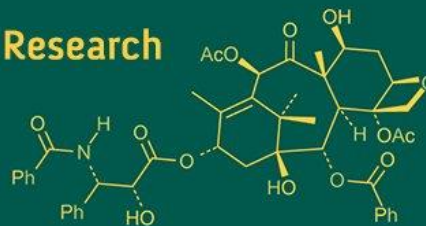


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Studies on management of alternaria blight (*Alternaria Alternata*) of garden pea (*Pisum sativum* L.)

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Abstract

For the majority of Indian vegetarians, pulses constitute an essential source of additional protein for their daily diet. For human consumption, peas are a valuable crop that are high in protein, vitamins, and minerals (K, P, Fe, and Zn). Numerous serious and minor diseases target peas (*Pisum sativum* L.). *Alternaria alternata* is the cause of Alternaria blight of pea, one of the most devastating and newly emerging diseases. Each year, the disease manifests in UP in moderate to severe form, resulting in a notable loss of yield, particularly in years with frequent winter rains. Host plants can become infected by airborne and seed borne transmission, planting in contaminated soil, or by rain splashing onto the soil or letting leaves come into direct contact with it. The first signs are tiny lesions on the pea's leaves and seed pods, which enlarge with time. Five bioagents, eight fungicides, and six plant extracts were tested for their ability to effectively combat *Alternaria alternata* in vitro. *Chaetomium globosum* (80.00%), *Pseudomonas fluorescens* (78.89%), and *Trichoderma harzianum* (77.78%) showed the highest mycelial growth inhibition. The two fungicides that showed the greatest suppression of *Alternaria alternata* were propiconazole 25% EC and hexaconazole 5% SC. The most effective plant extract against *Alternaria alternata* (82.22%) was garlic clove extract at 10% w/v concentration. This was followed by 10% Ajwain seed extract (67.78%) and 10% neem leaf extract (62.22%). Foliar application of propiconazole at 500 ml/ha after 15 DAS in field conditions resulted in the maximum yield (17.98 q/ha), test weight (192.6 gm), and the lowest disease incidence (7.79%) in the integrated disease management trial of the illness under field conditions.

Keywords: Fungicide, Hexaconazole 5% SC, Propiconazole 25% EC, Ajwain seed extract and Garlic clove extract

Introduction

India is primarily an agriculture-based country with rich flora and fauna. The subtropical climatic conditions and geographical location of the country offers an edge for agriculture over other counties. It harbors one of the oldest civilization and cultivation which dates back to 9000 B.C. Cereals and pulses are among the earliest cultivated crops. Pulses are valued both for their nutritional security and soil amelioration effects. They are rich in both protein and essential amino acids, thus making them ideal source of protein for the huge vegetarian population of the country. Their ability to easily fit in crop rotations and to fix atmospheric nitrogen make them a good option for sustainable and profitable crop production strategy. Pigeon pea, chickpea, urad, moong, lentil, pea are among the commonly cultivated pulse crops in India. In the year 2019-2020, total area under pulse production was 28.34 mha and the total pulse production was 23.15 million tonnes which was 3.15 million tonnes less than the targeted production. Rajasthan followed by Maharashtra, Madhya Pradesh and Uttar Pradesh are the major pulse producing states of the country accounting for more than 60 per cent of the total production. Compared to last year i.e., 2018-2019 the total area under pulse production has decreased from 29.16 mha to 28.34 mha in 2019-2020 but the production has increased from 22.08 million tonnes to 23.15 million tonnes. The productivity has significantly increased from 651.2 kg/ha (in 2013) to 817 kg/ha (in 2020) but is still not sufficient to meet the daily per capita minimum requirement of the pulses which is 60g/day. India occupies fourth position in area (10.53%) and 5th position in production (6.96%) of pea (Anonymous, 2014). In India field pea is grown over an area of 11.50 lakh ha with a production of about 10.36 lakh tonnes during XIIth Plan period (2012-2015). In the year 2019-2020 the total area under pea cultivation in India was 568 mha and the total production

was 5791 tonnes. Uttar Pradesh is the major field pea growing state. It alone produces about 49 per cent of pea produced in India (Anonymous, 2015-16).

Pea is the third most important pulse crop in the world, after dry bean and chickpea and the third most popular rabi pulse of India after chick pea and lentil. Garden Pea (*Pisum sativum* L.) (2n=14) probably originated in Mediterranean region of Europe and Western Asia (Vavilov, 1926) including North West India, Pakistan and Afghanistan. It belongs to *Papilionoidae* subfamily of legumes. It is one of the most important winter vegetable crops grown on commercial scale all over the world. The plant is a semi-erect herbaceous annual but may climb if support is available, have typical tap root system. It may reach a height of 200 cm but normally the height varies from 30- 200 cm.

It has succulent, slender, upright and hollow stem with pinnately compound leaves with one to three leaflet pair and terminally branched tendrils. Raceme type inflorescence arising from axils of leaves having typical individual papilionaceous flowers are characteristic feature of pea plant. The fruit is straight or curved pod with 4 to 9 seeds. The seed vary in shape. It could be round and smooth or may be angular or wrinkled. The color varies from green yellow to grey and brown. There are two forms of cultivated pea, the field pea (*P. arvense* L.) and the garden pea (*P. sativum* L.). It seems probable that garden pea was derived by selection from field pea (Smartt, 1976). Pea is a leguminous crop i.e. it has symbiotic nitrogen fixing bacteria in its root nodules. Symbiotic association of roots of pea plant with *Rhizobium leguminosarum* fixes nitrogen in the soil and adds to soil fertility, improves productivity of the successive crops without the added expense of supplemental fertilizer. The early maturing pea varieties fits well between crop rotations of rice- wheat and rice-maize. Pea is highly nutritive and very versatile crop grown for fresh green peas, tender green pods, dried seeds, and foliage (Duke, 1981). It contains high percentage of digestible proteins, carbohydrates, fats along with minerals (Ca, P and Mg) and vitamins A, B and C. They are commonly consumed in green fresh form but frozen and canned peas are also becoming very popular because of its all- season availability. Ripe dried seeds are consumed as whole, split or made into flour. The common preparations made from dried peas are dal and chhola. The dried peas are low in anti-nutritional factors and rich in high quality starch, protein and oligosides (Dhall, 2017). The crop is subjected to a number of yields deteriorating factors like diseases and environmental stress due to ever changing climate. It reduces both yield and quality. Various diseases that affect the plant can be categorized into fungal, bacterial, viral diseases and nutritional deficiencies and toxicity. There are a lot of major and minor diseases associated with the plant, the most commonly observed disease includes powdery mildew [*Erysiphe pisi* Syd. (syn. *E. polygoni* DC)], downy mildew (*Pernospora pisi*), leaf blight or alternaria blight (*Alternaria alternata* (Fr.) Keissl.), ascochyta blight or black spot (*Ascochyta pisi*), rust (*Uromyces fabae*), wilt of pea (*Fusarium oxysporum* f. sp. *pisi*), bacterial blight (*Pseudomonas pisi*), pea enation mosaic virus (PEMV), pea mosaic virus (PMV) and pea early browning virus (PEBV) (Davis and Shehata 1985; Muehlbauer *et al.*, 1995; Kraft *et*

al. 1998) [24, 25, 26]. Alternaria blight of pea is a fungal disease caused by *Alternaria alternata* (Fr.) Keissl which infects a small number of grain legume species. In U.P. the disease appears in moderate to severe form every year and causes significant yield loss especially during the years when winter rains are frequent.

Infection of host plants occur through air and seed borne transmission or planting into infected soil, where rain splash or leaves coming in direct contact with soil leads to infection. Initial symptoms are small lesions on the leaves and seed pods of pea, which grow in size overtime. Under heavy pathogen load the infection and symptoms can spread to the stems and pods where it can have a detrimental effect on seed quantity and quality. (Murray, 2009) [32]. The fungus is hemi-biotrophic and shows high genetic variability. It survives in plant debris and can be effectively transmitted through seeds, and has wide host range as well as has a broad ecological distribution. Eco-friendly and sustainable strategies for management of Alternaria blight has been reported in various other crop such as mustard and pigeon pea. Alternaria blight was considered a minor disease of pea but now a days, there is wide spread occurrence of Alternaria blight of pea in severe conditions in different pea growing areas in U.P. and parts of country.

Materials and method

The effect of five bio-agents and eight chemicals were tested for their efficacy against *Alternaria alternata* under *in vitro* condition. Different bio-agents were isolated from soil by serial dilution method. Chemicals were procured from store room, in the Department of Plant Pathology of Agricultural Research Farm field area Dev Bhoomi Uttarakhand University, Dehradun, Uttarakhand

Table 1: List of bio agents used *in vitro* against *Alternaria alternata in vitro*

S. No.	Treatments	Bio agents
1	T ₁	<i>Trichoderma viride</i>
2	T ₂	<i>Trichoderma harzianum</i>
3	T ₃	<i>Chaetomium globosum</i>
4	T ₄	<i>Bacillus subtilis</i>
5	T ₅	<i>Pseudomonas fluorescence</i>
6	T ₆	Control

Bioassay test was done by poisoned food technique (Schmitz, 1930) in the laboratory to find out the toxicity on fungi of different fungicides against the pathogen. The efficacy of eight fungicide (systemic and non-systemic) at different concentrations were assayed. The trade name, common name and concentration of fungicides used in the experiments are given in Table 2. The required concentrations of chemicals were prepared and incorporated into sterilized, cooled Potato Dextrose Agar. Twenty ml of medium was poured into 90 mm sterilized Petri plates and all plates were inoculated with actively growing 5 mm mycelial disc of *Alternaria alternata*. Three replications were maintained for each treatment. These plates were incubated at 26±1°C for five days in an incubator and colony diameter was recorded.

Table 2: List of fungicide used *in vitro* for evaluation against *Alternaria alternata*

S. No.	Treatments	Common Name	Trade Name (a.i.)	Concentration (in ppm)
1	T ₁	Thiifluzamide	Pulsor 24% SC	50, 100, 150
2	T ₂	Propiconazole	Tilt 25% EC	50, 100, 150
3	T ₃	Hexaconazole	Hexon 5% SC	50, 100, 150
4	T ₄	Thiophanate Methyl	Milduvip 70% WP	50, 100, 150
5	T ₅	Copper oxychloride	Blitox 50% WP	50, 100, 150
6	T ₆	Mancozeb	Indofil M-45	50, 100, 150
7	T ₇	Carbendazim 12% + Mancozeb 63%	Policy WP	50, 100, 150
8	T ₈	Chlorothalonil	Kavach 78% WP	50, 100, 150
9	T ₉	Control		

Six different plants were selected for the study. Mature leaves were collected from at least five different individual plants from campus of Agricultural Research Farm field area Dev Bhoomi Uttarakhand University, Dehradun, Uttarakhand. The leaves (200g) were properly washed with distilled water to remove any dirt adhering to it followed by surface sterilization of leaves in 0.1% sodium hypochlorite solution and washing thrice with distilled water. Then the plant part along with equal amount of water were macerated in sterilized mortar and pestle. The macerated extract was filtered through three-folded muslin cloth to remove fibrous

and suspended material, this extract was subjected to centrifugation at 12,000 rpm for 10 minutes. The pellets were discarded and the required amount of aqueous extract were mixed with sterilized PDA. 20 ml of poisoned media was poured into 90 mm sterilized petri plates and allowed to solidify in aseptic condition. All plates were inoculated with actively growing 5 mm mycelial disc of *Alternaria alternata*. Three replications were maintained for each treatment. These plates were incubated at 26±1°C for five days in a B.O.D. Incubator and colony diameter was recorded.

Table 3: List of different Plant extracts against the pathogen

T ₁ - Ajwain seed extract @ 5% concentration
T ₂ - Ajwain seed extract @ 10% concentration
T ₃ -Garlic clove extract @ 5% concentration
T ₄ - Garlic clove extract @ 10% concentration
T ₅ - Neem leaf extract @ 5% concentration
T ₆ - Neem leaf extract @ 10% concentration
T ₇ - Tulsi leaf extract @ 5% concentration
T ₈ - Tulsi leaf extract @ 10% concentration
T ₉ -Bael leaf extract @ 5% concentration
T ₁₀ -Bael leaf extract @ 10% concentration
T ₁₁ -Bhang leaf extract @ 5% concentration
T ₁₂ -Bhang leaf extract @ 10% concentration
T ₁₃ - Control

The field experiments for integrated disease management were conducted at Agricultural Research Farm field area Dev Bhoomi Uttarakhand University, Dehradun, Uttarakhand during rabi season of 2024-2025 in Randomized Block Design (RBD) with three replications. Plot size was 4.0 x 3.0 m² with 30cm inter row spacing. Sowing was done in the month of November and harvested on maturity in the month of March. The recommended seed rate of pea is 80kg/ha. 9.6 kg seed were sown per plot manually in a line at a depth of 8 cm. The row-to-row distance between pea was 30 cm and plant to plant distance

was 15cm after placement in furrows seeds were covered with soil. Necessary treatments were done prior to seed sowing. The recommended dose of fertilizer was applied as band placement at the time of sowing. Thinning was done 20 days after sowing to maintain the plant-to-plant distance of 15cm. Treatments were done in order to manage the disease. For evaluating the efficacy of the treatments against the *Alternaria alternata* untreated plot was taken as check/control plot. The treatment details of the experiments are given in Table 4

Table 4: Integrated disease management treatments details

S. No	Treatments	Treatments Details
1.	T ₁	Foliar spray of Carbendazim 0.1%
2.	T ₂	Foliar spray of Mancozeb 0.25%
3.	T ₃	Application of Mancozeb + Azoxystrobin @ 0.1%
4.	T ₄	Foliar spray of Hexaconazole 0.1%
5.	T ₅	Soil application of <i>Trichoderma harzianum</i> [1×10 ⁷ CFU @10 g m ⁻²]
6.	T ₆	Foliar spray of Propiconazole 0.1%
7.	T ₇	Spray of Nema-mrat @10%
8.	T ₈	Soil application of <i>Trichoderma harzianum</i> [1×10 ⁷ CFU @10 g m ⁻²] + FYM. (@ 2.5 kg m ⁻²)
9.	T ₉	Foliar spray of Copper-oxychloride
10.	T ₁₀	Spray of Ajwain seed extract @ 5.0% concentration
11.	T ₁₁	Control

Table 5: Effect of different bioagents on the radial growth of *Alternaria alternata*

Treatments	Inhibition after 48 hours		Inhibition after 96 hours		Inhibition after 144 hours	
	Radial Growth of pathogen (mm)	% Inhibition	Radial Growth of pathogen (mm)	% Inhibition	Radial Growth of pathogen (mm)	% Inhibition
T ₁ - Trichoderma viride	15.00	25.00	17.00	59.52	22.00	75.56
T ₂ - Trichoderma harzianum	14.50	27.50	16.50	60.71	21.50	76.11
T ₃ - Chaetomium globosum	12.00	40.00	13.00	69.05	17.00	81.11
T ₄ - Bacillus subtilis	17.50	12.50	29.00	30.95	35.00	61.11
T ₅ - Pseudomonas fluorescens	13.50	32.50	15.50	63.10	20.00	77.78
T ₆ - Control	20.00	—	42.00	—	90.00	—
SE(m)	—	1.024	—	0.845	—	0.592
CD	—	1.801	—	1.614	—	1.765

Table 6 Effect of different fungicides on the radial growth of *Alternaria Alternata* @ 50 ppm *in vitro*

Treatments	Inhibition after 48 hours		Inhibition after 96 hours		Inhibition after 144 hours	
	Radial Growth of pathogen (mm)	% Inhibition	Radial Growth of pathogen (mm)	% Inhibition	Radial Growth of pathogen (mm)	% Inhibition
Thiabendazole (T ₁)	10	50.00	13	67.50	16	73.33
Propiconazole (T ₂)	8	60.00	10	75.00	12	80.00
Hexaconazole (T ₃)	6	70.00	7	82.50	8	86.67
Thiophanate Methyl (T ₄)	11	45.00	14	65.00	18	70.00
Copper oxychloride (T ₅)	14	30.00	16	60.00	17	71.67
Mancozeb (T ₆)	9	55.00	10	75.00	13	78.33
Carbendazim 12% + Mancozeb 63% (T ₇)	7	65.00	9	77.50	11	81.67
Chlorothalonil (T ₈)	11	45.00	13	67.50	14	76.67
Control (T ₉)	20	—	40	—	60	—
SE(m)	—	0.765	—	0.814	—	0.853
CD (5%)	—	1.498	—	1.543	—	1.612

Table 7: Effect of Different Fungicides on Radial Growth of *Alternaria alternata* @100 ppm *in vitro*

Treatment	Radial Growth (mm)	% Inhibition	Radial Growth (mm)	% Inhibition	Radial Growth (mm)	% Inhibition
	After 48 hours		After 96 hours		After 144 hours	
T ₁ - Thiabendazole	7	65.00	10	75.00	12	80.00
T ₂ - Propiconazole	5	75.00	7	82.50	8	86.67
T ₃ - Hexaconazole	3	85.00	4	90.00	5	91.67
T ₄ - Thiophanate Methyl	10	50.00	13	67.50	16	73.33
T ₅ - Copper Oxychloride	11	45.00	15	62.50	17	71.67
T ₆ - Mancozeb	7	65.00	10	75.00	13	78.33
T ₇ - Carbendazim 12% + Mancozeb 63%	4	80.00	6	85.00	7	88.33
T ₈ - Chlorothalonil	8	60.00	11	72.50	13	78.33
T ₉ - Control	20	—	40	—	60	—
SE(m)	—	0.705	—	0.732	—	0.790
CD (5%)	—	1.462	—	1.512	—	1.584

Table 8: Effect of different fungicides on the radial growth of *Alternaria Alternata* @ 150 ppm *in vitro*

Treatments	Inhibition after 48 hours		Inhibition after 96 hours		Inhibition after 144 hours	
	Radial Growth of pathogen (mm)	% Inhibition	Radial Growth of pathogen (mm)	% Inhibition	Radial Growth of pathogen (mm)	% Inhibition
Thiabendazole (T ₁)	8	60.00	11	72.50	13	78.33
Propiconazole (T ₂)	6	70.00	8	80.00	9	85.00
Hexaconazole (T ₃)	4	80.00	5	87.50	6	90.00
Thiophanate Methyl (T ₄)	9	55.00	14	65.00	15	75.00
Copper oxychloride (T ₅)	10	50.00	12	70.00	14	76.67
Mancozeb (T ₆)	6	70.00	9	77.50	11	81.67
Carbendazim 12% +	5	75.00	7	82.50	8	86.67

Mancozeb 63% (T ₇)						
Chlorothalonil (T ₈)	9	55.00	11	72.50	12	80.00
Control (T ₉)	20	—	40	—	60	—
SE(m)	—	0.689	—	0.755	—	0.812
CD (5%)	—	1.423	—	1.506	—	1.574

Table 9: Effect of different plant extracts on the mycelial growth of *Alternaria alternata* @ 5% and 10% concentration

Treatments	Inhibition after 48 hours		Inhibition after 96 hours		Inhibition after 144 hours	
	Colony diameter (mm)	% Inhibition	Colony diameter (mm)	% Inhibition	Colony diameter (mm)	% Inhibition
T ₁ - Ajwain seed extract @ 5% concentration	21	30.00	29	35.56	37	58.89
T ₂ - Ajwain seed extract @ 10% concentration	16	46.67	21	53.33	27	70.00
T ₃ -Garlic clove extract @ 5% concentration	13	56.67	17	62.22	22	75.56
T ₄ - Garlic clove extract @ 10% concentration	10	66.67	12	73.33	15	83.33
T ₅ - Neem leaf extract @ 5% concentration	26	13.33	31	31.11	47	47.78
T ₆ - Neem leaf extract @ 10% concentration	22	26.67	30	33.33	41	54.44
T ₇ - Tulsi leaf extract @ 5% concentration	27	10.00	33	26.67	46	48.89
T ₈ - Tulsi leaf extract @ 10% concentration	24	20.00	31	31.11	43	52.22
T ₉ -Bael leaf extract @ 5% concentration	29	3.33	36	20.00	51	43.33
T ₁₀ -Bael leaf extract @ 10% concentration	28	6.67	35	22.22	48	46.67
T ₁₁ -Bhang leaf extract @ 5% concentration	17	43.33	22	51.11	30	66.67
T ₁₂ -Bhang leaf extract @ 10% concentration	12	60.00	16	64.44	21	76.67
T ₁₃ - Control	30	—	45	—	90	—
SE(m)	—	0.812	—	0.867	—	0.910
CD (5%)	—	1.592	—	1.603	—	1.622

Table 10: Integrated disease management of *Alternaria* blight of pea under field conditions

Treatment	Treatments Details	Diseases Incidence (%)	Yield (q/ha)	Test weight (gm)
T ₁	Foliar spray of Carbendazim 0.1%	36.12	14.95	168.4
T ₂	Foliar spray of Mancozeb 0.25%	37.45	14.60	166.9
T ₃	Foliar spray of Mancozeb + Azoxystrobin @ 0.1%	26.18	16.90	173.7
T ₄	Foliar spray of Hexaconazole 0.1%	22.44	18.30	175.8
T ₅	Soil application of <i>Trichoderma harzianum</i> [1×10^7 CFU @10 g m ⁻²]	35.88	14.75	161.5
T ₆	Foliar spray of Propiconazole 0.1%	34.67	15.10	168.9
T ₇	Spray of Nema-mrat @ 10% concentration	29.75	16.45	172.6
T ₈	Soil application of <i>Trichoderma harzianum</i> [1×10^7 CFU @10 g m ⁻²] + FYM. (@ 2.5 kg m ⁻²)	28.55	16.20	171.9
T ₉	Foliar spray of copper-oxychloride	32.78	15.75	170.1
T ₁₀	Spray of Ajwain seed extract @ 5.0% concentration	49.20	13.60	159.7
T ₁₁	Control	58.40	11.75	148.6
SE(m)		0.634	0.830	0.972
CD		1.376	1.748	1.687

In vitro effect of biocontrol agents on the growth of *Alternaria alternata*

Antagonism of 5 bioagents were evaluated for their efficacy against *Alternaria alternata* through dual culture technique as explained in material and methods. All five bioagents reduced the growth of *Alternaria alternata* significantly as

compared to control. *Chaetomium globosum* (80.00%) followed by *Pseudomonas fluorescense* (78.89%) and *Trichoderma harzianum* (77.78%) showed maximum inhibition. The result of the experiment is presented in Table- 5, fig-1. The inhibition of mycelial growth of pathogen by bio agents was recorded after 48, 96, and 144

hrs. The result revealed that there was significant mycelial growth inhibition of *Alternaria alternata* by all the tested biocontrol agents. The maximum mycelial growth inhibition was recorded by *Chaetomium globosum* (80.00%) which was significantly superior to all the tested bioagents, followed by and *Pseudomonas fluorescens* (78.89%) and *Trichoderma harzianum* (76.67%). The minimum mycelial growth inhibition was recorded by *Bacillus subtilis* (60.00%) followed by *Trichoderma viride* (76.67%) at 144 hours.

In vitro* screening of fungicides against *Alternaria alternata

An *in vitro* experiment was performed to find out efficacy of 8 different fungicides viz., Thifluzamide 24% SC, Propiconazole 25% EC, Hexaconazole 5% SC, Thiophanate Methyl 70% WP, Copper oxychloride, Mancozeb 75% WP, Carbendazim 12% + Mancozeb 63% and Chlorothalonil 75% WP at three different concentrations of 50, 100 and 150 ppm by Poisoned food technique. Result in tabulated form have been presented in Table No. 6, 7, 8 and Fig. No. 2, 3, 4 The radial growth of pathogen was recorded at 48 hours, 96 hours and 144 hours respectively after inoculation. At all three concentrations i.e., 50 ppm, 100ppm and 150ppm Hexaconazole 5% SC (88.30%, 90.00%, 91.67% respectively), Propiconazole 25% EC (83.30%, 85.00%, 88.33% respectively), exhibited maximum inhibition of *Alternaria alternata*. At 100 and 150ppm concentration Carbendazim 12% + Mancozeb 63% (83.00% and 85.00% respectively) also gave promising results. The results revealed that there was significant per cent inhibition of mycelial growth of *Alternaria alternata* with tested fungicides. The least inhibition per cent of mycelial growth was recorded (73.33%, 75.00% and 76.67%) Thiophanate Methyl 70% WP at all three concentrations (50ppm, 75ppm and 100ppm) after 144 hrs. incubation respectively.

In vitro* screening of different Plant extracts against *Alternaria alternata

An *in vitro* experiment was conducted to find out efficacy of 6 different plant extracts at two different concentrations i.e., 5% and 10% concentration. Aqueous plant extracts of following plants- ajwain seeds, garlic clove, neem leaf, tulsi leaf, bael leaf, bhang leaf was prepared as mentioned in materials and methods and their efficacy was evaluated. Garlic clove extract found to be most efficient against *Alternaria alternata* 82.22%, 73.33% growth inhibition was recorded by garlic clove extract at 10% and 5% w/w concentration respectively followed by 10% Bhang leaf extract (75.56%) and 10% Ajwain seed extract (73.33%). The results revealed that there is significant difference in per cent inhibition of mycelial growth of *Alternaria alternata* with tested plant extracts. Result in tabulated form have been presented in Table No. 8 and Fig. No. 5 Bael leaf extract at 5% concentration was found to be least effective with 44.44% inhibition of mycelial growth followed by 5% tulsi leaf extract (50.00%).

Integrated disease management under field conditions

Field experiment were conducted during *rabi* season 2024-2025 at Agricultural Research Farm field area Dev Bhoomi Uttarakhand University, Dehradun, Uttarakhand. The results in the Table No. 9 & fig - 6 revealed that all treatments significantly reduced the percent disease incidence,

increased the yield and test weight. The lowest percent disease incidence 20.15% was recorded in (T₄) Foliar application of Hexaconazole (@ 500 ml/ha after 15 DAS) followed by 23.39% in (T₃) Foliar spray of Mancozeb 0.25% + Azoxystrobin 0.1%. The highest percent disease incidence 47.35% was recorded in (T₁₀) Spray of Ajwain seed extract @ 5.0% concentration followed by 33.89% in (T₆) Soil application of *Trichoderma harzianum* [1×10^7 CFU @10 g m⁻²] compared to control (55.76%). The maximum yield was recorded 18.74 q/ha and test weight 177.4 g in (T₄) Foliar spray of Hexaconazole @ 500 ml/ha 15 DAS followed by 17.25 q/ha and test weight 175.3 in (T₃) Foliar spray of Mancozeb 0.25% + Azoxystrobin @ 0.1% concentration. The minimum yield and test weight 15.02 q ha⁻¹ and 162.3g and was recorded in (T₁₀) Spray of Ajwain seed extract @ 5.0% concentration was recorded in (T₂) Soil application of *Trichoderma harzianum* [1×10^7 CFU @10 g m⁻²] compared to control (12.06 q ha⁻¹) and (150.40 g) respectively.

Conclusion

On the basis of all the experiments and analysis of results from this work we came to the followings conclusions

In vitro evaluation of biocontrol agents suggested that *Chaetomium globosum* showed maximum inhibition the mycelial growth of pathogen followed by *Pseudomonas fluorescens* and *Trichoderma harzianum*. *In vitro* evaluation of fungicide suggested Hexaconazole 5% SC and Propiconazole 25% EC exhibited maximum inhibition of *Alternaria alternata* followed by Carbendazim 12% + Mancozeb 63% also gave promising results. *In vitro* evaluation of different plant extract suggested Garlic clove extract to exhibit maximum inhibition of *Alternaria alternata* followed by 10% Bhang leaf extract. For integrated disease management of disease, foliar application Hexaconazole (@ 500 ml/ha after 15 DAS was found most effective to reduce the disease incidence of alternaria blight in pea and increase the yield of pea followed by Foliar spray of Mancozeb 0.25% + Azoxystrobin 0.1%.

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