



## Evaluation of botanicals and fungicides for management of *Alternaria* leaf blight in carrot

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**ABSTRACT:** *Alternaria* leaf blight caused by *Alternaria alternata* is one of the most important diseases affecting carrot production globally. The present investigation was conducted to assess the efficacy of certain botanicals and fungicides to manage leaf blight under *in vitro* and pot culture conditions. The garlic extract followed by neem extract at 10% concentration showed maximum inhibition of mycelial growth to the tune of 94.14 and 92.12 per cent respectively. Under pot culture conditions too the results were comparable where the foliar spray of garlic extract (24.02%) resulted in the least disease intensity. Fungicides *viz.*, difenoconazole and hexaconazole at 100 ppm showed the maximum inhibition of mycelial growth under *in vitro* conditions, recording 100% and 98.75% inhibition, respectively. In pot culture evaluation also difenoconazole resulted in the lowest disease intensity (16.05%), followed by hexaconazole (21.05%). These findings highlight the potential of neem and garlic extract as well as fungicide, difenoconazole for managing *Alternaria* leaf blight in carrot.

**Keywords:** *Alternaria* leaf blight, carrot, plant extracts, neem, garlic, fungicides

### INTRODUCTION

Carrot (*Daucus carota* subsp. *sativus*) is one of the important vegetable root crops, valued for its medicinal, health, and nutritional significance. It is cultivated year-round in temperate regions and during the winter season in tropical and subtropical areas. Carrots are an abundant source of  $\alpha$ - and  $\beta$ -carotene, which serve as precursors of vitamin A (Pantastica, 1975; Anjum and Amjad, 2002). They are also rich in essential nutrients such as thiamine and riboflavin (Gopalan *et al.*, 1985), and contain appreciable amounts of iron, vitamins A and B, ascorbic acid, and sugars (Yawalkar, 1985). A large variety of fungi, as well as some bacterial diseases and a few physiological issues, are reported in carrot crop. *Alternaria* leaf blight (ALB) of carrot, caused by *Alternaria alternata*, *A. tenuissima* and *A. radicina*, is a globally prevalent disease and represents one of the most significant constraints in carrot production worldwide (Strandberg, 1992; Tülek and Dolar, 2015). Gugino *et al.* (2004) reported that ALB lesions on carrot leaves are typically small, irregular in shape, and more numerous along the margins and tips of leaflets, with coloration ranging from dark brown to black. On petioles, ALB produces greenish-brown lesions that usually develop

along the leaflet margins. Older lesions may become dark brown and may have a chlorotic halo around the periphery of the lesion. Under congenial environmental conditions, the lesions gradually coalesce and develop a blighted (burned) appearance. Subsequently, the affected leaves wither and die, eventually drying up or abscising from the plant. Lesions may also occur on petioles, where they can enlarge, girdle, and ultimately kill the leaves.

Rajasthan has significant area under carrot cultivation but productivity remains comparatively low. *Alternaria* leaf blight is a major constraint, causing substantial reductions in marketable yield and economic losses through decreased root size and compromised quality. Suitable methods which are ecofriendly, economically feasible, and safe must be selected. Plant-based extracts and beneficial microbes have emerged as eco-friendly alternatives for managing plant pathogens considering the consumer awareness on residue free foods (Bora and Bora, 2021; Sharma and Bora, 2025). Extracts from garlic (*Allium sativum*) and neem (*Azadirachta indica*) are well-known for their antifungal properties, attributed to bioactive compounds like allicin and azadirachtin, respectively (Choudhary *et al.*, 2014). Chemical fungicides remain a primary control measure against ALB

due to their immediate efficacy and ease of application. Botanicals such as garlic and neem have been evaluated against *A. alternata* in other crops, but their efficacy against Alternaria leaf blight of carrot under Rajasthan conditions has not been reported. Moreover, most of the fungicides currently used lack a specific label claim for the management of *Alternaria* leaf blight in carrot. Hence, the present study was undertaken to evaluate the efficacy of selected fungicides and plant extracts against *A. alternata* under *in vitro* and *in vivo* conditions.

## MATERIALS AND METHODS

### Experimental site and sample collection

Carrot leaves exhibiting typical disease symptoms were collected from farmers' fields in the Jobner vicinity (26.96° N, 75.37° E), Rajasthan, India. The infected samples were brought to the laboratory for preliminary microscopic examination, followed by incubation in a humid chamber to induce sporulation on naturally infected carrot tissues.

### Isolation and pathogenicity

For pathogen isolation, small sections of infected leaf tissue, including adjacent apparently healthy portions, were excised from the lesion margins. Rapid and reliable surface sterilization of infected carrot leaf tissues was achieved by immersing the tissues in 0.1 per cent mercuric chloride (HgCl<sub>2</sub>) for 1–2 min, which effectively eliminated epiphytic microorganisms while retaining the internal pathogen, enabling successful isolation of *A. alternata* (Khodke *et al.*, 2000; Nene and Thapliyal, 1979). After sterilization, the tissues were thoroughly rinsed three times with sterile distilled water to remove all HgCl<sub>2</sub> residues and minimize any potential toxic effects on the pathogen. After three successive washings with sterile distilled water, the tissue pieces were inoculated onto autoclaved potato dextrose agar (PDA) medium in Petri plates and incubated at 25 ± 1 °C in a B.O.D. incubator. After 7 days of incubation mycelial growth from the control leaf bits was transplanted on fresh PDA slant using sterilized inoculation needle and again re-incubated for next days to get further mycelial growth and sporulation for their purification. Isolation of the pathogen was achieved by use of single spore and hyphal tip method. The isolate thus obtained was sub-cultured on PDA slant to maintain the growth of the fungus.

The culture was maintained at refrigerator at 10°C and need based sub-culturing was made. For pathogenicity

test, 42 days old carrot plants were sprayed with spore suspension (1 × 10<sup>5</sup> spores/ml) of *A. alternata*. The control was also sustained by using only the sterilized distilled water. Visual observations were recorded from the time of disease initiation until the appearance of characteristic symptoms and were compared with the control. The pathogen was re-isolated from artificially inoculated plants, and the resulting culture was compared with the original isolate to confirm pathogen identity.

### Characterization and Identification of the pathogen

The isolated pathogen was identified based on morpho-cultural characterization under laboratory conditions. The sporulating pure culture was examined microscopically (40×) to record morphological characters such as the size, shape, colour and septation of conidia, along with the nature of conidiophores. Cultural characteristics were recorded on PDA by noting colony growth pattern, texture, margin, and pigmentation on both the upper surface and reverse side of the plate. The morphological and cultural features observed were compared with standard descriptions, and the isolate was identified as *Alternaria alternata*.

### *In vitro* efficacy of plant extracts

A laboratory experiment was conducted to evaluate the mycotoxic effect of five plant extracts, namely garlic (*Allium sativum*), ginger (*Zingiber officinale*), neem (*Azadirachta indica*), tulsi (*Ocimum sanctum*), and turmeric (*Curcuma longa*), against the test pathogen (Table 2). The extracts were tested at 5 and 10 per cent concentrations. Fresh plant materials-garlic cloves; ginger and turmeric rhizomes; and leaves of neem and tulsi-were weighed (100 g each) and washed thoroughly with distilled water two to three times. Prior to extraction, the plant materials were ground separately with 1000 mL of sterile distilled water. The homogenate was filtered by squeezing through double-layered sterile cheese cloth to obtain the crude aqueous extract. The obtained crude extract was considered as 100 per cent concentration. It was further filtered through muslin cloth and centrifuged at 5000 rpm for 30 min to remove particulate matter. The supernatant was collected and sterilized for subsequent use. To obtain stock solutions at the required concentrations, appropriate volumes of the plant extracts were incorporated into PDA. Sterile distilled water was used as the carrier for plant extracts and bioactive compounds, and further dilutions were prepared to achieve the desired concentrations. A water-

only control was maintained in which no plant extract was added; however, all other procedures, including grinding, filtration, centrifugation, and mixing with PDA, were followed identically.

Biological control of mycelial growth of *A. alternata* was determined by poisoned food technique (Nene and Thapliyal, 1979). To make a specific concentration of plant extracts, the 5 ml of each plant extract was mixed in 95 mL of melted PDA just before pouring onto sterilized petriplates to prepare 5% poisoned media. Similarly, 10ml extract was mixed thoroughly with 90 ml media to prepare 10% poisoned media to evaluate efficacy of botanicals (Bora *et al.*, 2021). In the media, 5 mm disc of 7 days old culture of the pathogen was placed on it using sterilized cork borer. All these operations were done under sterilized conditions in laminar air flow. The inoculated petri plates were incubated at 25± 1°C for seven days. A control was also maintained where medium was not supplemented with any of the plant extracts. The experiment was set up under completely randomised design which included three replications. Colony diameter (two diagonals) was determined after incubation had gone for seven days.

The mycelial growth of the test fungus was measured and percentage growth inhibition determined using the formula of Vincent (1947) thus:

$$\text{Percent growth inhibition (I)} = \frac{(C-T)}{C} \times 100$$

where,

I = Percent mycelial inhibition zone

C= Diameter of colony in check (average of both diagonals)

T= Diameter of colony in treatment (average of both diagonals)

**Table 1. Details of the disease rating scale**

S. No.	Description	Grade
1	No incidence/ healthy	0
2	Symptoms on leaf tip and leaves only	1
3	Symptoms on leaves and petiole	2
4	Symptoms on leaves, petiole and stem	3
5	Symptoms on leaves, petiole, stem and inflorescence	4
6	Seed	5

***In vivo* efficacy of plant extracts**

The experiment was conducted under net house conditions at the Department of Plant Pathology, S.K.N. College of Agriculture, Jobner, Jaipur, in a Completely Randomized Design (CRD) with four replications. Treatments were maintained in earthen pots (9 × 12 inches) using a local carrot variety, and recommended agronomic practices were followed throughout the experiment. The post soils were sterilized for 3 consecutive days to rule out the presence of any other pathogenic microbe. The crop was artificially inoculated with the pathogen at 45 days after sowing (DAS). A single foliar spray of each plant extract at 10% concentration was applied at 55 DAS (i.e., 10 days after inoculation). An inoculated untreated control was maintained for comparison, in which plants were inoculated but not sprayed with plant extracts. Disease intensity was recorded at 65 days after sowing (DAS), i.e., 20 days after inoculation (DAI), using a 0–5 disease rating scale.

The disease intensity was noted on 0-5 scale proposed by Jaiman *et al.* (2013) with some modifications as mentioned in (Table 1). Five plants at random were rated from each pot based on the above description and the percent disease intensity (PDI) was determined as below (Wheeler, 1969).

$$\text{PDI} = \frac{\text{Sum of all individual ratings}}{\text{Number of plants observed} \times \text{Maximum disease rating scale}} \times 100$$

The percent disease control (PDC) was calculated by using the following formula:

$$\text{PDC} = \frac{\text{Disease in control} - \text{Disease in treatment}}{\text{Disease in control}} \times 100$$

### ***In vitro* efficacy of fungicides**

*In vitro* mycelial growth inhibition of *A. alternata* was evaluated using the poisoned food technique (Nene and Thapliyal, 1979). Commercial formulations of six fungicides *viz.*, mancozeb (75% WP), azoxystrobin (23% SC), hexaconazole (5% EC), difenoconazole (25% EC), carbendazim 12% + mancozeb 63% WP and chlorothalonil (75% WP) were evaluated at 50, 100, and 250 ppm (expressed on an active ingredient basis). The required quantity of each fungicide was mixed thoroughly with sterilized molten potato dextrose agar (PDA) and poured into Petri plates. Plates were allowed to solidify and surface-dry at room temperature ( $\approx 30$ – $60$  min) before inoculation. Each plate was inoculated with a 5-mm mycelial disc cut from the margin of a 7-day-old culture of the pathogen using a sterilized corkborer and incubated at  $25 \pm 1^\circ\text{C}$  for 7 days. Control plates contained PDA amended with an equal volume of sterile distilled water (water-only control).

The growth of the test fungus was assessed by the growth of its mycelial mat, and percentage growth inhibition was determined using the formula of Vincent (1947). It was conducted in a completely randomized design with an experiment replicated three times.

$$\text{Percent growth inhibition} = \frac{(C-T)}{C} \times 100$$

Where, C = radial mycelial growth (mm) in the control and T = radial mycelial growth (mm) in the treatment (fungicide amended medium).

### ***In vivo* efficacy of fungicides against *Alternaria alternata***

The experiment was conducted under net house conditions at the Department of Plant Pathology, S.K.N. College of Agriculture, Jobner, Jaipur, in a Completely Randomized Design (CRD) with three replications. Treatments were maintained in earthen pots with sterilized soil ( $9 \times 12$  inches) using a susceptible local carrot cultivar. Plants were artificially inoculated with the pathogen at 45 days after sowing (DAS) following the procedure described in 2.2. A single foliar spray of the respective fungicide treatment was applied at 55 DAS (*i.e.*, 10 days after inoculation). An inoculated untreated control (experimental check) was maintained for comparison, in which plants were inoculated but not sprayed with fungicide. Disease intensity was recorded at 65 DAS using a 0–5 disease rating scale.

### **Statistical Analysis**

The data were subjected to analysis of variance (ANOVA), and significant differences among treatments were determined using the Critical Difference (CD) test at a 5% probability level ( $p=0.05$ ).

### **RESULTS and DISCUSSION**

The isolate obtained from diseased carrot leaves produced a fast-growing colony on PDA, which was initially whitish and later became olivaceous to dark brown with a velvety appearance. The reverse side of the colony developed dark brown to black pigmentation. Microscopic examination ( $40\times$ ) of sporulating cultures revealed septate, brown conidiophores bearing conidia mostly in chains. The conidia were brown, ovoid to obclavate, and muriform with both transverse and longitudinal septa, often with a short beak. Based on these cultural and morphological characters, the pathogen was identified as *Alternaria alternata*.

Earlier reports have also documented the association of *A. alternata* with Alternaria leaf blight/leaf spot and related rot symptoms in carrot. In the pathogenicity test, inoculated carrot plants developed typical Alternaria leaf blight symptoms as dark brown to black irregular lesions that later coalesced, while control plants remained healthy. The pathogen was re-isolated from inoculated plants and matched the original culture, confirming *A. alternata* as the causal agent.

The present investigation confirmed *A. alternata* as the causal agent of Alternaria leaf blight of carrot. Diseased leaf samples collected from the farmer's fields of Jobner, S.K.N. College of Agriculture, Jaipur were successfully isolated on potato dextrose agar. The pathogen was purified using the single-spore technique and identified based on its morphological and cultural characteristics. Pathogenicity of *A. alternata* was confirmed by spray inoculation of a conidial suspension following the method of Sotero (1979). Typical disease symptoms first appeared as dark brown to black lesions along the leaf margins, which later coalesced to give a blighted or scorched appearance. These symptoms were similar to those reported by Akhtar *et al.* (2004) in tomato infected by *A. alternata*, further confirming the identity of the pathogen.

The efficacy of botanicals against *A. alternata* observed in the present study agrees with earlier reports. Garlic extract exhibited the highest inhibition

of mycelial growth, followed by neem extract. Similar results were reported by Kantwa *et al.* (2014) in groundnut leaf blight and by Bochalya *et al.* (2012) in brinjal fruit rot, where garlic extract was most effective against *A. alternata*. The antifungal activity of garlic and neem extracts has also been reported by Khan *et al.* (2015), supporting their potential as alternative disease management options. The antifungal action of phytoextracts was attributed to their bioactive compounds. Garlic (*A. sativum*) contains allicin, which disrupts lipid synthesis and enzyme activity in fungal cells by reacting with thiol groups (Ankri and Mirelman, 1999). Neem (*A. indica*) contains azadirachtin and nimbin, which inhibit spore germination and interfere with cell wall formation and

mitosis in fungi (Choudhary *et al.*, 2014). However, due to their non-systemic nature and limited persistence on leaf surfaces, these extracts provide only partial and short-term protection under field conditions.

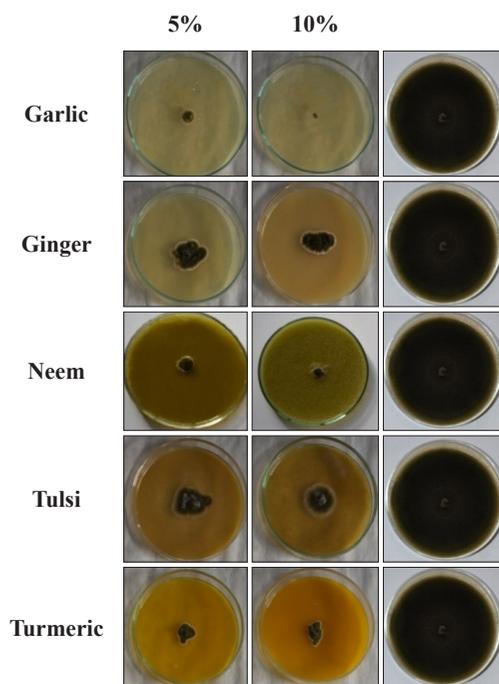
***In vitro* efficacy of plant extracts against *Alternaria alternata***

The antifungal activity of different botanicals at 5% and 10% concentrations against *A. alternata* revealed the garlic extract was found to be most effective in preventing the mycelial growth (94.14% mycelial inhibition), followed by neem (92.12%), turmeric and ginger extract (87.68%) (Table 2; Fig.1) compared to control. The significant mycelial inhibition was attributed to the presence of bioactive compounds in the extracts.

**Table 2. *In vitro* efficacy of plant extracts against *Alternaria alternata***

Common name	Scientific name	Part used	5%	10%
Garlic	<i>Allium sativum</i>	Clove	93.02 (74.68)	95.25 (77.41)
Ginger	<i>Zingiber officinale</i>	Rhizome	70.15 (56.88)	75.07 (60.05)
Neem	<i>Azadirachta indica</i>	Leaves	91.18 (72.72)	93.05 (74.71)
Tulsi	<i>Ocimum sanctum</i>	Leaves	50.50 (45.29)	56.43 (48.69)
Turmeric	<i>Curcuma longa</i>	Rhizome	87.26 (69.09)	88.10 (69.82)
Control	–	–	0.00 (0.00)	0.00 (0.00)

SEM± and CD (p = 0.05) (Factorial CRD); Plant extracts (P) (CD=1.55, p=0.05); Concentration (C) (CD=2.19, p=0.05); PxC (CD 3.3.80; p=0.05);\*Average of three replications. Figures in parentheses are angular transformed values.



**Fig. 1. Mycelial growth inhibition of *A. alternata* by plant extracts**

**Table 3. *In vivo* efficacy of plant extracts against *A. alternata***

Treatments	Dose (%)	Disease intensity* (%)	Disease control (%)
Garlic	10	24.02 (29.35)	57.51
Ginger	10	36.25 (37.02)	36.18
Neem	10	33.50 (35.37)	41.02
Tulsi	10	37.50 (37.76)	33.98
Turmeric	10	35.00 (36.27)	38.38
Control	-	56.80 (48.91)	0.00
SEm+		1.00	
CD (p=0.05)		3.07	

\*Average of four replications

Figures given in parenthesis are angular transformed values

#### ***In vivo* efficacy of plant extracts against *Alternaria alternata***

At 10% concentration, the pots were treated with garlic extract showed minimum disease intensity (24.02%), followed by neem (33.50%) and turmeric extract (35.00%) over untreated control (56.80%) (Table 3).

#### ***In vitro* efficacy of fungicides against *Alternaria alternata***

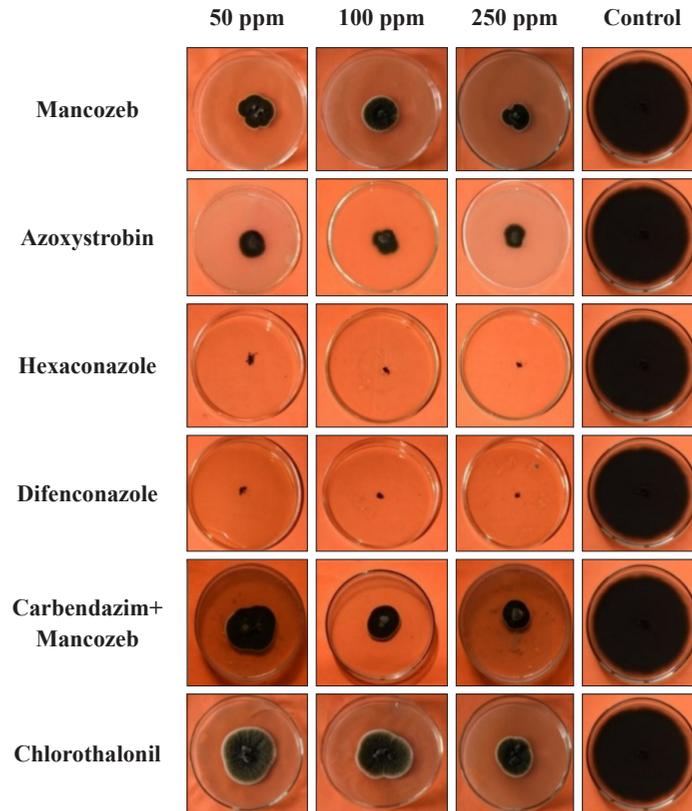
Six fungicides were evaluated at three

concentrations (50 ppm, 100 ppm and 250 ppm) under *in vitro* condition on the mycelial inhibition of *A. alternata*. Among all the fungicides, the percent reduction of mycelial growth was highest with difenconazole (100%) at 100 and 250 ppm, followed by hexaconazole (98.75%), azoxystrobin (91.80%) and carbendazim+mancozeb (84.35%) at 250ppm. Mancozeb (79.58%) and chlorothalonil (68.50%) was found to be the least inhibitor (Table 4; Fig. 2).

**Table 4. *In vitro* efficacy of fungicides against *Alternaria alternata***

Fungicide	50 ppm	100 ppm	250 ppm
Mancozeb	60.30 (50.94)	72.25 (58.21)	79.58 (63.14)
Azoxystrobin	77.50 (61.68)	82.10 (64.97)	91.80 (73.36)
Hexaconazole	90.00 (71.57)	95.07 (77.17)	98.75 (83.58)
Difenoconazole	98.20 (82.29)	100.00 (90.00)	100.00 (90.00)
Carbendazim + Mancozeb	66.14 (54.42)	74.10 (59.41)	84.35 (66.70)
Chlorothalonil	53.38 (46.94)	64.71 (53.55)	68.50 (55.86)
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

SEm± and CD (p = 0.05) (Factorial CRD); Fungicides (F) (CD=1.51, p=0.05); Concentration (C) (CD =2.30, p=0.05); F x C (CD =3.99; p=0.05); \*Average of three replications. Figures in parentheses are angular transformed values.



**Fig. 2. Mycelial growth inhibition of *A. alternata* under fungicide treatments**

***In vitro* efficacy of fungicides against *Alternaria alternata***

Among the fungicides applied as foliar sprays against blight, difenoconazole was the most effective, recording the lowest disease intensity (16.05%), followed by hexaconazole (21.05%). Azoxystrobin (25.25%), carbendazim + mancozeb (28.50%), and mancozeb

(32.25%) showed moderate levels of disease control, whereas chlorothalonil resulted in relatively higher disease severity (40.33%) compared with the untreated control (54.30%) (Table 5). Botanicals offer partial protection due to their contact, non-systemic nature, while systemic fungicides provide stronger and longer-lasting suppression.

**Table 5. *In vivo* efficacy of fungicides against *A. alternata***

Treatments	Dose (%)	Disease intensity* (%)	Disease control (%)
Mancozeb	0.2	32.25 (34.60)	40.61
Azoxystrobin	0.1	25.25 (30.17)	53.50
Hexaconazole	0.1	21.05 (27.31)	61.23
Difenconazole	0.1	16.05 (23.62)	70.44
Carbendazim+ Mancozeb	0.1	28.50 (32.27)	47.51
Chlorothalonil	0.1	40.33 (39.42)	25.72
Control	-	54.30 (47.47)	0.00
S <sub>Em</sub> +		0.94	
CD (p=0.05)		2.89	

\*Average of three replications ; Figures given in parenthesis are angular transformed values

Among the fungicides evaluated, difenoconazole showed the highest inhibition of mycelial growth, followed by hexaconazole. These findings are consistent with Alkseeva (2009) for *Alternaria* blight of carrot and Badri *et al.* (2013) for umbel blight of black cumin. Increasing concentrations of fungicides resulted in greater inhibition of pathogen growth as reported by Mane *et al.* (2011). Triazole fungicides inhibit ergosterol biosynthesis by blocking C-14 demethylase, leading to abnormal sterol accumulation, membrane instability, and suppression of fungal growth. Their systemic movement within plant tissues provides both protective and curative action, unlike botanicals which act mainly as surface protectants.

Under in vivo conditions, garlic extract provided significant reduction in disease severity, indicating its potential as a natural, eco-friendly component of integrated disease management. Although systemic fungicides such as difenoconazole and hexaconazole were more effective in suppressing disease development, garlic extract contributed significantly to disease control and could be particularly useful in low-input and organic production systems. Integrating botanicals with fungicides therefore offers a sustainable and balanced strategy for managing *Alternaria* leaf blight in carrot.

## CONCLUSION

The study demonstrates that both botanicals and fungicides are effective tools for managing *Alternaria* leaf blight in carrot. Among botanicals, garlic extract showed the highest bio-efficacy, indicating the potential of phytoextracts as eco-friendly disease management options. However, systemic triazole fungicides, particularly difenoconazole, provided superior and more consistent control by targeting ergosterol biosynthesis in *A. alternata*. An integrated approach combining botanicals with fungicides can reduce chemical dependence, improve sustainability, and ensure reliable disease control under varying disease pressures.

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## AUTHORS CONTRIBUTION

MG- Experimental work and data analysis; RRA- conceptualization and supervision; PB- methodology, review, and editing. All authors read and approved the final manuscript.

## CONFLICT OF INTEREST:

The authors declare that they have no conflict of interest.

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## REFERENCES

- Akhtar, K. P., Saleem, M. V., Asghar, M. and Haq, M. A. 2004. New report of *Alternaria alternata* causing leaf blight of tomato in Pakistan. *Plant Pathology*, **53**: 816.
- Alkseeva, K. L. 2009. Score for control of *Alternaria* on carrot. *Zashchitai Karantin Rastenii*, **7**: 26.
- Anjum, M. and Amjad, M. 2002. Influence of mother root size and plant spacing on carrot seed production. *Journal of Resource Science*, **13** (2): 105-112.
- Ankri, S. and Mirelman, D. 1999. Antimicrobial properties of allicin from garlic. *Microbes and Infection*, **1** (2): 125-129.
- Badri, Z. A. 2013. Evaluation of fungitoxicants against *Alternaria alternata* causing umbel blight of kala zeera (*Bunium persicum*). *Indian Phytopathology*, **66** (2): 195-198.
- Bochalya, M. S., Shekhawat, K. S., Singh, R. and Chohan, P. K. 2012. Management of *Alternaria* fruit rot of brinjal under in vitro conditions. *Biopesticides International*, **8** (2): 131-137.
- Bora, P. and Bora, L. C. 2021. Microbial antagonists and botanicals mediated disease management in tea, *Camellia sinensis* (L.) O. Kuntze: An overview. *Crop Protection*, **148**: 105711.
- Bora, P., Bora, L. C. and Bhuyan, R. P. 2021. Evaluation of some botanicals and microbial bioformulations against grey blight disease of tea (*Camellia sinensis*). *Indian Journal of Agricultural Sciences*, **91** (1): 54-57.
- Choudhary, M. I., Shaikh, R. and Khan, S. N. 2014. Bioactivity of neem compounds against plant fungal pathogens. *Journal of Plant Pathology and Microbiology*, **5** (5): 1-4.

- Choudhary, R., Sharma, S. and Mathur, K. 2014. Antifungal properties of garlic extract against *Alternaria alternata*. *Indian Phytopathology*, **67** (3): 205-208.
- Gopalan, C., Ramasastri, B. V. and Balasubramaniam, S. C. 1985. *Nutritive Value of Indian Foods*. National Institute of Nutrition, ICMR, Hyderabad, India.
- Gugino, B. K., Carroll, J., Chen, J., Ludwig, J. and Abawi, G. 2004. Carrot leaf blight diseases and their management in New York. Vegetable Integrated Pest Management, Department of Plant Pathology, Cornell University, NYSAES, Geneva.
- Jaiman, R. K., Patel, N. R., Patel, K. D., Agalodiya, A. V. and Patel, P. K. 2013. Management of Ramularia blight in fennel. *International Journal of Seed Spices*, **3** (1): 50-51.
- Kantwa, S. L., Tetarwal, J. P. and Shekawat, K. S. 2014. In vitro effect of fungicides and phyto-extracts against *Alternaria alternata* causing leaf blight of groundnut. *IOSR Journal of Agriculture and Veterinary Science*, **7** (6): 28-31.
- Khan, Z., Meena, R. S. and Kumar, S. 2015. Bioefficacy of plant extracts against mycelial growth of *Alternaria alternata* in vitro. *Journal of Mycology*, **51** (2): 134-140.
- Khodke, S. W., Pawar, R. V. and Bhopole, A. A. 2000. Pathogenicity of *Alternaria alternata* (Fr.) Keissler causing leaf spot disease of chilli. *PKV Research Journal*, **24** (2): 123.
- Mane, S. S., Sawant, D. M. and Patil, M. S. 2011. Comparative efficacy of triazole fungicides against *Alternaria alternata* in vitro. *International Journal of Plant Protection*, **4** (2): 260-263.
- Nene, Y. L. and Thapliyal, P. L. 1979. *Fungicides in Plant Disease Control*. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.
- Pantastica, E. B. 1975. Structure of fruits and vegetables. In: *Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables*. AVI Publishing Co., Westport, C.T., pp. 1-25.
- Sharma, A. and Bora, P. 2025. Engineering synthetic microbial communities to restructure the phytobiome for plant health and productivity. *World Journal of Microbiology and Biotechnology*, **41** (7): 228.
- Sotero, I. J. 1979. Pathogenicity and control of *Alternaria radicina* and *Alternaria dauci* in carrots. *New Zealand Journal of Agricultural Research*, **22**: 191-196.
- Strandberg, J. O. 1992. *Alternaria* species that attack vegetable crops: Biology and options for disease management. In: *Alternaria: Biology, Plant Disease and Metabolites* (Eds. J. Cielkowski and A. Visconti). Elsevier Science Publishers, Amsterdam, pp. 367-398.
- Tülek, S. and Dolar, F. S. 2015. Detection and identification of *Alternaria* species causing diseases of carrot in Ankara, Turkey. *Scientific Papers Series B, Horticulture*, **LIX**: 263-268.
- Vincent, J. M. 1947. The esters of 4-hydroxybenzoic acid and related compounds: Methods for studying fungistatic properties. *Journal of the Society of Chemical Industry*, **16**: 746-755.
- Wheeler, B. E. J. 1969. *An Introduction to Plant Diseases*. John Wiley and Sons Ltd., London.
- Yawalkar, K. S. 1985. *Vegetable Crops in India*. 3rd edn. Agri-Horticultural Publishing House, Nagpur.

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