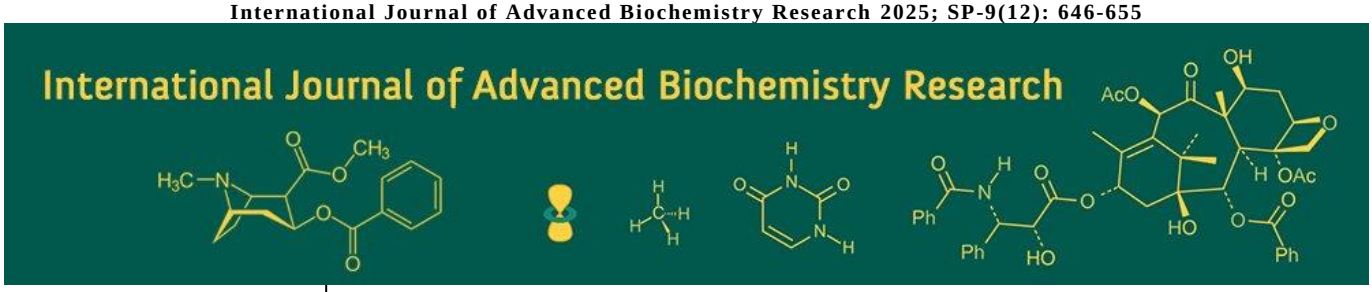

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Bio-efficacy of phytoextracts, bioagents and fungicides against *Alternaria porri* inciting purple blotch disease in white onion

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Abstract
Onion (*Allium cepa* L.) indeed holds significant importance globally, not just as a culinary staple but also for its numerous health benefits. Amongst all important diseases, purple blotch disease incited by *Alternaria porri* is the major hurdle in successful and profitable cultivation of onion. In recent years, purple blotch disease is an important emerging disease of onion in Konkan region as well as rest of the Maharashtra causing considerable yield losses. The effectiveness of phytoextracts, bioagents and fungicides against *Alternaria porri* were assessed *in vitro* using the standard "Dual culture technique." All the bio-agents evaluated were significantly effective in inhibiting the mycelial growth of *A. porri*. *Pseudomonas fluorescens* was shown to have the greatest (78.88%) mycelial growth inhibition of *A. porri*. Soapnut rind extract (10%) outperformed all treatments, with the highest suppression of mycelial growth (75.73%) of *A. porri*. Among the systemic fungicides, Tebuconazole 25.9% EC, Hexaconazole 5% EC and Propiconazole 25% EC each @ 0.1% concentration were found most significantly effective and caused complete inhibition of *A. porri*. Among the contact and combi fungicides, Tebuconazole 50% + Trifloxystrobin 25% WG (0.05%) and Copper oxychloride 50% WP (0.25%) were found most significantly effective in inhibiting the mycelial growth of *Alternaria porri* with complete inhibition over control.

Keywords: Purple blotch disease, *Alternaria porri*, onion, *Allium cepa* L., phytoextracts, bioagents, fungicides

1. Introduction
Onion (*Allium cepa* L.) indeed holds significant importance globally, not just as a culinary staple but also for its numerous health benefits. As a member of the Alliaceae family, it has been cultivated for centuries and is widely recognized for its medicinal properties. One of the key components responsible for the characteristic pungency of onion bulbs is Allyl-propyl-di-sulphide which is not only responsible for the onion's flavour but also contributes for its medicinal properties. Allyl-propyl-di-sulphide possesses a different beneficial effect including anti-cancerous antibacterial, antifungal, anti-helminthic, anti-inflammatory, antiseptic and antispasmodic properties (Augusti, 1996) [4]. The onion contains a variety of bioactive compounds, such as organosulfur compounds, flavanols, ascorbic acids and carbohydrate prebiotics. Additionally, its by-products contain a higher concentration of flavonoids compared to the bulb. The major organosulfur compounds found in onions are diallyl monosulfide, diallyl disulfide, diallyl trisulfide and diallyl tetrasulfide, while quercetin, kaempferol, anthocyanin and luteolin are considered as the main flavonoids. Ascorbic acid and fructo-oligosaccharides are also recognized as bioactive compounds. These bioactive compounds in onions have strong antioxidant potential for neutralizing the oxidative stress of cells. Onions offer not just versatility in cooking but also important health-promoting compounds, adding to their nutritional and medicinal value (Kabrah *et al*., 2016) [13]. Table 1.1. lists the nutritional value of white onions according to the Food Data Central database, USDA (United States Department of Agriculture).

Table 1.1: Nutritional value of white onion (per 100 g)

Calories	38-40 kcal
Carbohydrates	8.6-9.0 g
Sugars	4.2 g
Dietary Fibers	1.2-1.5 g
Proteins	1.0-1.1 g
Fats	0.1 g
Vitamin C	8-9 mg
Vitamin B6	0.12 mg
Folate (B9)	20 µg
Potassium	146 mg
Calcium	23 mg
Magnesium	10 mg
Iron	0.2 mg

India, China, Egypt, United States, Bangladesh, Turkey, Pakistan, Indonesia, Iran, and Algeria are the world's largest onion producers. India leads in onion production with 26,244 thousand tonnes, followed by China with 23,500 thousand tonnes. In India, onion cultivation is a significant agricultural activity, as of the latest estimates, the total area under onion cultivation in India is around 1540.69 thousand hectares with a productivity of about 15.75 tonnes per hectare (Anonymous, 2024) [2].

2. Materials and Methods

The present study was conducted at the Department of Plant Pathology, College of Agriculture, Dapoli during year 2023-24 and 2024-2025.

2.1. Materials

2.1.1. Phytoextracts

Aqueous extracts of locally available eight plant species namely garlic, neem, lantana, ginger, gliricidia, tulsi, soapnut and rui etc. available in the campus of Dr. B. S. K. K. V., Dapoli were used for the experiments under research topic.

2.1.2. Biocontrol agents

Pure cultures of eight biocontrol agents namely *Trichoderma viride*, *T. harzianum*, *T. longibrachiatum*, *T. koningii*, *Aspergillus niger*, *Pseudomonas fluorescens*, *Bacillus subtilis* and Yeast (*Saccharomyces cerevisiae* var. *ellipsoideus*) etc. available at the Department of Plant Pathology, Dapoli were used for various studies.

2.1.3. Fungicides

Following (systemic, contact and combi- product) fungicides as listed below were purchased from the market and as well obtained from the Department of Plant Pathology, Dapoli and used for various experiments (*in vitro* and *in vivo*), under study.

Table 2.1: List of fungicides used

Sr. No.	Common/ Technical Name	Trade Name	Company
1	Carbendazim 50% WP	Crosstin	Shivalik Crop Sci. Ltd. Gujarat
2	Difenoconazole 25% EC	Score	Syngenta India Ltd., Pune
3	Propiconazole 25% EC	Tilt	Syngenta India Ltd., Pune
4	Hexaconazole 5% EC	Contaf SE	Rallis India Ltd., Mumbai
5	Tebuconazole 25.9% EC	Folicur	Bayer. Crop Sci. Ltd., India
6	Thiophanate methyl 70% WP	Roksin	Shivalik Crop Sci. Ltd. Gujrat
7	Azoxystrobin 23% SC	Amistar	Syngenta India Ltd., Pune
8	Mancozeb 75% WP	Sythane M-45	Shivalik Crop Sci. Ltd. Gujarat
9	Copper oxychloride 50% WP	Blutoxx	Shivalik Crop Sci. Ltd. Gujarat
10	Chlorothalonil 75% WP	Kavach	Syngenta India Ltd., Pune
11	Zineb 75% WP	Indofil Z-78	Indofil Industries Ltd., Mumbai
12	Captan 50% WP	Captaf	Rallis India Ltd., Mumbai
13	Tebuconazole 50% + Tryfloxystrobin 25% WDG	Nativo	Bayer. Crop Sci. Ltd., India
14	Carbendazim 12% + Mancozeb 63% WP	SAAF	UPL, Mumbai
15	Cymoxanil 8% + Mancozeb 64% WP	Moximate	Indofil Industries Ltd., Mumbai

2.2. Methods

2.2.1. *In vitro* efficacy of phytoextracts

Aqueous extract of locally available eight plant species each at 10% concentration were evaluated *in vitro* against the *Alternaria porri* by applying standard poisoned food technique (Nene and Thapliyal, 1993) [17] and by using PDA as basal medium. For obtaining 10% plant extract, 10 ml of standard plant extract was mixed with 90 ml of PDA in 250 ml conical flask. Later, 20 ml of the PDA medium containing plant extracts was poured into sterilized Petri plates under aseptic conditions. Mycelial discs of 5 mm size from seven days old actively grown pure culture were used to inoculate the poured Petri plates. Control was maintained on PDA without adding any plant extract in a medium. Three replications were taken for each treatment. These plates were incubated at 27±2 ^{0}C for seven days and radial colony growth was measured.

Experimental details

- **Design:** Completely Randomized Design (CRD)
- **Replications:** Three
- **Treatments:** Nine

Treatments details

Table 2.2: List of phytoextracts evaluated against *Alternaria porri*

Tr. No.	Common name	Botanical name	Plant part used	Concentration used (%)
T_1	Garlic	*Allium sativum*	Clove	10
T_2	Neem	*Azadirachta indica*	Leaves	10
T_3	Lantana	*Lantana camara*	Leaves	10
T_4	Ginger	*Zingiber officinale*	Rhizome	10
T_5	Gliricidia	*Gliricidia sepium*	Leaves	10
T_6	Tulsi	*Ocimum tenuiflorum*	Leaves	10
T_7	Soapnut	*Sapindus mukorossi*	Rind	10
T_8	Rui	*Calotropis gigantea*	Leaves	10
T_9	-	Control	-	-

Observations on radial mycelial growth was recorded in all of the replicated treatments after control (untreated) plates were fully covered with mycelium growth of the test pathogen. The cumulative data was averaged and Per cent inhibition of the growth of the test pathogen, over untreated control was calculated by applying formula given by Vincent, 1947 [23].

$$\text{Per cent Growth Inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,
I = Per cent Inhibition
C = Growth (mm) of test fungus in control plate.
T = Growth (mm) of test fungus in treated plates.

2.2.2. *In vitro* efficacy of bioagents

Eight highly promising bioagents (fungal and bacterial) were assessed for their efficacy against *Alternaria porri* using the 'Dual Culture Technique' (Dennis and Webster, 1971) [9] and PDA as the base culture medium. The test bioagents and the pathogen were grown on their respective culture media for seven days before being used in the study. A 5 mm culture disc of both test pathogen and the fungal bioagent (cut out with a sterilized cork borer) were inoculated with positioned at equal distances and directly opposite each other on autoclaved and solidified PDA medium in Petri plates. For bacterial bioagents, a 5 mm culture disc of the test pathogen was placed along the periphery of the PDA plate and opposite to it, a pure culture suspension of the test bacterial bioagent was streaked using a sterilized inoculation needle. Three PDA plates were inoculated for each test bioagent and all treatments were replicated three times. Untreated control was maintained with PDA plates only inoculated with the pure culture disc of the test pathogen. The experimental details were as follows.

Experimental details

- **Design:** Completely Randomized Design (CRD)
- **Replications:** Three
- **Treatments:** Nine

Treatments details

Table 2.3: List of bioagents evaluated against *Alternaria porri*

Tr. No.	Bio-agents used
T_1	*Trichoderma harzianum*
T_2	*Trichoderma koningii*
T_3	*Trichoderma longibrachiatum*
T_4	*Trichoderma viride*
T_5	*Aspergillus niger*
T_6	*Pseudomonas fluorescens*
T_7	*Bacillus subtilis*
T_8	Yeast (*Saccharomyces cerevisiae* var. *ellipsoideus*)
T_9	Control

Observations on mycelial growth of the test fungus and bioagents was recorded after 7 days. Per cent inhibition of test fungus over untreated control was calculated by using formula given by Vincent (1947) [23].

$$\text{Per cent Growth Inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,
I = Per cent Inhibition
C = Growth (mm) of test fungus in control plate.
T = Growth (mm) of test fungus in intersecting plate.

2.2.3. *In vitro* efficacy of fungicides

Efficacy of seven systemic and eight contact and combi fungicides were evaluated for their efficacy *in vitro* against the *Alternaria porri*, using PDA as basal culture medium and applying Poisoned food technique (Nene and Thapliyal, 1993) [17].

The required quantity of each test fungicide was calculated based on the active ingredient. After calculation, the fungicides were dispensed and thoroughly mixed with sterilized and cooled PDA medium in separate glass conical flasks with a capacity of 250 ml. This was done in order to achieve the desired concentrations of the fungicide-amended PDA medium. The PDA medium amended with each test fungicide was then aseptically poured into sterilized Petri plates @ 20 ml per plate and allowed to solidify at room temperature. Three PDA plates per treatment were

maintained and each treatment was replicated thrice for each test fungicide and its concentration.

On solidification of poisoned medium each plate was inoculated with 5 mm culture disc of test pathogen centrally. The culture disc was obtained from a 7-day-old pure culture of the test pathogen isolate. PDA plates without fungicide, inoculated with the pure culture disc of the test pathogen, were maintained as untreated control. Both treated and untreated control plates were then incubated in an inverted position in a BOD incubator at 27 ± 2 ºC. The study was conducted for systemic and contact plus combi fungicides, separately. The experimental details were as provided below.

Experimental details

- **Design:** Completely Randomized Design (CRD)
- **Replications:** Three

Treatments details

Table 2.4: List of systemic fungicides evaluated against *Alternaria porri*

Tr. No.	Name of fungicides	Concentration
T_1	Carbendazim 50% WP	0.1%
T_2	Difenoconazole 25% EC	0.1%
T_3	Propiconazole 25% EC	0.1%
T_4	Hexaconazole 5% EC	0.1%
T_5	Tebuconazole 25.9% EC	0.1%
T_6	Thiophanate Methyl 70% WP	0.1%
T_7	Azoxystrobin 23% SC	0.1%
T_8	Control	-

Table 2.5: List of contact and combi fungicides evaluated against *Alternaria porri*

Tr. No.	Name of fungicides	Concentration
T_1	Mancozeb 75% WP	0.2%
T_2	Copper oxychloride 50% WP	0.25%
T_3	Chlorothalonil 75% WP	0.2%
T_4	Zineb 75% WP	0.2%
T_5	Captan 50% WP	0.2%
T_6	Tebuconazole 50% + Trifloxystrobin 25% WG	0.05%
T_7	Carbendazim 12% + Mancozeb 63% WP	0.2%
T_8	Cymoxanil 8% + Mancozeb 64% WP	0.2%
T_9	Control	-

Observations on radial mycelial growth was recorded in all of the replicated treatments after control (untreated) plates were fully covered with mycelium growth of the test pathogen. The cumulative data was averaged and per cent inhibition of the growth of the test pathogen, over untreated control was calculated by applying formula given by Vincent, 1947 [23].

$$\text{Per cent Growth Inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,

I = Per cent Inhibition

C = Growth (mm) of test fungus in control plate.

T = Growth (mm) of test fungus in treated plates.

3. Results and Discussions

3.1. *In vitro* efficacy of phytoextracts against *Alternaria porri*

Using the poisoned food technique and PDA as a basic culture medium, the present investigation assessed the *in vitro* efficacy of aqueous extracts of eight plant species (each at a 10% concentration) against *Alternaria porri*, which causes purple blotch disease in onion. Table 3.1, Plate I and Fig. 1 present the outcomes of the study, which are described below.

The results (Table 3.1, Plate I and Fig. 1) indicated that all the plant extracts evaluated each at 10% concentration exhibited antifungal activity against *Alternaria porri*. The mycelial growth of test fungus was varied from 21.83 to 39.50 mm. Whereas, inhibition of mycelial growth of test fungus was ranged from 56.10 to 75.73 per cent. Among the eight plant extracts evaluated, soapnut rind extract (10 %) outperformed all treatments, with the least colony growth of 21.83 mm and the highest suppression of mycelial growth (75.73%) of *A. porri*. The second most effective treatment was ginger rhizome extract (10%) which showed 24.00 mm mycelial growth and 73.33 per cent mycelial growth inhibition. Tulsi leaf extract @ 10% was likewise found effective, with a mycelial growth of 28.83 mm and the inhibition of mycelial growth of 67.95 %. The rest best treatments were rui leaf extract (34.00 mm & 62.21 %), neem leaf extract (34.50 mm & 61.66 %), garlic clove extract (36.50 mm & 59.44 %) and lantana leaf extract (38.00 mm & 58.51 %). Gliricidia leaf extract showed the least mycelial inhibition of *A. porri*, by 56.10 per cent as compared other treatments.

Table 3.1: *In vitro* efficacy of phytoextracts against *Alternaria porri*

Tr. No.	Common name	Botanical name	Conc. (%) used	Colony diameter (mm)*	Per cent inhibition
T_1	Garlic	*Allium sativum*	10	36.50	59.44
T_2	Neem	*Azadirachta indica*	10	34.50	61.66
T_3	Lantana	*Lantana camara*	10	38.00	58.51
T_4	Ginger	*Zingiber officinale*	10	24.00	73.33
T_5	Gliricidia	*Gliricidia sepium*	10	39.50	56.10
T_6	Tulsi	*Ocimum tenuiflorum*	10	28.83	67.95
T_7	Soapnut	*Sapindus mukorossi*	10	21.83	75.73
T_8	Rui	*Calotropis gigantea*	10	34.00	62.21
T_9	Control	-	-	90.00	-
	S.E.m. ±			0.48	
	C.D. at 1%			1.87	

*Mean of three replications

Plate I: *In vitro* efficacy of phytoextracts against *Alternaria porri*

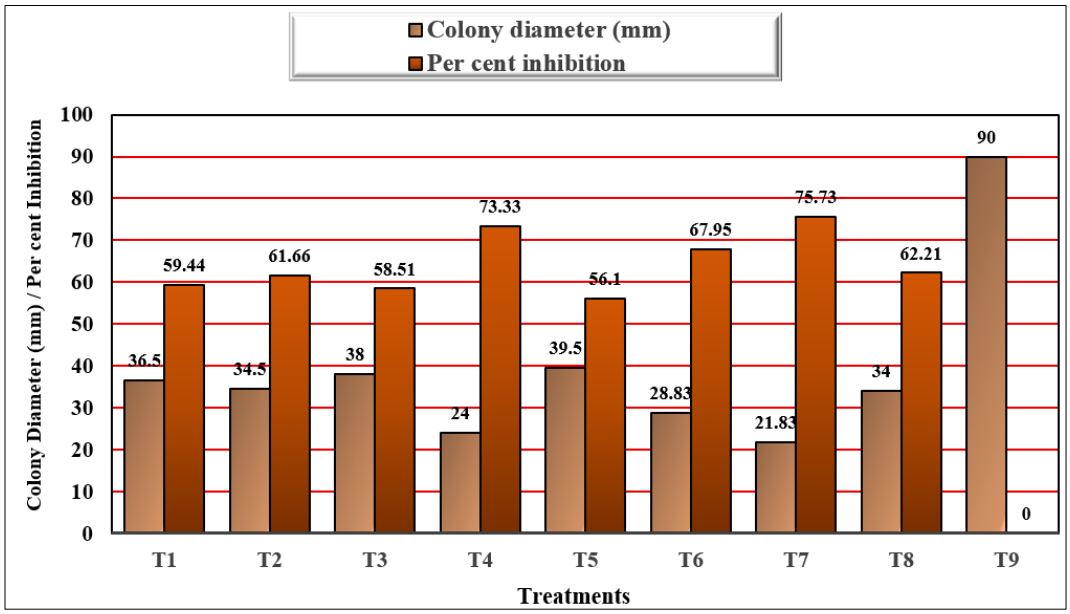

Fig 1: *In vitro* efficacy of phytoextracts against *Alternaria porri*

The findings of the present investigation are consistent with those of numerous previous researchers. Chethana *et al.* (2012) [7] studied *in vitro* efficacy of various phytoextracts against purple blotch disease of onion and found that garlic extract was significantly superior over neem oil, pongamia oil, cinnamon, turmeric and clerodendron in inhibiting the mycelial growth. Garlic extract caused significantly maximum inhibition (100%) at 20 per cent concentration followed by 88.50 per cent, 52.50 per cent and 42.33 per cent inhibition at 15 per cent, 10 per cent and 5 per cent concentrations, respectively. Maharana *et al.* (2016) [15] studied *in vitro* efficacy of eleven phytoextracts against *A. porri* causing purple blotch disease of onion and found that at 10 % concentration, maximum inhibition was found in neem (82.60%) followed by tulsi (78.40%) and at a concentration of 20%, the extracts of neem, tulsi, eucalyptus, garlic and ginger were the most effective in inhibiting the growth of mycelium, with mean inhibition rates of 90.40%, 86.80%, 79.50%, 78.00% and 75.20%, respectively. Similarly, Jhala *et al.* (2017a) studied *in vitro* efficacy of four phytoextracts against *A. porri* causing purple blotch disease in onion at 2 and 4 per cent concentrations and found that neem leaf extract caused maximum inhibition of linear growth (62.09% and 68.61%) of *A. porri* followed by garlic extract (53.13 and 57.42%). Bhandekar *et al.* (2019) [6] reported that tulsi (*Ocimum tenuiflorum*) leaf extract and neem leaf extract (10%) was most effective in arresting maximum mycelial growth of *A. porri* to the tune of 60.83 and 58.62%, respectively. Also, Arunakumara *et al.* (2023) [3] studied *in vitro* efficacy of various phytoextracts at 15% concentration against *A. porri* causing purple blotch disease of garlic and found that garlic (*Allium sativum*) cloves extract was most effective in inhibiting the mycelial growth (64.64%) followed by *Clerodendron inerme* (57.10%), *Aloe vera* (55.14%), *Eucalyptus globes* (48.30%) and least inhibition was recorded in *Gliricidia maculata* (26.04%). Dibisa *et al.* (2023) [10] also reported highest per cent inhibition of mycelium growth of *A. porri* due to garlic clove extract (76.34%) followed by *Aloe vera* leaf extract (72.67%) and Ginger (66.48%).

3.2. *In vitro* efficacy of bio-agents against *Alternaria porri*

The efficacy of eight distinct bioagents against *Alternaria porri* were assessed *in vitro* using the standard "Dual culture technique." Table 3.2, Plate II and Fig. 2 display the findings on *A. porri* mycelial development and inhibition.

Table 3.2: *In vitro* efficacy of bio-agents against *Alternaria porri*

Tr. No.	Bio-agents evaluated	Colony diameter (mm)*	Per cent inhibition
T_1	*Trichoderma harzianum*	22.83	74.62
T_2	*Trichoderma koningii*	23.00	74.44
T_3	*Trichoderma longibrachiatum*	20.16	77.58
T_4	*Trichoderma viride*	22.16	75.36
T_5	*Aspergillus niger*	22.50	74.99
T_6	*Pseudomonas fluorescens*	19.00	78.88
T_7	*Bacillus subtilis*	27.50	69.44
T_8	Yeast (*Saccharomyces cerevisiae* var. *ellipsoideus*)	35.33	60.73
T_9	Control	90.00	-
	S.E.m. ±	0.37	
	C.D. at 1%	1.44	

*Mean of three replications

The results illustrated in Table 3.2, Plate II and Fig. 2 stated that all the bio-agents evaluated were significantly effective in inhibiting the mycelial growth of *A. porri*. *Pseudomonas fluorescens* was shown to have the greatest (78.88%) mycelial growth inhibition potential of *A. porri* among the eight bioagents evaluated. However, *Trichoderma longibrachiatum* was also found equally effective with least colony growth of test pathogen (20.16 mm) with 77.58 per cent inhibition of mycelial growth and was at par with *P. fluorescens*. It was followed by *T. viride* (22.16 mm & 75.36 %), *Aspergillus niger* (22.50 mm & 74.99 %), *T. harzianum* (22.83 mm & 74.62 %) and *T. koningii* (23.00 mm & 74.44 %). *Bacillus subtilis* (27.50 mm & 69.44 %) and Saccharomyces cerevisiae var. *ellipsoideus* (35.33 mm & 60.73 %) showed the highest colony growth and the least pathogen inhibition, respectively.

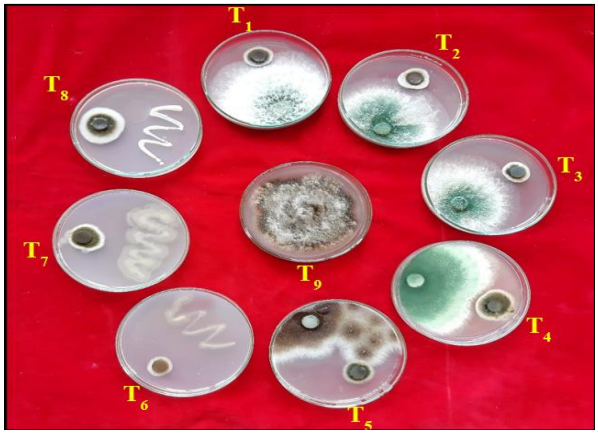

Plate II: *In vitro* efficacy of bio-agents against *Alternaria porri*

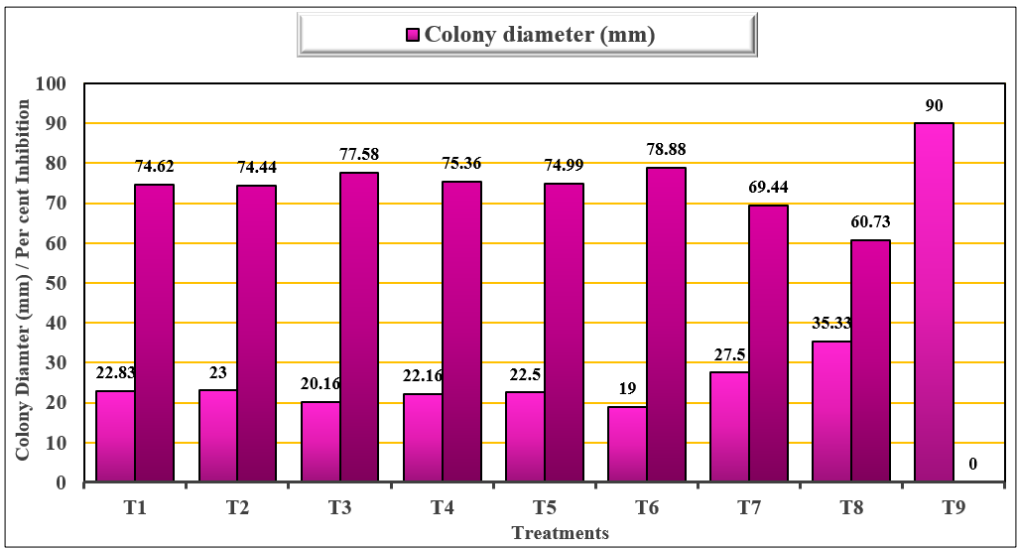

Fig 2: *In vitro* efficacy of bioagents against *Alternaria porri*

Several researchers reported results that were more or less similar to those of the present investigation. Chethana *et al.* (2012) [7] reported that among all the antagonists evaluated *Trichoderma harzianum* was found most effective against *A. porri* inciting purple blotch disease of onion which recorded 79.35 per cent inhibition of mycelial growth. Similarly, Mishra and Gupta (2012) [16] reported that *Trichoderma viride* (55.95%) was most effective in inhibiting the mycelial growth of the test pathogen over control followed by *T. harzianum* (53.17%) and *Trichoderma koningii* (46.65%). Similarly, Rahman *et al.* (2015) [19] found maximum inhibition of colony growth of *A. porri* incitant of purple blotch disease of onion due to *T. viride* which was statistically significant over all the other bioagents tested. Maharana *et al.* (2016) [15] reported that among the bio control agents evaluated against *A. porri*, the higher percentage of growth inhibition was recorded in *T. harzianum* (88%) followed by *T. viride* (83%). Kapgate *et al.* (2019) [14] resulted that *T. viride* showed maximum mycelial suppression (76.55 per cent) of *A. porri* followed

by *T. harzianum* (70.74 per cent), *Pseudomonas fluorescence* (56.27 per cent) and *Bacillus subtilis* (58.53 per cent). Bhandekar *et al*. (2019) [6] also resulted that *T. viride* recorded maximum mycelial suppression (85.45%) of *A. porri* inciting purple blotch disease of onion followed by *B. subtilis* (60.34%) and *P. fluorescence* (57.75%), respectively. Hariprasad *et al.* (2021) [11] recorded that maximum mycelial inhibition of (94.50%) of *A. porri* inciting purple blotch disease of onion in *T. viride* followed by *T. harzianum* with mycelial inhibition per cent (90.58). The results of present study also in close conformity with results of Vijaykumar *et al.* (2022b) [22] who found that maximum mycelial growth inhibition (83.89%) of *A. porri* causing purple blotch disease of garlic was due to with *T. harzianum* followed by *P. fluorescens* (63.40 %) and *T. viride* (61.20 %). The least mycelial growth inhibition of 38.97 per cent was recorded with *B. subtilis.*

3.3. *In vitro* efficacy of fungicides against *Alternaria porri*

3.3.1. *In vitro* efficacy of systemic fungicides against *Alternaria porri*

Using the poisoned food technique and PDA as a basic culture medium, the present investigation assessed the *in vitro* efficacy of different systemic fungicides against *Alternaria porri*, incitant of purple blotch disease in white onion.

Table 3.3: *In vitro* efficacy of systemic fungicides against *Alternaria porri*

Tr. No.	Name of the Fungicides	Conc. (%) used	Colony diameter (mm)*	Per cent inhibition
T_1	Carbendazim 50% WP	0.1	17.66	80.92
T_2	Difenoconazole 25% EC	0.1	7.66	91.47
T_3	Propiconazole 25% EC	0.1	0.00	100.00
T_4	Hexaconazole 5% EC	0.1	0.00	100.00
T_5	Tebuconazole 25.9% EC	0.1	0.00	100.00
T_6	Thiophanate methyl 70% WP	0.1	20.50	77.21
T_7	Azoxystrobin 23% SC	0.1	23.33	74.07
T_8	Control	-	90.00	-
	S.E.m. ±		0.28	
	C.D. at 1%		1.19	

*Mean of three replications

Data from Table 3.3, Plate III and Fig. 3 illustrated that all the systemic fungicides evaluated were significantly effective in reducing mycelial growth of *A. porri*. Among the systemic fungicides, Tebuconazole 25.9% EC, Hexaconazole 5% EC and Propiconazole 25% EC (each @ 0.1% concentration) were found most significantly effective in inhibiting the mycelial growth of *A. porri* with 100 per cent inhibition over control and was closely followed by Difenoconazole 25% EC (0.1%) which resulted in minimum mycelial growth of 7.66 mm with inhibition of 91.47 %. Carbendazim 50% WP (0.1%) (17.66 mm & 80.92 %) and Thiophanate methyl 70% WP (0.1%) (20.50 mm & 77.21 %) were the next best treatments in order of merit. Azoxystrobin 23% SC was found least effective in inhibiting the mycelial growth of test pathogen with maximum colony growth of 23.33 mm and least inhibition of mycelial growth by 74.07 %.

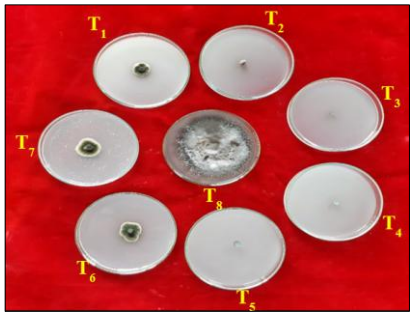

Plate III: *In vitro* efficacy of systemic fungicides against *Alternaria porri*

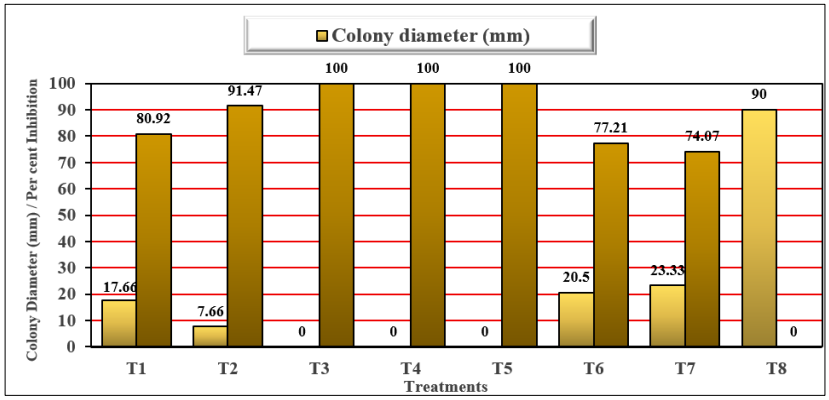

Fig 3: *In vitro* efficacy of systemic fungicides against *Alternaria porri*

3.3.2. *In vitro* efficacy of contact and combi fungicides against *Alternaria porri*

A total of eight contact and combi fungicides at different concentrations were studied *in vitro* for their efficacy against *Alternaria porri* by using poisoned food technique and PDA as a basic culture medium. Table 3.4 presents the outcomes of the study, which are described below.

Table 3.4: *In vitro* efficacy of contact and combi fungicides against *Alternaria porri*

Tr. No.	Name of fungicides	Conc. (%) used	Colony diameter (mm)*	Per cent inhibition
T_1	Mancozeb 75% WP	0.2	22.83	74.62
T_2	Copper oxychloride 50% WP	0.25	0.00	100.00
T_3	Chlorothalonil 75% WP	0.2	18.50	79.44
T_4	Zineb 75% WP	0.2	14.83	83.51
T_5	Captan 50% WP	0.2	12.50	86.10
T_6	Tebuconazole 50% + Trifloxystrobin 25% WG	0.05	0.00	100.00
T_7	Carbendazim 12% + Mancozeb 63% WP	0.2	22.66	74.81
T_8	Cymoxanil 8% + Mancozeb 64% WP	0.2	10.50	88.32
T_9	Control	-	90.00	-
	S.E.m. ±		0.23	
	C.D. at 1%		0.90	

*Mean of three replications

Table 3.4, Plate III and Fig. 4 illustrated that all the contact and combi fungicides tested were significantly effective in reducing mycelial growth of *A. porri*. Among the contact and combi fungicides, Tebuconazole 50% + Trifloxystrobin 25% WG (0.05%) and Copper oxychloride 50% WP (0.25%) were found most significantly effective in inhibiting the mycelial growth of *Alternaria porri* with 100 per cent inhibition over control. Among rest of the fungicides, Cymoxanil 8% + Mancozeb 64% WP (0.2%) resulted with minimum mycelial growth of 10.50 mm with inhibition of 88.32 % followed by Captan 50% WP (0.2%) (12.50 mm & 86.10 %), Zineb 75% WP (0.2%) (14.83 mm & 83.51 %) and Chlorothalonil 75% WP (0.2%) (18.50 mm & 79.44 %), respectively with average mycelial growth and its corresponding average inhibition. Mancozeb 75% WP (0.2%) and Carbendazim 12% + Mancozeb 63% WP (0.2%) were found least effective in inhibiting the mycelial growth of test pathogen with maximum colony growth of 22.83 mm & 22.66 mm and least inhibition of mycelial growth by 74.62 % & 74.81 %, respectively.

Plate XII: *In vitro* efficacy of contact and combi fungicides against *Alternaria porri*

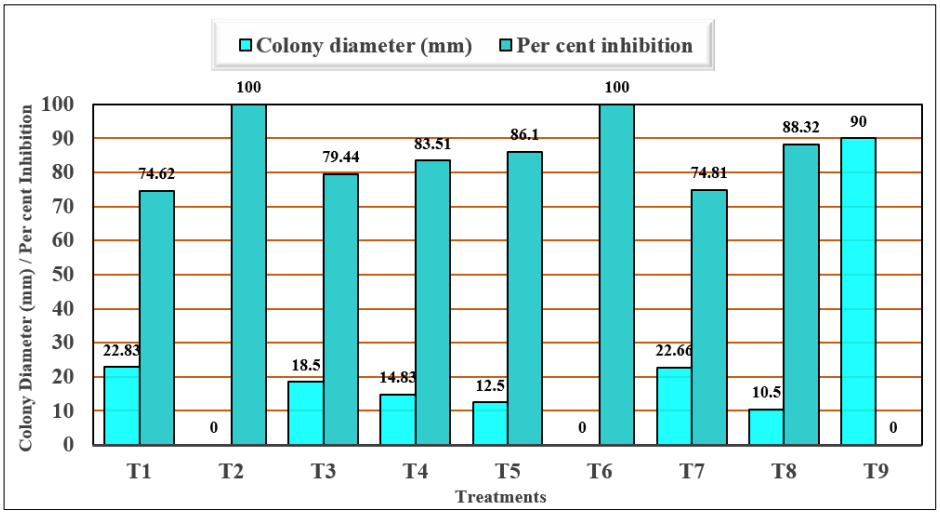

Fig 4: *In vitro* efficacy of contact and combi fungicides against *Alternaria porri*

The current investigation results are in accordance with those of several previous researchers. According to Rohan *et al*. (2018) [20] who studied *in vitro* efficacy of different fungicides at 0.05%, 0.1% and 0.15% concentration against *A. porri* and found that Tebuconazole 50% + Trifloxystrobin 25% WG at 0.15% revealed 100 per cent inhibition of the mycelial growth of *A. porri.* Propiconazole 25% EC @ 0.15% (94.44 %) was next best fungicide which was at par with Tebuconazole 25.9% EC @ 0.15% (92.59%) followed by Hexaconazole 5% EC @ 0.15% (91.85%). Aujila *et al.* (2013) [5] reported that complete mycelial growth inhibition of the *A. porri* causing purple blotch disease of onion was observed due to Difenoconazole 25% EC and Tebuconazole 50% + Trifloxystrobin 25% WG at 0.1 per cent. Agale *et al*. (2014) [1] studied *in vitro* efficacy of various different fungicides against purple blotch disease of onion incited by *A. porri* and resulted that Propiconazole 25% EC (0.1 %) completely inhibited the mycelial growth of *A. porri.* Difenoconazole 25% EC (0.1 %), Tebuconazole 25.9% EC (0.1 %) and combi fungicide Carbendazim 12% + Mancozeb 63% WP (0.2 %), showed 88.00, 85.77 and 84.66 per cent inhibition, respectively. Wanggikar *et al*. (2014) [24] reported that cent per cent (100.00 %) inhibition of mycelial growth of *A. porri* inciting purple blotch disease of onion was observed in plate with Hexaconazole 5% EC followed by Difenoconazole 25% EC (83.91%), which was followed by Mancozeb 75% WP (63.58%). Priya *et al*. (2015) [18] studied *in vitro* efficacy of different fungicides against *A. porri* and found that maximum inhibition of mycelial growth of pathogen due to Propiconazole 25% EC (92.5%) followed by Hexaconazole 5% EC (91.1%), Difenoconazole 25% EC (86.36%) and Tebuconazole 25.9% EC (80.30%). Yadav *et al*. (2017) [25] also reported that Tebuconazole 25.9% EC, Trifloxystrobin 25% + Tebuconazole 50% WG and Propiconazole 25% EC proved the most effective among the tested fungicides as they completely (100%) inhibited the mycelial growth of test pathogen. Dangi (2018) also reported that Tebuconazole 25.9% EC, Hexaconazole 5% EC and Propiconazole 25% EC provided complete mycelial growth inhibition of *A. porri* at 1000 ppm concentration level. Swain *et al*. (2021) [21] reported that Propiconazole 25% EC (0.2%), Tebuconazole 25.9% EC (0.15%) and Hexaconazole 5% SC (0.2%) recorded complete (100%) mycelial growth inhibition of the *A. porri* inciting purple blotch disease of onion.

The results are also in proximity with the results obtained earlier by Uddin *et al.*, Kumar *et al.* (2022), Khandagale *et al*. (2022), Chandan *et al.* (2023) and Dibisa *et al.* (2023) [10].

4. Conclusion

Soapnut rind extract was most effective plant extract with highest inhibition (75.73%) of mycelial growth of *A. porri in vitro*. Among the different bioagents evaluated *in vitro* *Pseudomonas fluorescens* and *Trichoderma longibrachiatum* were found most effective in inhibiting the mycelial growth of *A. porri* with 78.88 and 77.58% inhibition, respectively. Among the different systemic fungicides evaluated, Tebuconazole 25.9% EC, Hexaconazole 5% EC and Propiconazole 25% EC (each @ 0.1% conc.) and contact and combi fungicides *viz*., Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.05% and Copper oxychloride 50% WP @ 0.25% were the most significantly effective and caused complete inhibition of *A. porri.*

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