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Effectiveness of plant extracts and oils in managing blue mould rot of orange caused by *Penicillium italicum*

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Abstract
The study aimed to evaluate the efficacy of the plant extracts and oils, in the inhibition of *Penicillium italicum* causal agent of blue mould on orange fruits. The results showed that all the tested extracts at 5, 10 percent and oils at 4 percent had a high inhibitory effect against *Penicillium italicum.* Extracts of garlic cloves is highly effective and showed 95.26 percent inhibitory effect against mycelial growth and 52.75 percent reduced disease severity at 10 percent concentration. Edible and non-edible oils were applied at 4 percent concentration in which eucalyptus oil found most effective in control of mycelial growth (94.65%) and disease severity (50.63%) on orange fruits. Results have shown that treatments have caused abnormal radial growth. In plant extracts and oils maximum inhibition was recorded with the use of garlic cloves and eucalyptus oil.

Keywords: Orange, blue mould, inhibition, plant extracts, oils, mycelial growth

Introduction
Orange (*Citrus reticulata*) is the most common among citrus fruits grown in India. *Citrus reticulata* derived from Latin word reticulata it means "netted". Orange contributed nearly 40% production of the total area under citrus grown area in India. In India most common fruits are the orange (*Citrus reticulata*), sweet orange (*Citrus sinensis*) and acid lime (*Citrus aurantifolia*) which sharing 41, 23 and 23 percent respectively of all citrus fruits produced in the country. In India Maharashtra, Madhya Pradesh, Assam, Odisha, West Bengal, Rajasthan, Nagaland and Mizoram are growing states of orange. India is leading producer of citrus with an area of 428 million hectare, production 5101 metric ton and productivity was 11.9 metric ton/hectare during 2017-18 (Anonymous, 2017-18) [3].

The germ tube elongation of *Penicillium italicum* stimulated by the citrus volatile myrcene and then followed by limonene, which plays inhibited role on *Penicillium expansum* (Droby *et al*., 2008) [13]. In fruits post-harvest diseases that account for decay losses of citrus fruits (Palou, 2014) [28].

Among the post-harvest diseases of citrus, green mould (*Penicillium digitataum*) and blue mould rot (*Penicillium italicum*) are commonnly observed in all citrus growing areas throughout the world (Palou *et al*., 2001; Plaza *et al*., 2004) [27, 30].

Disease severity from 9 to 14% caused by green mould was recorded in sweet oranges (Reddy *et al*., 2008) [33].

Higher incidence and severity of green mould has been reported in fruit markets located in tropical conditions (Smilanick and Sorenson, 2001) [38].

The blue and green moulds (Penicillium species) have become increasing most important on post-harvest losses of citrus in Nepal (Gautam *et al*., 2002) [16].

Extracts of garlic cloves at all concentrations controlled the growth of artificially inoculated *Penicillium digitatum* and *Penicillium italicum* the cause of blue and green mould respectively as compared to water control (Obagou and Korsten, 2003) [26]. Pathogens being necrotrophs, enter into fruit through rind wounds caused during the pre-harvest and post-harvest phase including transportation (Ballester *et al*., 2010) [8].

Crude extract of medicinal plants gave goodantifungal activity of extracts was observed (Daferera *et al*., 2000) [11].

Influence of fresh leaves of aromatic fragrance, medicinal plants *Azadirachta indica*, *Mentha pipernata*, *Ocimum sanctum* and *Murraya koenigii* on the growth of fungi during storage of mungbean seed was evaluated, in which leaves of *Murrraya koenigii* were found to reduce maximum growth of fungi during storage (Gehlot *et al*., 2011) [17].

P. digitattum and P. italicum are responsible for 80 percent of total post-harvest citrus fruit decay under Mediterranean climate condition (Embaby *et al*., 2013) [15]. Major post-harvest decays of citrus fruit caused by *P. digitatum* occured in arid and subtropical climate (Adaskaveg and Forster, 2015) [1]. Subedi *et al*., 2016 [39] explained about the extracts at various concentrations were effective in inhibiting the growth and development of *Penicillium digitatum* Sacc. For long storage of citrus fruits naturally isolated edible plant extracts, medicinal plant extracts and citrus extracts were used to inhibit *Penicillium digitatum* and *Penicillium italicum in vitro* and *in vivo* (Chen *et al*., 2019) [10]. Jahani *et al*. (2020) [20] examined on natural crop protection products as alternatives to the use of synthetic fungicides are currently popular. These results showed that the highest anthocyanin contents, total soluble solids, and pH related to the grapes treated with black caraway, chamomile, and marjoram essential oils and the lowest values belonged to the grapes treated with chamomile, marjoram, and chamomile essential oils. Citrus fruits are susceptible to different post-harvest diseases and their relative importance is influenced by the climate of the production area (Smilanick *et al.*, 2020) [37].

The review of Assia *et al*. (2022) [5] highlights the potential of plant extracts, and essential oils to control post-harvest pathogens and extend fruit shelf life. Nidhin *et al.* (2024) [25] examined the antifungal activity of *Monarda citriodora* essential oil (MEO) and trans-cinnamaldehyde (trans-c) vapours on *Aspergillus fijiensis* (C4), a new causative agent of postharvest rot of lemon, these results indicate that the MEO and trans-c vapours irreversibly damage the plasma membrane of *A. fijiensis* and could be exploited for the postharvest storage of lemons.

The growing areas of citrus orchards declined due to attack of post-harvest disease. Reduction of post-harvest losses helps to increase food availability for the growing world population decrease the area needed for production and conserve natural resources. Oranges being perishable are highly susceptible to destruction by various post-harvest pathogens. Orange is susceptible to the number of post-harvest diseases that cause significant losses during the post-harvest phase. These are attacked by several fungi *viz. Penicillium italicum, P. digitatum, Geotrichum candidum, Alternaria alternata, Alternaria citri, Botryodiplodia theobromae, Fusarium* sp., *Glomerella cingulata, Aspergillus niger, Rhizopus* sp. etc.

Materials and Methods

Plant extracts

The effect of five plant extracts on mycelial growth of *Penicillium italicum* and severity of blue mould rot in orange was studied during the present investigations. These extracts were tested at 5 and 10 percent concentration. The details of the test plant extracts are given below:

Table 1: Plant extracts tested against *Penicillium italicum*

S. No.	Name of Plant	Botanical Name	Plant part used	Concentration (%)	
				in vitro	*in vivo*
1.	Tulsi	*Ocimum sanctum*	Leaves	5, 10	5, 10
2.	Ginger	*Gingiber officinalis*	Rhizomes	5, 10	5, 10
3.	Garlic	*Allium sativum*	Clove	5, 10	5, 10
4.	Neem	*Azadirachta indica*	Leaves	5, 10	5, 10
5.	Gwarpatha	*Aloe barbadensis*	Leaves	5, 10	5, 10

Preparation of plant extracts

The respective plant parts were thoroughly washed in running tap water, rinsed with sterile distilled water and then air dried. Weighed plant material was macerated with equal volume of sterile distilled water (1:1 w/v) in a homogenizer for 5 minutes and then filtered through double layered muslin cloth. The filtrate was centrifuged at 5000 rpm for 20 minutes. The supernatant was collected and filtered through bacteria proof filter. This filtrate was considered as standard plant extract preparation of 100 percent. The extracts were stored in refrigerator for further use.

Effect of plant extracts on mycelial growth of *Penicillium italicum*

The inhibitory effect of plant extracts was tested against *P. italicum* on potato dextrose agar (PDA) medium following poisoned food technique (Grover and Moore, 1962) [18]. Appropriate amount of respective plant extracts was separately mixed with molten PDA to get the final concentrations of 5 and10 percent of the extracts. The medium was then poured aseptically into sterile Petridishes and allowed to solidify. Mycelial discs of five millimeter diameter taken from seven days old actively growing culture of the test pathogen were transferred at the center of agar surface in Petridishes. The inoculated Petridishes were incubated at 25 °C. Three replications were kept for each treatment. The mycelial growth was recorded after seven days i.e. when the full growth of pathogen was recorded in control Petridishes. The potato dextrose agar without plant extract served as control. The inhibition of mycelial growth of *Penicillium italicum* was calculated as follows (Vincent, 1947) [43]:

$$\text{Percent inhibition} = \frac{C - T}{C} X\ 100$$

Where

C = Mycelial growth observed in control

T = Mycelial growth observed in PDA amended with plant extract

Effect of plant extracts on severity of blue mould rot

The healthy and mature orange fruits were dipped in respective plant extract preparations at 5 and 10 percent concentrations for five minutes. After 24 hours of treatment, the fruits were inoculated with the test pathogen following cork-borer injury method. The inoculated fruits were kept in sterilized polythene bags which were loosely tied and

incubated at 25±1 °C. In case of control, the fruits were treated with sterile distilled water. The experiment was conducted following Completely Randomized Design with three replications. The observation on severity of rot was recorded at 5, 8 and 12 days after inoculation. The percent disease reduction index was calculated as described earlier (4.1.1). The percent disease reduction index (PDRI) was calculated as suggested by Gutter (1969) [19]:

$$PDRI=\frac{\%\text{ Disease severity in control} - \%\text{ Disease severity in treatment}}{\%\text{ Disease severity in control}} X\ 100$$

Effect of oils

The effect of edible and non-edible oils *viz*., mustard, neem, linseed, sesame, eucalyptus and clove oil on mycelial growth of *P. italicum* and severity of blue mould rot in orange was studied. All these oils were tested at 4 percent concentration.

Effect of oils on mycelial growth of *Penicillium italicum*

As described in earlier section, the inhibitory effect of six different oils was tested against the pathogen following poisoned food technique. Suitable amount of various oils was separately added to molten PDA so that the concentration of the oil was adjusted to 4 percent. Mycelial discs of five millimeter diameter taken from seven days old actively growing culture of *P. italicum* was transferred at the center of agar surface in Petridishes. The inoculated Petridishes were incubated at 25±1 °C. The mycelial growth was recorded after seven days of inoculation. The potato dextrose agar without oil served as control. The experiment was conducted following CRD with three replications for each treatment. The inhibition of mycelial growth of the pathogen was calculated as described earlier.

Table 2: Effect of oils on mycelial growth of *Penicillium italicum*

S. No.	Oils	Scientific name of plant	Concentration (%)
1.	Mustard oil	*Brassica juncea*	4
2.	Neem oil	*Azadirachta indica*	4
3.	Linseed oil	*Linum usitatissimum*	4
4..	Sesame oil	*Sesamum indicum*	4
5.	Eucalyptus oil	*Eucalyptus globulus*	4
6	Clove oil	*Syzygium aromaticum*	4

Effect of oils on severity of blue mould rot

The healthy and mature orange fruits were dipped in respective oil preparations at 4 percent concentrations for five minutes. After 24 hours of treatment, the fruits were inoculated with the test pathogen following cork-borer injury method. The oil suspension was prepared in sterile distilled water. For this purpose, 4 ml of individual oil and two ml of liquid detergent (Rankleen, RFCL Ltd., New Delhi) were added to sterile distilled water in beaker and volume was made to 100 ml. As described earlier, the inoculated fruits were kept in sterilized polythene bags and incubated at 25±1 °C. Suitable control was kept in which the fruits were treated with sterile distilled water containing the detergent in oil suspension. The observation on severity of rot was recorded at 5, 8 and 12 days after inoculation and PDRI was calculated as described earlier.

Results and Discussion

Inhibition of mycelial growth

Effect of five plant extracts *viz., Ocimum sanctum, Allium sativum, Azadirachta indica, Aloe barbadensis* and *Zingiber officinale* on mycelial growth of *Penicillium italicum* at 5 and 10 percent concentration was studied *in vitro* in potato dextrose agar medium.

The results of pre-harvest application of plant extracts and oils on orange fruits varied significantly in terms of radial diameter produced by blue mould, *Penicillium italicum* (Table 3 and Table 5). Data from all experiments were subjected to analysis of variance considering the plant extrcts and oils as factors. Table 3 represents the mycelial growth inhibition of *Penicillium italicum* on Petridishes amended with 5 and 10 percent after seven day of incubation at 25±1 °C. According to results, the two plant extracts garlic and neem tested greatly inhibited the growth of *Penicillium italicum.* Garlic clove extract at 10 percent concentration was found 95.26 percent inhibition of fungal growth. The antifungal efficacy of oils against mycelial growth of *Penicillium italicum* presented in Table 4. Mycelial growth of *Penicillium italicum* was significantly inhibited by eucalyptus and clove oil. As the concentration of plant extracts increased from 5 to 10 percent the colony diameter decreased. Based on observation of *Penicillium italicum* in mycelial growth on PDA medium with eucalytptus oil at 4 percent during incubation period at 25±1 °C inhibited the mycelial growth of *Penicillium italicum* was 94.65%.

Effect of plant extracts and oils on disease severity

Based on the observation of disease severity on blue mould rot of orange, all the plant extracts and oils decrease the disease severity of blue mould rot. Table 4 represents that pre-harvest application of different plant extracts varied in terms of disease severity, recorded at 5, 8 and 12 days of intervals. Maximum disease severity found under controlled conditions at 12th day of both the years. Garlic clove extract effectively control the disease severity of blue mould rot compared to other plant extracts. Results of Table 6 represents that all the treatments of edible and non-edible oils found significantly effective as compared to control. Among the six treatments at (4%) of oils, most effective oils were eucalyptus and clove oils, due to these antimicrobial activities.

Table 3: Effect of plant extracts on inhibition of mycelial growth of *Penicilium italicum* on potato dextrose agar medium

Plant extracts	Concentration (%)	Mycelial growth (mm)*	Percent inhibition of mycelial growth
Tulsi	5	47.75	28.17
	10	41.30	37.89
Ginger	5	59.40	10.60
	10	54.65	17.82
Garlic	5	7.75	88.34
	10	3.20	95.26
Neem	5	18.40	72.33
	10	13.90	79.09
Aloe vera	5	60.50	9.02
	10	56.40	15.10
Control	-	66.50	0.00
	SEm±	0.31	
	CD (p=0.05)	0.96	

*Average of four replications

Table 4: Effect of pre- inoculation treatments with plant extracts on severity of blue mould rot of orange fruits at different intervals

Plant extracts	Conc. (%)	Percent disease severity (days after inoculation)												PDRI
		2020				2021				Pooled				
		5	8	12	Mean	5	8	12	Mean	5	8	12	Mean	
Tulsi	5	26.79	51.28	70.79	49.62	26.97	51.96	70.07	49.67	26.88	51.62	70.43	49.64	11.93
		(31.17)	(45.73)	(57.28)	(44.78)	(31.29)	(46.12)	(56.83)	(44.81)	(31.23)	(45.93)	(57.06)	(44.80)	
	10	23.27	47.72	68.76	46.58	22.72	46.32	67.02	45.35	23.00	47.02	67.89	45.97	18.45
		(28.84)	(43.69)	(56.02)	(43.04)	(28.47)	(42.89)	(54.95)	(42.33)	(28.65)	(43.29)	(55.48)	(42.69)	
Ginger	5	29.25	55.11	73.92	52.76	29.52	55.42	74.38	53.11	29.39	55.27	74.15	52.93	6.10
		(32.74)	(47.93)	(59.29)	(46.58)	(32.91)	(48.11)	(59.59)	(46.78)	(32.83)	(48.02)	(59.44)	(46.68)	
	10	26.75	54.02	72.42	51.06	26.86	54.32	72.74	51.31	26.81	54.17	72.58	51.19	9.20
		(31.14)	(47.31)	(58.32)	(45.61)	(31.22)	(47.48)	(58.53)	(45.75)	(31.18)	(47.39)	(58.42)	(45.68)	
Garlic	5	14.82	38.33	46.52	33.22	15.02	37.91	45.93	32.95	14.91	38.12	46.23	33.09	41.31
		(22.63)	(38.25)	(43.00)	(35.19)	(22.80)	(38.00)	(42.67)	(35.03)	(22.71)	(38.13)	(42.84)	(35.11)	
	10	10.54	31.42	38.05	26.67	11.65	30.92	37.24	26.60	11.10	31.17	37.65	26.64	52.75
		(18.94)	(34.09)	(38.09)	(31.09)	(19.96)	(33.78)	(37.61)	(31.05)	(19.46)	(33.94)	(37.85)	(31.07)	
Neem	5	16.32	41.89	57.42	38.54	16.78	40.15	56.71	37.88	16.55	41.02	57.07	38.21	32.21
		(23.83)	(40.33)	(49.27)	(38.38)	(24.18)	(39.32)	(48.86)	(37.99)	(24.01)	(39.83)	(49.06)	(38.18)	
	10	13.25	37.77	51.47	34.16	14.08	38.01	51.96	34.68	13.67	37.89	51.72	34.42	38.93
		(21.35)	(37.92)	(45.84)	(35.77)	(22.04)	(38.06)	(46.12)	(36.08)	(21.69)	(37.99)	(45.98)	(35.92)	
Aloe vera	5	28.17	52.23	73.29	51.23	28.44	52.28	73.57	51.43	28.31	52.26	73.43	51.33	8.94
		(32.06)	(46.28)	(58.88)	(45.70)	(32.23)	(46.31)	(59.06)	(45.82)	(32.14)	(46.29)	(58.97)	(45.76)	
	10	25.94	48.16	69.07	47.72	25.31	48.51	69.94	47.92	25.63	48.34	69.51	47.82	15.16
		(30.62)	(43.95)	(56.21)	(43.70)	(30.20)	(44.15)	(56.75)	(43.81)	(30.41)	(44.05)	(56.48)	(43.75)	
Control	-	31.79	58.75	76.77	55.77	32.71	59.49	78.71	56.97	32.25	59.12	77.74	56.37	0.00
		(34.32)	(50.04)	(61.19)	(48.31)	(34.88)	(50.47)	(62.52)	(49.01)	(34.60)	(50.25)	(61.85)	(48.66)	
SEm±		0.83	1.26	1.55		0.84	1.26	1.56		0.53	0.80	0.98		
CD (p=0.05)		2.56	3.88	4.77		2.58	3.89	4.80		1.64	2.45	3.03		

*Average of four replications
Figures given in parenthesis are angular transformed values
PDRI= Percent disease reduction index

Table 5: Effect of oils on mycelial growth of *Penicillium italicum* on potato dextrose agar medium

Oils	Conc. (%)	Mycelial growth (mm)*	Percent inhibition of mycelial growth
Mustard	4	47.00	27.26
Neem	4	22.50	64.66
Linseed	4	52.25	19.87
Sesame	4	35.75	45.46
Clove	4	4.80	93.59
Eucalyptus	4	3.40	94.65
Control (without treatment)	-	65.50	0.00
	SEm±	0.35	
	CD (p=0.05)	1.09	

*Average of four replications

Table 6: Effect of pre- inoculation treatments with different oils on severity of blue mould rot of orange fruits at different intervals

Oils	Conc. (%)	Percent disease severity (days after inoculation)												
		2020				2021				Pooled				
		5	8	12	Mean	5	8	12	Mean	5	8	12	Mean	PDRI
Mustard	**4**	25.02	47.27	69.83	47.37	24.45	46.72	68.53	46.57	24.74	47.00	69.18	46.97	15.99
		(30.01)	(43.44)	(56.68)	(43.49)	(29.63)	(43.12)	(55.88)	(43.03)	(29.82)	(43.28)	(56.28)	(43.26)	
Neem	4	21.00	35.21	57.86	38.02	21.72	34.98	57.89	38.20	21.36	35.10	57.88	38.11	31.83
		(27.27)	(36.40)	(49.52)	(38.07)	(27.78)	(36.26)	(49.54)	(38.17)	(27.53)	(36.33)	(49.53)	(38.12)	
Linseed	4	29.12	51.77	70.91	50.60	28.45	50.97	71.28	50.23	28.79	51.37	71.10	50.42	9.82
		(32.66)	(46.01)	(57.36)	(45.34)	(32.23)	(45.56)	(57.59)	(45.13)	(32.45)	(45.79)	(57.48)	(45.24)	
Sesame	4	23.27	44.43	67.42	45.04	24.72	45.88	66.74	45.78	24.00	45.16	67.08	45.41	18.78
		(28.84)	(41.80)	(55.19)	(42.15)	(29.81)	(42.64)	(54.78)	(42.58)	(29.33)	(42.22)	(54.99)	(42.37)	
Clove	4	15.24	30.06	52.78	32.69	14.57	29.27	51.95	31.93	14.91	29.67	52.37	32.31	42.21
		(22.98)	(33.25)	(46.59)	(34.87)	(22.44)	(32.75)	(46.12)	(34.41)	(22.71)	(33.00)	(46.36)	(34.64)	
Eucalyptus	4	8.57	25.38	48.11	27.35	9.24	26.29	48.02	27.85	8.91	25.84	48.07	27.60	50.63
		(17.02)	(30.25)	(43.92)	(31.53)	(17.70)	(30.85)	(43.87)	(31.85)	(17.36)	(30.55)	(43.89)	(31.69)	
Control (without treatment)		31.78	58.37	76.71	55.62	32.11	58.97	77.51	56.20	31.95	58.67	77.11	55.91	0.00
		(34.31)	(49.82)	(61.14)	(48.23)	(34.52)	(50.17)	(61.69)	(48.56)	(34.42)	(49.99)	(61.42)	(48.39)	
SEm±		0.44	0.74	1.21		0.46	0.75	1.05		0.39	0.65	0.91		
CD (p=0.05)		1.37	2.29	3.73		1.41	2.32	3.23		1.20	2.00	2.80		

*Average of four replications
Figures given in parenthesis are angular transformed values
PDRI= Percent disease reduction index

Discussion

Effect of plant extracts on blue mould rot

In the present investigation, *Allium sativum* extract at 10 percent concentrations proved to be most inhibitory to *P. italicum* (95.26%). Extracts of *Allium sativum*, *Azadirachta indica* and *Ocimum sanctum* also showed toxicity towards to mycelial growth of the pathogen. The study also revealed that *Allium sativum*, *Azadirachta indica* and *Ocimum sanctum* used at 5 and 10 percent concentrations significantly checked the disease severity. Disease reduction index was highest in *Allium sativum* extract at 10 percent (52.75%) during severity at different intervals. This agreement is similar with findings of Obagwu and Koraten (2003). Their findings agrees that ethanol and water extracts of garlic cloves checked growth of artificially inoculated with *P. digitatum* and *P. italicum*, which was due to antifungal activity of plant extracts contains phenolic compounds found in garlic. Disease control potentiality of plant extracts against post-harvest rots in fruits has also been reported earlier workers (Dargan and Saxena, 2002; Tripathi and Dubey, 2003; Yadav and Majumdar, 2004 and Meena *et al*., 2009) [12, 41, 45, 23]. Mehta and Mehta (2005) [24] observed that *Allium sativum* (10%) and *Allium cepa* (50%) completely inhibited the growth of *Geotrichumcandidum*. Both the extracts checked the rot development of grape fruits infected by *G. candidum*. The efficacy of *Allium sativum* in suppressing blue mould rot in kinnow has been reported by Sharma *et al*. (2009) [35]. Khilare and Gangawane (1997) [21] reported that out of 25 medicinal plant extracts tested, *Azadirachta indica* extract was highly effective against green mould of mosambi caused by *Penicillium digitatum*. The fungitoxicity of the *Allium sativum* extract may be due to antifungal substances *viz*., allicin, allypropyl disulphide, diallyl disulphide or due to the enzyme allinase present in it (Radha *et al*., 1998) [32]. Leaves, bark and roots of *Azadirachta indica*posses antimicrobial, antiseptic and insecticidal properties. The leaves of *Azadirachta indica* contain nimbin, nimbinene, 6-desacetylnimbinene, nimbandiol, nimbolide and quercetin (Ross, 1999 and Prajapati *et al*., 2003) [34, 31]. Methyl eugenol an aromatic compound is the main constituent of oils extracted from leaves of *Ocimum sanctum* (Vani *et al*., 2009). More studies are required for isolation, purification and characterization of toxic principles present in plant extracts and their commercial exploitations for the management of post-harvest rotting in kinnow fruits. Use of plant extracts such as *Allium sativum*, *Azadirachta indica* etc. may be suggested as cheaper and ecofriendly alternative to chemical fungicides for an effective management of blue mould rot incited by *P. italicum*. Efficacy of plant extracts evaluated against the fungus Penicillium spp. were found effective to control in inhibiting the growth and development of Penicillium (Subedi *et al*., 2016 and Chen *et al*., 2019) [40, 10].

Effect of oils on blue mould rot of orange

In the present studies, six different edible and non-edible oils were tested *in vitro* and *in vivo* in order to explore the possibility of oils as an alternative of chemical method of management of post-harvest decay of orange fruits. It was observed that eucalyptus oil (4%) significantly checked the mycelial growth of *P. italicum* (94.65%) and also blue mould rot severity (50.63%) in orange fruits. Few other oils such as clove, neem, sesame, linseed and mustard oil also inhibited the fungal growth. But these were not as effective as eucalyptus and clove oil in controlling the disease. Effectiveness of commercial oils against storage rots of fruits have also been reported by earlier researchers (Ali *et al*., 1992; Sharma, 2002) [2, 36]. Yigit *et al*. (2000) [47] reported the inhibitory effects of various essential oils *viz*., cumin, black thyme, dill, coriander and rosemary on *P. digitatum* which causes green mould rot in citrus. Efficacy of neem, castor and mustard oils against post-harvest decay due to *P. digitatum* has been recorded (Sharma, 2002) [36]. The inhibitory effect of cumin oil on mycelial growth and spore germination of *P.italicum* and *P. digitatum* was also reported by Azizi *et al*. (2006) [6]. The cumin oil contains an aromatic aldehyde known as cumin aldehyde and has strong

antifungal effect which might be responsible for its efficacy in controlling post-harvest decay of fruits (Kurita *et al.*, 1981 and Yigit *et al*., 2000) [22, 47]. Oils are the natural, volatile and complex compounds known for their antimicrobial, antioxident and medicinal properties (Bakkali *et al*., 2008) [7].

With the findings of many scientists that clove oil and eucalyptus oils were most effective to control of fruit rots. These oils has antifungal activities which inhibit the growth of mycelium and decrease fungus decay (Pinto *et al*., 2009; Chavan and Kakde, 2011) [29, 9].

Conclusion

In conclusion, the study investigated the efficacy of various plant extracts and oils in controlling Penicillium italicum-induced blue mould rot in oranges. Results demonstrated that extracts from Allium sativum, Azadirachta indica, and Ocimum sanctum, particularly at higher concentrations, effectively inhibited fungal growth. Similarly, oils such as eucalyptus and clove exhibited significant antifungal properties. These findings underscore the potential of natural extracts and oils as eco-friendly alternatives to synthetic fungicides for managing post-harvest diseases in fruits, offering promising avenues for further research and practical applications in agricultural practices.

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Conflict of Interest

The authors declare no conflict of interest.

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