International Journal of Multidisciplinary Research and Development
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
www.allsubjectjournal.com
Volume 3; Issue 7; July 2016; Page No. 202-208

Effect of botanicals against post-harvest rot fungi of Apple (*Malus domestica* Borkh)

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Abstract
Survey of pathogens associated with post-harvest decay of Apple fruit was carried out in three major markets in Allahabad district during January-February (2016). Rotten apple fruit obtained from three selected markets *viz.* Mundera Mandi, Baiharana and Pullpur Mandi of Allahabad were brought to the laboratory. Two different fungal species were isolated from the infected fruits. The most frequently encountered fungus species was *Penicillium expansum* and *Geotrichum candidum*. Seven plant leaf and bulb extracts *viz* Ginger, *(Zingiber officinals)* Onion *(Allium cepa* L.*)* Garlic *(Allium sativum* L*)*, *Eucalyptus*, *globulus*, Neem *(Azadirachta indica) Aloe -vera* and Mint *(Menthe piperita)* were tested against fungi isolated under *in vitro* condition. All the leaf extracts significantly (P< 0.05) inhibited the radial mycelial growth of the tested fungi (*Penicillium expansum* and *Geotrichum candidum*).The highest percentage growth inhibition was achieved with garlic (87.5%) followed by onion (60.42%) against *Penicillium expansum*. Also the highest percentage growth inhibition was achieved with eucalyptus (28.04%) against *Geotrichum candidum* followed by onion (20.81%). The present investigation showed that leaf extract of the mentioned plant have antifungal effect on the apple post-harvest rot fungi.

Keywords: apple, *Geotrichum candidum*, leaf extracts, *Penicillium expansum* and post-harvest disease

Introduction
Apple (*Malus* × *domestica* Borkh.) is the fourth most important fruit crop after citrus, grapes and banana, and one of the commercially most important horticultural crops grown in temperate parts of the world. Apple belongs to the Rosaceae family which includes many well-known genera with economically important fruits, particularly edible, temperate-zone fruits and berries such as apple, pear, almond, apricot, cherries, peach, plums, strawberries and raspberries. Among these, apple with a world production of more than 71 million tons, cultivated in many countries in the world, can be considered as one of the most important horticultural plants. Apple fruit has multiple uses and this fact makes it popular in the entire world, also in areas where it is more difficult to grow. In most cases, apples are consumed fresh or after storage for up to 6 months or even longer (usually requiring ultra-low oxygen storage facilities). Apples can also be processed into juice, sauce, slices, vinegar and cider. Apple has been considered as a symbol for the healthy fruit which eliminates the need for a doctor: "an apple a day keeps the doctor away" (Afzadi, 2012).

Materials and Methods
Survey was carried out in three selected fruits markets of Allahabad district namely Mundera Mandi, Baihrana and Phulpur Mandi because they are the main markets of fruits. The survey was done in the dry season (January-February) 2016. Thirty apple fruits were selected randomly from 10 apples traders and the type of diseases on each fruit was recorded after careful visual observation of symptoms on the selected fruits.

Apple fruits showing symptoms of rot and discoloration were randomly collected from these selected markets of Allahabad district. The apple samples were collected from various traders in the three selected markets by sorting and selecting the apple fruits with symptoms of rot and discoloration. The infected apple fruits were separated from the healthy ones. Samples were kept in a polythene bag and labeled separately and were taken to the Plant Pathology department laboratory of Sam Higginbottom Institute of Agriculture, Technology and Sciences for further study.

For all laboratory experiments, Borosil and Corning glassware were used. The glassware's were kept for 24 hours in the cleaning solution containing 60.0 g of potassium dichromate, 60, 0 ml of concentrated sulphuric acid in 1000 ml of water. They was washed with detergent solution followed by rinsing with tap water and finally with distilled water. The petri dishes and pipettes were wrapped in clean paper and sterilized in hot air oven at a temperature of 160℃ for 2 hours. Sterilization of solid media was achieved by autoclaving at 1.1 kg/cm2 (121.6 ℃) pressure for 20 minutes for all the laboratory studies. All culture studies were conducted in aseptic condition under laminar air flow. The tips of inoculation needle, forceps and cork borers were sterilized under flame. The culture media used in experiment was prepared according to standard Geo formula. For isolating and culturing of pathogens (*Penicillium expansum* and *Geotrichum candidum*) Potato Dextrose Agar (PDA) medium was used (**Tuite, 1969**).

The (200 g) potato was peeled and cut in to small pieces and boiled in 500 ml of distilled water till they become soft. The extract obtained was filtered through muslin cloth and all the liquid was squeezed in beaker. Twenty gram of agar was added bit by bit to the rest of 500 ml hot water to dissolve. Then 20 g of dextrose was added. Volume of Broth was made up to 1000 ml by adding more distilled water. Then 200 ml of this solution was dispensed to each of five conical flasks and sterilized at 121^0C at 15 lbs. pressure /square inch for 15-20 minutes in an autoclave. The PDA was sterilized in an autoclave at 121 ^{o}C. Autoclaved media in which agar-agar had been mixed was cooled down to around 45^0C and poured in

sterilized Petri plates. Also the test tubes containing 5 ml liquid medium was slanted by putting them in to a wooden slant after autoclaving. After solidification they were used for culturing.

The infected apple fruits were collected in the polythene bags, which were made airtight .collected materials, were labeled properly and then brought to the laboratory of plant pathology, mycology and microbiology. The pathogen was isolated on apple dextrose agar (PDA) medium .the infected parts of apple fruits were cut into small pieces. The pieces were then washed in running tap water sterilized in 0.1 percent sodium hydrochloride solution and washed repeatedly for several times in sterilized distilled water, to remove mercuric chloride solution. Three pieces were transferred to plate. Plates were incubated at 25 C ± 2 C for 15 days for recovery of pathogen (Farzana, *et al* 2014)

$$\% \text{ Occurrence} = \frac{\text{Number of times a fungus was encountered}}{\text{Total fungal isolations}} \times 100$$

A small portion of the fungal colony was scooped from the plate using a sterile inoculating needle onto a glass slide. One to two drops of Lacto phenol cotton blue was added and cover with the cover slip. After that the slide was viewed under compound microscope under x10 and later x100.

Five different plants leave *viz. Ginger (Zingiber officinals) Onion (Allium cepa L.) Garlic (Allium sativum) Eucalyptus globulus Neem (Azadirachtaindica) Mint (menthe piperita) Aloe Vera,*10 g of each plant leaves or bark was washed and separately ground in a blender with 300ml of distilled water. The solutions were allowed to stand overnight and then strained through a 45µ mesh. The filtrates were dispensed into universal specimen bottle and stored in the Refrigerator. Before use, the filtrates were centrifuged at 1000rpm (revolution per minute) for 15 minutes (plate 3.5 and 3.6) (Onyeani *et al.,* 2012). The *in vitro* experimental design was completely randomized used as describe by Gomez and Gomez (1984). Each mycelial plug in a Petri dish constituted a replicate. To assess differences in the mycelia growth of *Penicillium expansum and Geotrichum candidum* among the treatments the percentage inhibition was calculated from the radial growth as: by Vincent (1947).

Percent inhibition of colony = [control- treatment/control × 100]

Where:

C = Colony diameter in control

T = Colony diameter in treatment

Results and discussion

In the survey of the markets to determine the incidence of postharvest diseases of apple, was carried out a total of two fungal genera namely, *Geotrichum candidum,* and *Penicillium expansum,* were isolated from the infected apple fruits collected from the selected markets. Two diseases were encountered and they are blue mould and sour rot. (Table 4.1). All the markets recorded very high incidences of the postharvest diseases. The most predominant disease during the dry season survey was blue mold followed by sour rot.

Table 4.1: Incidence of postharvest diseases of apple in three selected markets in Allahabad district during the dry season

Postharvest disease incidence (%)		
Markets	Blue mold rot	Blue mould
Mundera Mandi	32.5	25
Baihrana	28.5	22
Phulpur Mandi	30	23
Mean	30.33	23.32

Penicillium expansum recordedthe highest percentage incidence of post-harvest disease (30.33%), followed by *Geotrichum candidum* (23.32%) (Table4.1).

Table 4.2: Percentage occurrence of isolated fungi associated with storage sour rot and blue mold of apple fruits from the selected markets

Fungus	Frequency of isolation from rotten fruits (%)
Geotrichum candidum	18.0
Penicillium expansum	25.0

Table 4.3: Effect of different treatments on the mycelial growth (mm) of *Penicillium expansum*

S/N	Treatment	Radial growth (mm) of *Penicillium expansum*						
		24 hr	48 hr	72 hr	96 hr	120 hr	144 hr	168 hr
T_1	Carbendazim (Treated check)	0.00	0.00	0.00	2.00	3.00	3.00	3.00
T_2	Ginger*(Zingiber officinals*)	3.83	7.00	7.83	9.67	11.17	15.17	16.33
T_3	Onion *(Allium sepa* L.)	6.50	9.00	10.83	11.83	12.50	12.17	15.83
T_4	Garlic *(Allium sativum* L.)	2.00	2.33	3.00	4.33	4.83	5.00	5.00
T_5	*Eucalyptus globulus*	8.17	14.20	19.67	23.33	26.50	29.83	33.33
T_6	Neem*(Azadirachta indica)*	5.00	6.17	8.67	9.33	13.00	17.17	18.83
T_7	Control (untreated check)	9.00	15.50	22.50	27.00	28.50	33.00	40.00
F-test		S	S	S	S	S	S	S
S E m=		1.29	1.48	2.47	2.48	2.59	2.27	2.92
CD (5%)		3.93	4.49	7.50	7.53	7.87	6.88	6.95

After 24 hours minimum average radial growth of *Penicillium expansum* was observed in T_4 garlic (2.00 mm) followed by T_2 ginger (3.83 mm), T_6 Neem (5.00 mm), T_3 onion (6.50 mm) and T_5 eucalyptus (8.17 mm) as compared to the treated check T_1 carbendazim (0) and untreated check T_7 (9.00 mm). Among the treatments T_6 T_2 T_4 and T_5 T_3 T_6 and T_7 T_5 are non-significant and at par with each other.

After 48 hours minimum average mycelial growth of *Penicillium expansum* was observed in T_4 garlic (2.33 mm) after inoculation followed by T_6 Neem (6.17 mm), T_2 ginger (7.00 mm), T_3 onion (9.00 mm) and T_5 eucalyptus (14.20 mm) as compared to the treated check T_1 carbendazim (0) and untreated check T_0 (15.50 mm). Among the treatments T_2 T_6 T_4 and T_5 T_3 T_2 and T_7 T_5 are non-significant and at par with each other.

After 72 hours minimum average radial growth of *Penicillium expansum* rot pathogen of apple was observed in T_4 garlic (3.00 mm) after inoculation followed by, T_2 ginger (7.83 mm) T6 neem (8.67mm) T_3 onion (10.83 mm) and T_5 eucalyptus (19.67 mm) as compared to the treated check T_1 carbendazim (0) and untreated check T_0 (22.50 mm). Among the treatments T_6 T_2 and T_3 T_6 and T_7 T_5 are non-significant and at par with each other.

After 96 hours minimum average mycelial growth of *Penicillium expansum* was observed in T_4 garlic (3.67 mm) after inoculation followed by, T_3 Neem (9.33 mm) T_2 ginger (9.67 mm), T_3 onion (11.83 mm) and T_5 eucalyptus (23.33 mm) as compared to the treated check T_1 carbendazim (2.00 mm) and untreated check T_0 (27.00 mm). Among the treatments T_4 T_1 and T_3 T_2 T_6 and T_7 T_5 are non-significant and at par with each other

After 120 hours minimum average mycelial growth of *Penicillium expansum* was observed in T_4 garlic (4.67 mm) after inoculation followed by, T_2 ginger (11.17) T_3 onion (12.50 mm) T_6 Neem (13.00 mm), and T_5 eucalyptus (26.50 mm) as compared to the treated check T_1 carbendazim (3.00 mm) and untreated check T_0 (29.17 mm). Among the treatments T_4 T_1 and T_6 T_3 T_2 T_4 and T_7 T_5 are non-significant and at par with each other.

After 144 hours minimum average radial mycelial growth of *Penicillium expansum* rot pathogen of apple was observed in T_4 garlic (5.00 mm) after inoculation followed by T_4 onion (15.83 mm) T_2 ginger (16.33 mm) T_6 neem (18.83 mm), and T_5 eucalyptus (33.33 mm) as compared to the treated check T_1 carbendazim (3.00 mm) and untreated check T_0 (33.00 mm). Among the treatments T_4 T_1 and T_6 T_2 T_3 and T_7 T_5 are non-significant and at par with each other.

After 168 hours minimum average radial mycelial growth of *Penicillium expansum* rot pathogen of apple was observed in T_4 garlic (5.00 mm) after inoculation followed by, T_3 onion (15.83 mm) T_5 ginger (16.33 mm) T_6 neem (18.83 mm), and T_6 eucalyptus (33.33 mm) as compared to the treated check T_1 carbendazim (3.00 mm) and untreated check T_0 (40.00 mm). Among the treatments T_4 T_1 and T_6 T_2 T_3 and T_7 T_5 are non-significant and at par with each other.

Table 4.4: *In-vitro* effect of treatments on the inhibition of radial mycelial growth of *Penicillium expansum*

S/N.	Treatments	Concentration (%)	Mycelial inhibition (%)
T_1	Carbendazim (Treated check)	0.1%	77.5
T_2	Ginger*(Zingiber officinals)*	10 %	59.17
T_3	Onion *(Allium cepa L.)*	10 %	60.42
T_4	Garlic *(Allium sativum)*	10 %	87.5
T_5	*Eucalyptus globulus*	10 %	31.67
T_6	Neem *(Azadirachta indica)*	10 %	52.92
T_7	Control (Untreated check)	10 %	0.00
F – test			S
S. Ed. (±)			2.29
C. D. (P = 0.05)			6.95

After 7 days of inoculation highest inhibition of radial growth of mycelium was observed in treatment T_4- garlic (87.5%) followed by T_3 -onion (60.42%) , T_2- ginger (59.17%), T_6 Neem (52.92%) and T_5 – eucalyptus (31.67%) as compared treated check T_1- carbendazim (77.5%) and untreated check to (0.00%).

The effect of various plant leaf extracts on the radial growth of *P. expansum* rot pathogen of apple is presented in (Table. 4.4) All leaf extracts significantly inhibited the radial mycelial growth of the test pathogen at 168 hours after inoculation. The maximum inhibition per cent was recorded in garlic (87.50%) followed by onion (60.42 %), (ginger 59.17 %), neem (52.92 %) and eucalyptus (31.67 %), as compared to treated check carbendazim (75.28 %) and untreated check control (0%).

Table 4.5: Effect of different treatments on the mycelial growth (mm) of *Geotrichum candidum*

S/N	Treatments	Radial growth (mm) of *Geotrichum candidum*				
		24 hrs	48 hrs	72 hrs	96 hrs	120 hrs
T_1	Carbendazim(Treated check)	0.00	0.00	0.00	4.00	5.00
T_2	*Aloe vera*	4.00	11.00	18.00	24.33	30.50
T_3	Onion (*Allium cepa L.*)	4.50	9.67	20.50	27.50	29.17
T_4	Mint (*Menthe piperita*)	8.83	13.33	17.17	28.67	38.17
T_5	Eucalyptus *globulus*	5.50	11.00	15.67	21.67	26.50
T_6	Neem(*Azadirachta indica)*	6.50	14.00	19.67	26.67	32.50
T_7	Control (Untreated check)	11.17	15.17	24.00	32.17	36.83
F-test		S	S	S	S	S
S E m=		1.65	1.65	1.30	1.84	2.18
CD (5%)		5.01	5.01	3.95	5.59	6.62

After 24 hours minimum average mycelial growth of *Geotrichum candidum* was observed in T_2 aloe vera (4.00 mm) after inoculation followed by T_3 onion (4.50 mm), T_5 eucalyptus (5.50 mm), T_6 neem (6.50 mm), T_4 mint (8.83 mm), as compared to the treated check T_1 carbendazim (0) and untreated check T_0 (11.17 mm). Among the treatments T_5 T_3 T_2 and T_4 T_6 and T_7 T_4 are non-significant and at par with each other.

After 48 hours minimum average radial mycelial growth of *Geotrichum candidum* was observed in T_3 onion (9.67 mm)

after inoculation followed by T_2 aloe vera (11.00 mm), T_5 eucalyptus (11.00 mm), T_4 mint (13.33 mm), T_6 neem (14.00 mm), as compared to the treated check T_1 carbendazim (0) and untreated check T_7 (15.17 mm). Among the treatments T_5 T_2 T_3 and T_6 T_4 and T_7 T_6 are non-significant and at par with each other.

After 72 hours minimum average radial mycelial growth of *Geotrichum candidum* rot pathogen of apple was observed in T_5 eucalyptus (15.67 mm) after inoculation followed by T_4 mint (17.17 mm), T_2 aloe vera (18.00mm), T_6 neem (19.67 mm), T_3 onion (20.50 mm), as compared to the treated check T_1 carbendazim (0) and untreated check T_7 (24.00 mm). Among the treatments T_2 T_4 T_5 and T_3 T_6 T_2 and T_7 T_3 are non-significant and at par with each other.

After 96 hours minimum average radial mycelial growth of *Geotrichum candidum* was observed in T_5 eucalyptus (21.67 mm) after inoculation followed by aloe vera T_2 (24.33 mm), T_6 Neem (26.67 mm), T_3 onion (27.50 mm) T_4 mint (28.67 mm), as compared to the treated check T_1 carbendazim (4.00) and untreated check T_7 (32.17 mm). Among the treatments T_6 T_2 T_5 and T_4 T_3 and T_7 T_4 are non-significant and at par with each other.

After 120 hours minimum average radial mycelial growth of *Geotrichum candidum* was observed in T_5 eucalyptus (26.50 mm) after inoculation followed by T_3 onion (29.17 mm), T_2 aloe vera (30.50mm), T_6 Neem (32.50 mm), T_4 mint (38.17 mm), as compared to the treated check T_1 carbendazim (5.00) and untreated check T_0 (40.83 mm). Among the treatments T_2 T_3 T_5 and T_4 T_6 and T_7 T_4 are non-significant and at par with each other.

Table 4.6: *In-vitro* inhibition of radial mycelial growth of *Geotrichum candidum as* affected by treatments

S/N.	Treatments	Concentration (%)	Mycelial inhibition (%)
T_1	Carbendazim (Treated check)	0.1%	86.42
T_2	*Aloe vera*	10 %	17.64
T_3	Onion *(Allium sepa* L.)	10 %	20.81
T_4	Mint *(Menthe piperita*)	10 %	3.17
T_5	*Eucalyptus globulus*	10 %	28.04
T_6	Neem *(Azadirachta indica)*	10 %	11.75
T_7	Control (untreated check)	10 %	0.00
F – test			S
S. Ed. (±)			1.77
C. D. (P = 0.05)			5.37

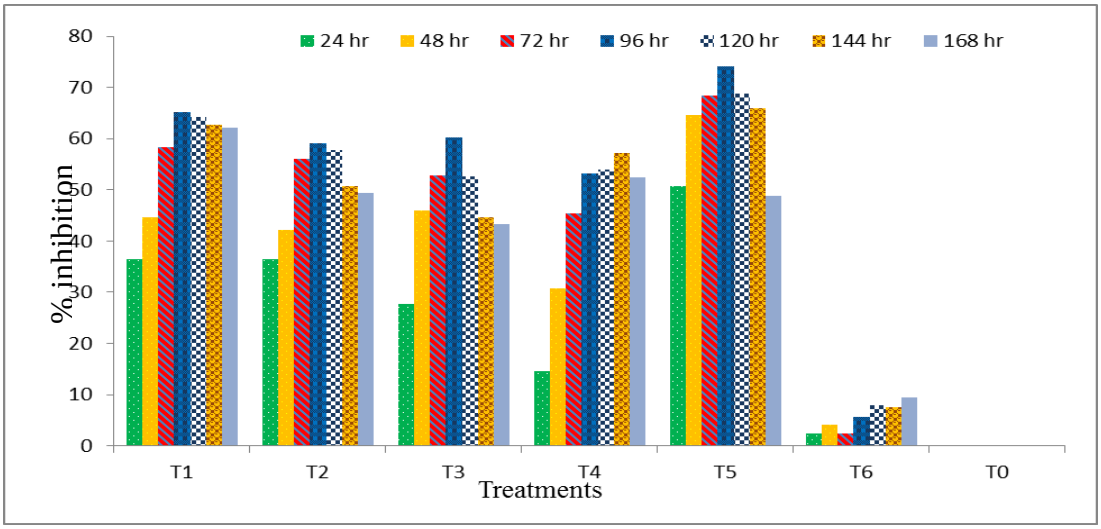

Fig. 4.1: effect of leaf extracts % inhibition on radial mycelial growth of Penicillium expansum *in vitro*.

After 7 days of inoculation highest inhibition of radial growth of mycelium was observed in treatment T_5-eucalyptus (28.04 %) followed by T_3 -onion (20.81 %) , T_2- aloe vera- (17.64 %), T_6-neem (11.75 %) and T_4 – eucalyptus (3.17 %) as compared treated check T_1- carbendazim (86.42%) and untreated check T_7 (0.00%).

The effect of various plant leaf extracts on the radial growth of *Geotrichum candidum* rot pathogen of apple is presented in (Table 4.5). All leaf extracts significantly inhibited the radial mycelial growth of the test pathogen at 120 hours after inoculation. Leaf extract of eucalyptus was able to inhibit the growth of *Geotrichum candidum* by (28.04%) followed by onion (20.81%), aloe vera (17.64%), neem (11.75%), mint (3.17%), as compared to treated check (carbendazim 86.42%) and untreated check (control 0%). There was significant difference between all leaf extract treatments.

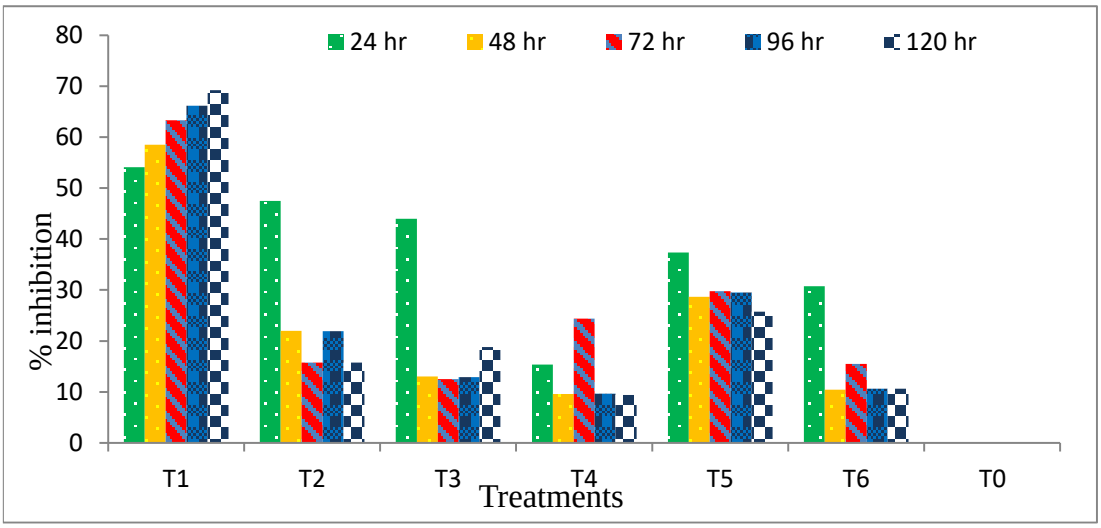

Fig. 4.2: effect of leaf extracts % inhibition on radial mycelial growth of *Geotrichum candidum* in vitro.

A survey was conducted to assess the losses of apple caused by post-harvest pathogens. In the selected three markets *viz* Phulpur Mandi, Baihrana and Mundera Mandi blue mold, sour rot were the predominant disease of apple. (Tiwari, 2014) in similar survey, identified the same diseases as the important post-harvest disease of apple in Lucknow, Uttar Pardesh, India .Blue mould, gray mold and sour rot were the most important postharvest diseases of apple identified. Among these postharvest diseases, blue mould was the most predominant disease in the dry season surveys (Abdulsalam *et al* 2015). Also Wagh and Bhale (2012) conducted survey of post-harvest fungal fruit rot diseases of sapota from various markets of Thane district of Maharashtra and they reported that it was to be found frequently infected by *Geotrichum candidum* causing sour rot of sapota. In the present study isolated *Geotrichum candidum* rot pathogen of apple this achievement is similar to the Brown (1979) who isolated *Geotrichum candidum* from the soil and from fruit surfaces using a selective medium of Difco potato dextrose agar containing novobiocin (100 ppm), benomyl (100 ppm) and dicloran (50 ppm).

In the management of postharvest rot pathogens of apple the leaves extracts from garlic, onion ,ginger, Neem, and eucalyptus, were found to be effective in reducing mycelial growth of the various postharvest fungal pathogens of apple. The above leaf extracts significantly the radial mycelial growth of all the test fungi, with inhibition varying from one extract to another (Table4.3). In similar studies, Bobbarala *et al*. (2009) examined antifungal activity of selected plant extracts against phyto pathogenic fungi *Penicillium expansum* and. In their study forty nine different plants used in traditional Indian medicine using agar well diffusion method. Among the forty nine plants studied 86% of the plants had antifungal activity.

In the present study percent inhibition of radial growth of the *Penicillium expansum* test fungus was in leaf extract of garlic (87.5% growth inhibition) and lowest in onion (60.42%) and ginger (59.17%), neem (52.92%) and eucalyptus (31.67%) leaf extract (Table 4.4). This is agreement to the result of Baviskar (2011) who reported the antifungal activity leaf extracts of garlic *in vitro* the management of carbendazim resistant isolates *Penicillium expansum* was tested against leaf extracts of 24 medicinal plants out which *Eucalyptus globulous ,Azardirachta indica*, *Zinziber officinalis ,Seasmum indicum, Oscimum sanctum* extracts were showed PCE (percent control efficacy) range from(65.02-60.29) individually followed by the medicinal plants as *allium sativum, allium cepa*, and aloe vera were PCE was ranges from (56.35) and (32.55) individually highest. Also the highest percent inhibition of radial growth of the *Geotrichum candidum* was in leaf extract of eucalyptus (28.04 % growth inhibition), followed by onion (20.81%) inhibition, *aloe vera* (17.64%) inhibition, mint (3.17%) inhibition, lowest in Neem (11.75%) as compared to treated (86.42 %) and untreated (0.00%) leaf extract check table (Table 4.3). This is agreement to the result of Swami (2013) who reported the antifungal activity of leaves extracts of *Eucalyptus* micro theca *in vitro* by agar well diffusion method against *Penicillium digitatum* and *Aspergillus niger* fungi.

This investigation has shown that the leaf extracts of garlic, ginger, onion neem, eucalyptus, *Aloe vera* and mint were found to be effective in reducing the mycelia growth of the various postharvest fungal pathogens of apple. Garlic, onion ginger, neem and eucalyptus leaf extracts were being the most highly effective in reducing the mycelial growth against *Penicillium* spp postharvest rot fungi of apple *in vitro.* The probable reason for such finding is that, plants have limitless ability to synthesize aromatic secondary metabolites, most of which are phenols or their oxygen-substituted derivatives. Important subclasses in this group of compounds include phenols, phenolic acids, quinones, flavonoids, flavonols, tannins and coumarins. These groups of compounds show antimicrobial effect and serves as plant defense mechanisms against pathogenic microorganisms (Gurjar *et al.,* (2012)**.** *Azadirachta indica* extract of the plant material were found to be fungi toxic against the yam rot spoilage fungi who Lupoae *et al.,* (2013) reported allium family antimicrobial activity was tested in order to establish the inhibition potential of growth of some microorganisms.

This study aims to find the safe and cheap way to manage the postharvest rot fungi on onion and to provide good and economically accessible method of disease management with botanicals. Keeping the above in view the present study

entitled, "Effect of botanical against post-harvest rot fungi of apple *(Malus domestica*) are presented in this chapter.

1. To survey fruits markets of Allahabad for post-harvest disease incidence of apples

1. To evaluate the efficacy of selected botanicals against *Penicillium expansum* (blue mold) and *Geotrichum candidum* (sour rot) under *in-vitro* conditions.

The survey on apple postharvest diseases revealed that blue mould rot, and sour rots, incidence in the three major markets during the dry season were high among all postharvest disease of apple. The postharvest disease with the highest incidence in all three surveyed markets was blue mould rot. Two genera with two fungal species namely; *Penicillium expansum* and *Geotrichum candidum were* associated with apple fruits rots in the three selected markets surveyed in Allahabad. Among these rots - inducing fungi, *Penicillium expansum* was the most frequently encountered pathogen. All the isolated rots inducing fungi were found to be pathogenic to apple fruits.

Investigation has shown that the sterilized leaf extracts of garlic, onion ginger, neem and eucalyptus leaf extracts were found to be effective in reducing the mycelial growth of the various postharvest fungal pathogens of apple. The effect of various plant leaf extracts on the mycelial growth of *Penicillium expansum* pathogen of apple *in vitro* condition are presented in Table 4.4 All leaf extracts significantly inhibited the radial mycelial growth of the test pathogen at 168 hours after inoculation. Leaf extract of garlic was able to inhibit the radial mycelial growth of *P. expansum* by (87.5 %) followed by onion (60.42 %), ginger (59.17 %), neem (52.92%), eucalyptus (31.67%), as compared to treated check (carbendazim 77.5%) and untreated check control 0.00 %). There was significant difference between all treatments.

Effect of the selected plant leaf extracts on the radial growth of *Geotrichum candidum* rot pathogen of apple *in vitro* condition are presented in (Table. 4.5). All leaf extracts significantly inhibited the radial growth of the test pathogen at 168 hours after inoculation. Leaf extract of eucalyptus was able to inhibit growth of *G. candidum* by 28.04 % followed by onion (20.81 %), *Aloe vera* (17.67%), neem (11.75%), and mint (3.17%), as compared to treated check (carbendazim (86.42%) and untreated check control (0.00%) There was significant difference between all treatments. Eucalyptus and onion leaf extracts were being the most highly effective in reducing the mycelial growth of *G. candidum* postharvest rot fungus of apple *in vitro.* Also *Aloe-vera* leaf extract was highly effective in reducing the mycelial growth of *G. candidum.* The leaf extracts of the tested plants can serve as alternative to chemical control because of lack of residual effect in the environment, humans, animals and plants products and can applied cheaply and safely. Plant material are cheaper to be obtain and not harmful to lives than the pesticides which are harmful and often costly. The high occurrence of fungi in the spoilage apple fruits is a public health risk. Farmers are hereby recommended to apply appropriate control measures during harvesting, processing, transportation, and handling of the apples. These measures can help in reducing blue mould and sour rots on their apple. Good storage facilities should also be put in place to protect the apple fruits from attacks by these fungi, thereby minimizing wastes due to deterioration and unacceptability.

The survey on apple postharvest diseases revealed that blue mould rot *(Penicillium expansum*) and sour rots(*Geotrichum candidum)* incidence in the three major fruit markets of Allahabad during the dry season were high among all postharvest diseases of apple. The postharvest disease with the highest incidence in all three surveyed markets was blue mould rot. *Penicillium expansum* was the most frequently encountered pathogen followed by *Geotrichum candidum* fruits. Garlic bulb extract at 10% concentration showed the highest inhibition percentage against *Penicillium expansum* and Eucalyptus leaf extract at 10% concentration showed highest inhibition percentage against *Geotrichum candidum.* The present research findings are limited to survey conducted at Allahabad, Uttar Pradesh, India and the result of study are limited to one experiment as such more survey and *in vitro* studies should be carried out in future to validate the findings.

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