage. **Journal of Mycology and Plant Pathology**, v. 35, p. 125-127, 2005.

Gambhir, S. P.; Khairnar, D. C. Tolerance of Blitox by spormosphere micro-fungi of ground nut. **Acta Botanica Indica**, v. 14, p. 127-129, 1986.

Gangopodhyay, S. **Advances in vegetables diseases**. New Delhi: S. K. Dutta Association Publishing, 1984. p. 261-264.

Gomez, K. A.; Gomez, A. A. **Statistical producers for agricultural research**. New York: John Wiley and Sons, 1984.

Grover, R. K.; Moore, J. D. Toximetric study of fungicides against brown rot organism, *Secleroina fruticola*. **Phytopathology**, v. 52, p. 876-880, 1962.

Hassan, H. A. H. *Alternaria* mycotoxins in black rot lesion of tomato fruits: conditions and regulations of their productions. **Acta Immunolgica Hungarica**, v. 43, p. 125-133, 1996.

Hooker, W. J. **Compendium of potato diseases**. St. Paul, Minnesota, USA: American Phytopathological Society, 1986.

Kalra, J. S.; Sohi, H. S. Studies on post harvest rot of tomato fruits. Control of *Alternaria* fruit rot. **Indian Journal of Mycology and Plant Pathology**, v. 15, no. 3, p. 256-260, 1985.

Kassim, M. Y. Chemical control of post harvest disease of potato and tomato. **Indian Phytopathology**, v. 39, p. 243-244, 1985.

Kaur, S.; Mukherji, K. G. Potato disease and management. In: Mukherji, K. G. (Ed.). **Disease management of fruits and vegetables**. Netherlands: Kluwer, Acedemic Publishers, 2004. p. 233-280.

Khan, M. A.; Ahmad, M.; Saeed, M. A. Evaluation of fungicides on the growth of *Alternaria alternata in vitro* and the control of post harvest tomato fruit rot. **Pakistan Journal of Phytopathology**, v. 7, No. 2, p. 166-168, 1995.

Khurane, S. M.; Paul-Garg, I. D.; Singh, B. P.; Gadewar, A. U. Major disease of potato and their management. In: Upadthyay, R. K. (ed.). New Delhi: APH Publ. Corpn., 1998. p. 11-64.

Kiraly, Z.; Klement, Z.; Solymosy, F.; Voros, J. **Methods in plant pathology with special reference to breeding for resistance to breeding for resistance**. New York: Elsevier Publishing Company, 1974.

Lambert, D. H.; Currier, A. I. Difference in tuber rot development for North American clones of *Phytophthora infestans.* **American Journal of Potato Research**, v. 74, p. 39-43, 1997.

Maheshwari, S. K.; Gupta, P. C.; Sohay, L. S. A note on studies of the effect of different fungicides to control *Aspergillus* rot of onion. **Haryana Journal of Horticultural Science**, v. 17, p. 127-129, 1988.

McKinney, H. H. Influence of soil temperature and moisture on the infection of wheat seedlings by *Helminthosporium sativum*. **Journal of Agriculture Research**, v. 26, p. 195-217, 1923.

Miller, J. S.; Olsen, N.; Woodell, L.; Porter, L. D.; Clayson S. Post-harvest applications of zoxamide and phosphite for control of potato tuber rots caused by oomycetes at harvest. **American Journal of Potato Research**, v. 83, No. 3, p. 269-278, 2006.

Miller, J. S.; Johnson, D. A.; Hammn, P. B. Agressiveness of *Phytophthora infestans* isolated in pacific North West. **Phytopathology**, v. 85, p. 1127, 1995.

Nagaraju, P.; Urs, S. D. Comparative efficacy of fungicides and bioagents against *Aspergillus niger*, a causal agent of collar rot of groundnut. **Current Research**, v. 27, p. 137-139, 1998.

Pansy, V. G.; Sukhatme, P. V. **Statistical methods for agricultural workers**. New Delhi: Indian Council of Agricultural Research, 1985.

Patel, N. A.; Dange, S. R. S.; Patel, S. I. Efficacy of chemicals in controlling fruit rot of tomato caused by *Alternaria* tomato. **Indian Journal of Agricultural Research**, v. 39, no. 1, p. 72-75, 2005. Available from: <http://www.arccjournals.com/uploads/articles/ijar2391014.pdf>. Accessed on: Nov. 26, 2016.

Peters, J. C.; Lees, A. K.; Cullen, D. W.; Sullivan, L.; Stroud, G. P.; Cunnington, A. C. Characterization of *Fusarium* species responsible for causing rot of potato in Great Britian. **Plant Pathology**, v. 57, No. 2, p. 262-271, 2003.

Prasad, M. S.; Prasad, M. S. L.; Sharma, Y. P. Effect of containers and fungicidal application on the storage of Khasi Mandarin. Proc. Int. Symp. Citriculture, Nov. 23-27, NRC for Citrus. Nagpur, 1999. p. 1123-1128.

Raju, K.; Naik, M. K. Effect of pre-harvest spray of fungicides and botanicals on storage diseases of onion. **Indian Phytopathology**, v. 59, p. 133-141, 2006.

Schmitthenner, A. F. Phytophthora rot of Soybean. In: Plant Health Progress Compendium of Soybean Diseases. 4 ed. St. Paul, MN, U.S.A.: The American Phytopathological Society, 1999. p. 39-42, https://dx.doi.org/10.1094/PHP-2000-0601-01-HM

Shahnaz, E.; Razdan, V. K.; Rania, P. K. Survival, dispersal and management of foliar blight pathogens of onion (*Allium cepa*). **Journal of Mycology and Plant Pathology**, v. 37, No. 2, p. 210-212, 2007.

Sharma, L.; Chaudhary, M. Incidence of post harvest rot of tomato in Himachal Pradesh. **Journal of Mycology and Plant Pathology**, v. 34, p. 906-908, 2004.

Sharma, R. L. Efficacy of fungicide impregnated paper liners against storage rot of tomato fruit. **Journal of Mycology and Plant Pathology**, v. 26, p. 310-311, 2006.

Singh, B. P.; Bhattacharyya, S. K. Control of late blight tuber infection by systemic fungicides. **Indian Journal of Plant Protection**, v. 18, p. 119-123, 1990.

Singh, D.; Singh, A. K. Chemical control of storage rot of potato. **Journal of Mycology and Plant Pathology**, v. 21, p. 285-286, 1991.

Sinha, P.; Sharma, R. P.; Roy, M. K. Management of storage rots in onion through gramma irradiation and chemicals. **Journal of Food Science and Technology**, v. 31, p. 341-343, 1994.

Sinha, P. P. Control of *Phomopsis* blight and fruit rot of brinjal. **Indian Journal of Mycology and Plant Pathology**, v. 9, p. 320-321, 1989.

Theron, D. J. *Fusarium* species associated with dry and stem-end rot potatoes in South Africa. **Phytophylactica**, v. 21, p. 17-18, 1989.

Thirumala Rao, S. K.; Sitaramaiah, K. Stimulation of *Trichoderma* spp. and inhibition of *Aspergillus niger* in water extract of neem cake amended soil *in vitro*. **Indian Journal of Mycology and Plant Pathology**, v. 30, p. 263-238, 2000.

Torres, H.; Martin, C.; Henfling, J. Chemical control of pink rot of potato (*Phytophthora erythroseptica*). **American Journal of Potato Research**, v. 62, p. 355-361, 1986.

Tylkowska, K.; Szopinska, D.; Fledorow, Z. Wplyw fungicydow oraz grzybow z rodzajow *Penicillium* i *Trichoderma* na zdrowotnosc i kielkowanie nasion cebuli. **Roczniki Akademii Rolniczej w Poznaniu, Seria Ogrodnictwo**, v. 27, No. 344, p. 339-344, 1998.

Vijaja, M.; Rahman, M. N. Efficacy of fungicides in the control of leaf blight disease of onion. **Journal of Mycology and Plant Pathology**, v. 34, p. 654-655, 2004.

Vincent, J. M. Distortion of fungal hyphæ in presence of certain inhibitors. **Nature**, v. 159, p. 850, 1947. https://dx.doi.org/10.1038/159850b0