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Evaluation of Different Bioagents, Botanicals Extracts and Chemical Fungicides against Black Scurf of Potato caused by *Rhizoctonia solani*

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ABSTRACT: Potato is commonly known as disease oriented problematic crop throughout the world. Diseases are one of the yield and quality reducing factors, which causes low yield of potato. Potato production is threatened by many factors in which diseases have maximum importance, which are caused due to Nematodes, Fungi, Bacteria, viruses *etc*. Black scurf reduce tuber quality, marketability and cause a serious disease of potato worldwide. In India responsible for 10-25% yield loss, yield losses may reached up to 50% in severely affecting potato crops. From the present studies results revealed that the minimum radial growth 29.2 mm and maximum growth inhibition 67.55 % of fungus was recorded in T_1-(*Trichoderma harzianum)* followed by 34.2 mm and 62.00 % in T_2-(*Trichoderma viride)* while, maximum radial growth 48.5 mm and minimum growth inhibition 46.11 % of fungus was recorded in T_3-(*Pseudomonas fluoescens)* over control 90 mm at 6 DAI. Minimum radial growth 33.5 mm and maximum growth inhibition 62.67 % of fungus was recorded in T_3-(Garlic clove extract @ 7 %) which was found to be at par with other concentration of garlic clove extract *i.e.* T_2 (Garlic clove extract @ 5 %) and T_1 (Garlic clove extract @ 3 %) respectably, followed by 52.5 mm and 41.66 % in T_6- (Neem leaf extract @ 7 %) at 6 DAI. While, maximum radial growth 78.00 mm and minimum growth inhibition 13.33 % of fungus was recorded in T_7- (*clerodendran enermy* @ 3 %) followed by 76.00 mm and 15.55 % in T_8- (*clerodendran enermy* @ 5 %) over control 90 mm at 6 DAI. Minimum radial growth (9.20 mm) and maximum growth inhibition (89.77 %) of fungus was recorded in T_4-(chlorothalonil @ 100 ppm) followed by 10.40 mm and 88.44 % in T_8-(thiophanate methyl @ 100 ppm) at 6 DAI. While, maximum radial growth (30.40 mm) and minimum growth inhibition (66.22 %) of fungus was recorded in T_5- (copper oxychloride @ 50 ppm) followed by 28.50 mm and 68.30 % in T_1- (carbendazim @ 50 ppm) at 6 DAI over control (90 mm).

Keywords: Potato, black scurf, bioagents, botanicals, fungicides and Inhibition percent.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the world's fourth most important food crop after wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.), and provides a balanced source of starch, vitamins and minerals to many communities in almost all over the world (Rowe, 1993). It is considered as a "King of Vegetable". The potato's origins can be traced back to South American tribes in the Peruvian Andes Mountains in 5000 B.C. With the return of Spanish explorers about1570, the potato made its way to Europe. There are around 160 kinds of wild potato, and the majority of them have high quantities of alkaloids. The first edible potato is thought to have been grown in Peru 4000 years ago (Ochea, 1962). It is a low-cost energy source that contains less energy but is nutritionally high in protein, important vitamins and minerals, as well as trace elements, and provides a source of low-cost energy to the human diet (Mehdi *et al*., 2008). Potatoes are also a good supply of important amino acids such as leucine, tryptophane, and isoleucine, as well as a major source of starch and glucose. It is used for a variety of industrial applications, including the manufacturing of starch and alcohol, as well as the processing of various products like as chips, French fries, cubes, granules, and canned goods. Tubers are mostly utilised as a vegetable, while the vegetative green sections are used as fodder.

Moisture (74.7g), protein (2.0g), fat (0.1g), carbs (22.6g), energy (85 calories), calcium (13mg), phosphorus (40mg), iron (0.70mg), carotene (24g), vitamin A (40 units), thiamine (40 units) make up the average potato tuber composition per 100g edible chunk (0.11mg), riboflavin (0.01mg) and vitamin-C (12mg) (Das *et al*., 2000).

Potato was firstly domesticated in the region of southern Peru and extreme North-western Bolivia (Spooner *et al*., 2005) between 8000 and 5000 BC. Since, it has spread around the world and become a staple crop in many countries. In late eighteenth to early nineteenth century, potatoes were sufficiently cultivated in the hills and plains of India that varieties had acquired local names, such as: Phulwa ("flowering in the plains"), Gola ("round potatoes"), and Satha ("maturing in sixty days") (Spooner *et al*., 2005).

Potatoes are grown on a total of 1,50,864 hectares, with a global yield of 38 million tonnes. China produces the most potatoes in the world, with 99,205,600 tonnes in 2019, followed by India with 48,605,000 tonnes (FAOSTAT, 2020). China and India together account for 38 percent of total global manufacturing. Potatoes are not just a rural staple in India, but also a cash crop that offers significant money to farmers. Uttar Pradesh is the greatest producer of potato in India, with 14,755,000 tonnes, accounting for 30.40 percent of total production. Potato production climbed by 6-8 percent in 2020 compared to the previous year, as farmers gained better income from the crop, (**Anonymous, 2020).** Among the Uttar Pradesh, Kannauj is a largest producer of potato with 956601.30 tons with the productivity of 25.43 tonnes/hac.

In many parts of the world, the potato is regarded as a disease prone crop. Diseases are one of the factors that reduce production and quality, resulting in reduced potato yield. Potato production is endangered by a variety of reasons, the most important of which are illnesses caused by nematodes, fungi, bacteria, viruses, and other microorganisms. Fungi were responsible for a variety of diseases, including late blight (*Phytophthora infestans*), early blight (*Alternaria solani*), potato wart disease (*Synchytrium endobioticum*), Phoma leaf spots (*Phoma andigena* var. *andina*), Pink rot (*Phytophthora erythroseptica*), Charcoal rot (*Macrophomina phaseolina*), black scurf (*Rhizoctonia solani*) etc.

Black scurf, caused by *Rhizoctonia solani,* is one of the most devastating potato diseases (perfect stage-*Thanetophorus cucumeris*). *R. solani* is a complicated pathogen with a large host range in all potato-growing countries. *Rhizoctonia* stem canker is a devastating and soil borne disease of potatoes. Black scurf is a devastating potato disease that reduces tuber quality and marketability. In India, where yield losses range from 10% to 25% (Sharma, 2015), yield losses in highly affected potato crops can reach up to 50%. Julius Kühn first described black scurf from potato in 1858 (Kühn 1858). Rhizoctonia (the Greek word for "death of roots") canker, also known as black scurf, is one of the oldest and most prevalent infections of potato stems and stolons beneath the soil surface. It causes stem canker, while sclerotia formed by the pathogen on tubers is known as black scurf.

Among all agricultural and horticultural crops, *Rhizoctonia solani* is quite important. It is a highly destructive pathogen with global significance, a diverse variety of characteristics, and the ability to thrive in hard environments (Sneh *et al.,* 1996). Soil-borne pathogenic fungi have a greater host range than airborne pathogenic fungi, and they can survive for lengthy periods of time without adequate hosts (Agrios 1997). This pathogen's inoculum frequently survives the winter as mycelium or spore. If potatoes are consistently produced in the same soil, the sclerotia of this pathogen that overwinter in the soil have a high propensity to cause infection the following season. Sclerotia can grow on the tuber surface even when the inoculum level is low, and black scurf disease progresses as the inoculum level rises. As a result, chemical fungicide management is not always effective, especially when initial inoculum levels are high (Tsror and Peretz 2005; Kyritsis and Wale, 2002).

The most reasonable approach to control the black scurf disease of potato is the use of resistant germplasms **(Rauf, 2002).** Although the differences among the susceptibility levels of *R. solani* can be seen between the cultivars but there is no immune cultivar of potato against *R. solani* (Jeger *et al*., 1996; Naz *et al*., 2008). Diversity within black scurf isolates has been studied by morphological characterization and pathogenicity testing. In India, study on grouping of potato isolates of *R. solani* on the basis of morphological and their pathogenic behaviour is limited. *R. solani* is a complex pathogen with wide host range.

The adoption of resistant germplasms is the most logical way to controlling the black scurf disease of potatoes (Rauf, 2002). Although there are differences in *R. solani* susceptibility levels between cultivars, there is no potato cultivar that is immune to *R. solani* (Jeger *et al.,* 1996; Naz *et al.,* 2008). Morphological characterisation and pathogenicity testing have been used to investigate the diversity within black scurf isolates. In India, research on categorising *R. solani* potato isolates based on morphological and pathogenic characteristics is limited. *R. solani* is a sophisticated pathogen that infects a wide range of hosts.

MATERIALS AND METHODS

A. Preparation of Potato dextrose agar (PDA) media

List if ingredient's required for PDA

Constituents		Quantity
Peeled potato	:	200 g
Dextrose	:	20 g
Agar-agar	:	20 g
Distilled water to make final volume	:	1000 ml

Procedure: PDA was made by cutting 200 g peeled potatoes into slices and boiling them in 500 ml distilled water until they softened. The muslin fabric was used to filter the potato extract, and the filtrate was collected in the beaker. The remaining 500ml water was heated, and 20gm agar and 20gm dextrose were correctly added by shaking through a glass rod. Both solutions were combined in a beaker, and the volume was maintained at 1000 ml by adding distilled water as needed. Each conical flask with a capacity of 250 ml filled 200 ml of this solution. Non-absorbent cotton plugs were used to plug flasks, which were then covered in silver foil.

Sterilization of culture media: Flasks containing medium were sterilized at 121°C at 15lbs pressure/inch^2 for 15 minutes in an autoclave. To prevent bacterial contamination, 1 g/l streptomycin sulphate was added to the sterilized medium right before pouring it into petri plates.

B. Isolation, purification, identification and maintenance of Rhizoctonia solani isolates:

Isolation. During the survey, sick tubers with little crusty bodies and very dark or black sclerotia were gathered from different places and isolated in the laboratory. To remove soil adhering to the potato, the diseased tubers were rinsed several times. With the help of a sterile scalpel, sclerotia and some potato skin were cut. To remove surface contaminations, sclerotia were rinsed three times in sterile distilled water after being surface sterilized with 1.0 percent sodium hypochloride solution for 30 seconds. On sterile tissue papers, sclerotia were allowed to dry. Twenty ml of the PDA medium was poured in sterilized petri plates and allowed them to solidify. The pieces were then placed on the poured medium in a laminar air flow under aseptic conditions. To avoid contamination, the plates were sealed with parafilm before being incubated at 25 ± 2^{O}C and examined for growth on a regular basis

Purification of pathogen. Purification of isolated fungus of each isolate was carried out by using hyphal tip technique as described by Dhingra and Sinclair (1985). Purified test pathogen was used for identification.

Identification of pathogen. The isolates collected from tubers were initially identified as *Rhizoctonia* by visual observation of their hyphal characteristics on potato dextrose agar (PDA) medium by Ogoshi (1987). *Rhizoctonia* Hyphae have right-angle branches. Meyer *et al.*, (1998) used hyphal staining with 05% trypan blue in lactophenol to validate their identity, followed by light microscopy under a compound microscope to examine their hyphal morphology. After seven days of incubation on PDA, *Rhizoctonia solani* formed dark brown to black sclerotia. Pathogen exhibited *R. solani* like hyphae with typical right-angle branching, according to hyphal staining. (Pandit, 2017).

C. *Maintenance and preservation of culture*

Pure cultures of different isolates were maintained on PDA slants by sub culturing it at 30 days interval. For preservation of cultures the plugged end of the culture tubes were dipped in melted wax and stored at 7.5 ± 1°C in a refrigerator.

Antagonistic activity of potential bio-agents, botanicals and chemical fungicides against *Rhizoctonia solani* under *in-vitro* condition.

Bioagents against *Rhizoctonia solani* by dual culture technique. The cultures of antagonists used in the present study were obtained from the Biocontrol Lab, Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P). The fungal antagonists were revived on potato dextrose agar (PDA) plates, whereas, the bacterial antagonists were revived on the nutrient agar medium (NAM) plates by incubating at 27±1°C in BOD incubator for 3-4 days after inoculation. The PDA medium was poured at 20 ml/plate in Petri plates (90 mm) and allowed to solidify. The plates were inoculated with 5.0 mm mycelial disc of five days old culture of antagonistic fungus *viz*., *T. harzianum*, *T. viride* as well as 5.0 mm mycelial disc of five days old culture of *R. solani* at equidistance and exactly opposite to each other in PDA plates. In case of evaluation of bacterial antagonist, the bacterium *viz*., *Bacillus subtilis or Pseudomonas fluorescens* was streaked with inoculating loop at one end of the Petri plates and mycelial disc (5.0 mm) of the test fungus (*i.e.*, *R. solani*) was placed at the other end. The PDA plates inoculated in centre with the 5.0 mm mycelial disc of five days old culture of *R. solani* served as a control. The plates were incubated at 27±1°C in BOD incubator with four replications in a completely randomized design.

Treatment details of Antagonistic bio-agents are given below:

Treatments:

T_1 : *Trichoderma harzianum*
T_2 : *Trichoderma viride*
T_3 : *Pseudomonas fluorescens*
T_4 : *Bacillus subtilis*
T_5 : Control

The per cent inhibition of radial mycelial growth of the pathogen over control was calculated by using the formula given by Vincent (1947).

$$I = \frac{C-T}{C} X100$$

Whereas; I = Percent Growth Inhibition
C = Radial Growth of Pathogen in Control Set
= Radial Growth of Pathogen in Treatment Set

Botanical extract against *Rhizoctonia solani* by food poison technique. All the plant products were collected from road side under the campus of Chandra Shekhar Azad University of Agriculture and Technology,

Kanpur (U.P.), *Allium sativum* (bulb) were purchased from market. Three botanical extracts namely- Garlic extract, Neem leaf extract and clerodendron leaf extract were evaluated against *R. solani in vitro* by following the poison food technique. Cold water extract of Garlic clove, Neem leaf and clerodendron leaf extract were evaluated against *R. solani in vitro* to evaluate their inhibitory effect on the growth of the fungus. For preparation of cold water extracts, fresh leaves were washed with tap water followed by distilled water. It was then processed with distilled water in 1:1 ratio, *i.e*. 100 gram leaf tissue in 100 ml distilled water. The plant parts were crushed in mixer grinder and strained through double layer muslin cloth. This formed the standard extract solution (100%). The botanical extracts were incorporated into PDA medium at three different concentrations, i.e. 3, 5 and 7 per cent. For obtaining 3, 5 and 7 per cent concentrations of plant extracts in the medium 3, 5 and 7 ml of plant extracts, respectively, were added in PDA to make volume 100 ml. Streptomycin @ 30 ppm were also added to the medium before pouring in the Petri-plates to prevent bacterial contamination. PDA not amended with extract served as check. The amended PDA @ 20 ml/plate was poured into 90 mm sterilized Petri-plates, aseptically. Three plates were poured for each treatment. List of plant extracts used in the present study is given below as treatments details-

Treatments:

T_1 : Garlic Extract @ 3% water solution.
T_2 : Garlic Extract @ 5% water solution.
T_3 : Garlic Extract @ 7% water solution.
T_4: Neem Extract @ 3% water solution.
T_5: Neem Extract @ 5% water solution.
T_6: Neem Extract @ 7% water solution.
T_7: *Clerodendron enermy* Extract @ 3% water solution.
T_8: *Clerodendron enermy* Extract @ 5% water solution.
T_9: *Clerodendron enermy* Extract @ 7% water solution
T_{10}: Control

The data were converted in per cent inhibition of growth over check by using the formula:

$$\text{Inhibition (\%)} = \frac{C-T}{C} X100$$

Whereas; I = Percent Growth Inhibition
C = Radial Growth of Pathogen in Control Set
T = Radial Growth of Pathogen in Treatment Set

Chemical fungicides against *Rhizoctonia solani* by food poison technique. Chemical fungicides were taken from store room, Department of plant pathology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) i.e. Carboxin, Chlorothalonil and Thiophanate methyl were evaluated under *in-vitro* condition against *Rhizoctonia solani*. The efficacy of four chemical fungicides *viz.,* Carboxin, copper oxychloride, Chlorothalonil and Thiophanate methyl on the growth of *R. solani* were tested *in vitro* using the standard procedure of poison food technique as given by Mayer (1962). Stock solution of each fungicide was prepared in double strength, *i.e.,* 50 and 100 ppm by dissolving weighed or measured quantity of fungicide in a measured volume of sterilized water. The PDA medium was also prepared and sterilized at15 p.s.i. for 15 minutes. An equal volume of chemical solution and PDA was mixed in a sterilized conical flask and poured aseptically in the Petri plates. After solidification of medium, each Petri plate was centrally inoculated with 5 mm disc of mycelial mat taken from 5 days old culture of *Rhizoctonia solani* with the help of sterilized cork borer and incubated at 27±1°C. Suitable controls were maintained. Three replications for each fungicide were maintained in completely randomized design (CRD) under the laboratory condition. List of chemical fungicides used in the present study is given below as treatments details-

Treatments:

T_1: Carboxin (Vitavax) @ 50 ppm
T_2: Carboxin (Vitavax) @ 100 ppm
T_3: Chlorothalonil (Kavach) @ 50 ppm
T_4: Chlorothalonil (Kavach) @ 100 ppm
T_5: Copper oxychloride (Blitox-50) @ 50 ppm
T_6: Copper oxychloride (Blitox-50) @ 100 ppm
T_7: Thiophanate methyl (Topsin M) @ 50 ppm
T_8: Thiophanate methyl (Topsin M) @ 100 ppm
T_9: Control

Observations recorded:

Colony diameter. The colony diameter of the fungus was recorded in metric scale (mm) by taking one measurement horizontally and another vertically of the size of the fungal colony and mean of these two was taken as the colony diameter.

Radial Growth. Half of the measurement of the colony diameter gave radial growth of the pathogen.

Per cent growth inhibition- Colony diameter of the fungus of each treatment along with control after every 24 hour intervals was recorded with metric scale (mm) till the fungus of controlled treatment occupied the full area of Petri plate. The per cent inhibition of mycelial growth over control was calculated by following equation given by **Vincent (1947).**

$$\text{Inhibition (\%)} = \frac{C-T}{C} X100$$

Whereas;
I = Percent Growth Inhibition
C = Radial Growth of Pathogen in Control Set
T = Radial Growth of Pathogen in Treatment Set

RESULTS AND DISCUSSION

In bioagents studies are presented in Table 1, four bioagents *viz*., *Trichoderma harzianum, Trichoderma viride*, *Pseudomonas fluorescens*, and *Bacillus subtilis* were tested *in-vitro* for their ability to inhibit mycelial growth of *Rhizoctonia solani*. *T. harzianum* had the highest inhibition percentage of mycelial growth (67.55 %), followed by *T. viride* (62.00 %), while the bacterial bioagents, *P. fluorescens* and *B. subtilis*, were the least effective when compared to fungal antagonists, causing

46.11 and 49.66 percent inhibition of mycelial growth of the tested fungus, respectively. The ability of all antagonists to inhibit the growth of fungal differed significantly (*R. solani*). Similar, findings was confirmed by earlier workers Malik *et al.,* (2014); Hussain *et al.*, (2014) revealed that *T. harzianum* showed substantial antagonism against *R. solani*, followed by *T. viride* which significantly inhibited the mycelial growth of *R. solani*. Bioagents such as *T. harzianum* and *T. viride* were found to be effective against *R. solani in-vitro*. Similarly, the different isolates of *Trichoderma* spp. significantly inhibited the mycelial growth of *Rhizoctonia solani* **(Wilson *et al.*, 2008).** Results showed that maximum growth inhibition of the *R. solani* was perceived by *T. harzianum* followed by *T. viride.* However, some workers reported that the efficacy of *T. viride* followed by *T. harzianum* was found significantly superior in reducing mycelial growth of *R. solani* (Khatik *et al.,* 2005; Seema and Devaki, 2012).

Table 1: *In-vitro* evaluation of different Bioagents against *Rhizoctonia solani*.

Treatment detail /Bioagents	48 Hours DAI		96 Hours DAI		144 Hours DAI	
	Radial Growth of fungus (mm)	Percent inhibition over control (%)	Radial Growth of fungus (mm)	Percent inhibition over control (%)	Radial Growth of fungus (mm)	Percent inhibition over control (%)
T_1- *Trichoderma harzianum*	23.6	28.48	28.4	50.17	29.2	67.55
T_2-*Trichoderma viride*	26.4	20.00	32.4	43.15	34.2	62.00
T_3- *Pseudomonas fluorescens*	28.3	14.24	38.7	32.10	48.5	46.11
T_4- *Bacillus subtilis*	27.5	16.66	37.6	34.03	45.3	49.66
T_5- Control	33	-	57	-	90	-
CD at 5 %	**1.185**		**0.911**		**0.853**	
CV	**2.806**		**1.543**		**1.135**	

* Each treatments were replicated by four times; ** DAI- days after inoculation

In case of botanical extracts studies are presented in Table 2, three botanical extracts (garlic clove, neem leaf and *clerodendran enermy* leaf extract) at different concentration 3, 5 and 7 % under *in-vitro* conditions were evaluated to inhibit the mycelial growth of *Rhizoctonia solani*. All the botanical extracts at different concentrations invariably inhibited mycelial growth of the pathogen. Among these botanicals, Garlic clove extract @ 7 % were highly effective and inhibiting 62.67 % radial growth of the tested fungus, whereas, the lowest inhibition of mycelial growth of the fungus was 13.33 % with *Clerodendran enermy* leaf extract @ 3 %. Similarly, The efficacy of neem (*Azadirachta indica*) leaf, pongamia (*Pongamia glabra*) leaf, garlic bulb, tulsi (*Ocimum sanctum*) leaf and lantana (*Lantana camara*) leaf extracts, each at 2.50, 5.00 and 10.00 %, was also investigated in *in-vitro* against *R. solani*. The maximum inhibition of mycelial growth of the pathogens was observed with 10% garlic bulb and neem leaf extracts, whereas, tulsi leaf and pongamia leaf extracts were found effective against *R. solani* (Mallesh *et al.,* 2008). Also similar results has been reported by earlier researchers Kumar and Tripathi, (2012) conducted a laboratory experiment to evaluate six plant extracts viz., onion (*Allium cepa*), garlic (*Allium sativum*), neem (*Azadirachta indica*), bhang (*Canabis sativa*), ginger (*Zingiber officinale*) and datura (*Datura stramonium*) for their fungi toxicity against *R. solani* Kuhn at different concentrations (12.5, 25.0 and 50.0%).

Table 2: *In-vitro* evaluation of different Botanical extract against *Rhizoctonia solani*.

Treatment detail	48 Hours DAI		96 Hours DAI		144 Hours DAI	
	Radial Growth of fungus (mm)	Percent inhibition over control (%)	Radial Growth of fungus (mm)	Percent inhibition over control (%)	Radial Growth of fungus (mm)	Percent inhibition over control (%)
T_1-Garlic clove extract @ 3%	15.4	46.89	28.8	49.47	35.4	60.66
T_2-Garlic clove extract @ 5%	13.2	54.48	26.6	53.33	34.6	61.55
T_3-Garlic clove extract @ 7%	12.3	57.58	25.4	55.43	33.5	62.77
T_4-Neem leaf extract @ 3%	21.5	25.86	43.5	23.68	59.0	34.44
T_5-Neem leaf extract @ 5%	19.6	32.41	41.5	27.19	54.5	39.44
T_6-Neem leaf extract @ 7%	18.2	37.24	40.0	29.82	52.5	41.66
T_7-*Clerodendron enermy* leaf extract @ 3%	25.3	12.75	49.3	13.50	78.00	13.33
T_8-*C. enermy* leaf extract @ 5%	23.6	18.62	46.0	19.29	76.00	15.55
T_9-*C. enermy* leaf extract @ 7%	22.8	21.37	44.8	21.40	73.00	18.88
T_{10}- Control	29.0	-	57.0	-	90.0	-
CD at 5 %	**1.277**		**1.138**		**1.354**	
CV	**3.705**		**1.647**		**1.484**	

The inhibition of growth of the fungus increased with the increase in concentration of the text extracts prepared in all the three solvents. Mandhare and Suryawanshi, (2009) the antifungal properties of the extracts (at 10% each) of *Azadirachta indica* (leaves), *Ocimum sanctum* (leaves), *Eucalyptus sp*. (leaves), N*erium indicum* (leaves), *Allium sativum* (cloves) and *Zingiber officinale* (rhizomes) against *R. bataticola* by poisoned food technique. The *A. indica* extract inhibited the growth of the fungus by 80%. The growth of *R. bataticola* was inhibited by 77.77 and 64.44% by the extracts of *A. sativum* and *A. indica*, respectively.

In fungicidal studies are presented in Table 3 four chemical fungicides *viz*., Carboxin (Vitavax), Chlorothalonil (Kavach), Copper oxychloride (Blitox-50) and Thiophanate methyl (Topsin-M) each at 50 and 100 ppm concentration were tested under *in-vitro* condition to inhibit mycelial growth of *Rhizoctonia solani*. All the fungicides at both concentrations invariably inhibited the mycelial growth of the pathogen. Among these fungicides, chlorothalonil proved highly effective against the tested fungus and inhibiting 89.77 % radial growth of *Rhizoctonia solani* at 100 ppm, followed by (88.44 %) growth inhibition with thiophanate methyl @ 100 ppm whereas, the lowest inhibition of mycelial growth of the fungus was 66.22 % with copper oxychloride @ 50 ppm. When the concentrations of fungicides were raised from 50 to 100 ppm, there was increase in mycelial growth inhibition of *R. solani* as compared to the control. Similar, observation was observed by many researchers Dutta and Kalha (2011) reported that chlorothalonil and propiconazole inhibited the mycelial growth of the pathogen while working with *R. solani* under *in vitro* condition. Sugha, *et al*., (1989) revealed that nine systemic fungicides viz., carbendazim 50 WP, bitertanol 25 WP, benomyl 50 WP, metsulfovax 20WP, benalaxyl 35 SD, benomyl + mancozeb, benalaxyl + copper oxychloride, thiabendazole 60WP, and thiophanate methyl 70 WP was tested on three isolates of *Rhizoctonia solani* AG-1, AG-2 and AG-3. The potato isolate AG-3 was least sensitive to the fungicides. However, it was more sensitive to carbendazim and bitertanol, moderately to benalaxyl and least to the remaining fungicides.

Table 3: *In-vitro* evaluation of chemical fungicides against *Rhizoctonia solani*.

Treatment detail	48 Hours DAI		96 Hours DAI		144 Hours DAI	
	Radial Growth of fungus (mm)	Percent inhibition over control (%)	Radial Growth of fungus (mm)	Percent inhibition over control (%)	Radial Growth of fungus (mm)	Percent inhibition over control (%)
T_1-Carboxin @ 50 ppm	7.40	73.09	17.20	69.82	28.50	68.30
T_2- Carboxin @ 100 ppm	3.20	88.36	6.90	87.89	11.40	87.30
T_3-Chlorothalonil @ 50 ppm	6.30	77.09	13.40	76.49	22.60	74.88
T_4- Chlorothalonil @ 100 ppm	2.50	90.90	5.70	90.00	9.20	89.77
T_5-Copper oxychloride @ 50 ppm	8.60	68.72	19.20	66.31	30.40	66.22
T_6- Copper oxychloride @ 100 ppm	4.50	83.63	8.10	85.78	13.60	84.88
T_7-Thiophanate methyl @ 50 ppm	6.90	74.90	15.20	73.33	25.30	71.88
T_8- Thiophanate methyl @ 100 ppm	2.80	89.81	6.10	89.29	10.40	88.44
T_9- Control	27.50	-	57.00	-	90.00	-
CD at 5 %	**0.310**		**0.803**		**0.294**	
CV	**2.312**		**2.808**		**0.634**	

CONCLUSION

Consequent reduction of radian growth of *Rhizoctonia solani* was found in all the treatment as compare to control. From the present studies results revealed that the evaluation of antagonistic potential of bioagents minimum radial growth 29.2 mm and maximum growth inhibition 67.55 % of fungus was recorded in T_1- *Trichoderma harzianum* over control 90 mm at 6 DAI. Among the plant extract minimum radial growth 33.5 mm and maximum growth inhibition 62.67 % of fungus was recorded in T_3- Garlic clove extract @ 7 %) over control 90 mm at 6 DAI. In case of fungicides minimum radial growth (9.20 mm) and maximum growth inhibition (89.77 %) of fungus was recorded in T_4-(chlorothalonil @ 100 ppm) at 6 DAI over control (90 mm).

FUTURE SCOPE

Continuous evaluation of different bioagents, botanicals and new fungicides against pathogen and its compatibility is required for checking the pathogen resistance. More cultural and morphological studies of *Rhizoctonia solani* and other species need to be further studies.

To find out eco-friendly management practices *viz.* bioagents, botanicals and medicinal plant extracts for organic farming and lastly spray of effective fungicides under IDM programme are to be investigated and economics are be studied.

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Conflict of Interest. None.

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