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Effect of *Trichoderma viride* and Botanical Extracts on Alternaria Leaf Spot Disease of Cabbage (*Brassica oleraceae* var. *capitata* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cabbage is most important vegetable crop. This vegetable has leaf spot disease from bacteria, fugal and virus. Therefore, the present investigation on "Effect of *Trichoderma viride* and botanical extracts on alternaria leaf spot disease of cabbage (*Brassica oleraceae* var. *capitata* L.)" was

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carried out in *Rabi*-2023-24 under field conditions. The effect of treatments were evaluated on different growth parameters, disease intensity (%), yield and cost benefit ratio of cabbage.
The significantly effective in reducing disease intensity (%) was obtained in combine treatment of *Trichoderma viride* with Neem leaf extract at 45 days after transplanting (17.27 %), 60 days after transplanting (22.66 %) and 75 days after transplanting (27.34 %), with highest C:B ratio (1:2.32) followed by *Trichoderma viride* with Eucalyptus leaf extract at 45 (17.87 %), 60 days after transplanting (23.31 %) and 75 days after transplanting (28.72 %), with C:B ratio (1:2.13) and least disease intensity was recorded in *Trichoderma viride* with Garlic bulb extract at 45 days after transplanting (19.54 %), 60 days after transplanting (25.67 %) and 75 days after transplanting (33.64 %), with least C:B ratio (1:1.21) as compared to control at 45 days after transplanting (23.35 %), 60 days after transplanting (31.33 %) and 75 days after transplanting (45.38 %), with lowest C:B ratio (1:0.86).
The treatment of *Trichoderma viride* with Neem leaf extract resulted in maximum number of leaves at 45 days after transplanting (14.20), 60 days after transplanting (25.47) and 75 days after transplanting (36.27), head diameter (14.20 cm), head weight (0.69 kg) with highest yield (25.45 t/ha) followed by *Trichoderma viride* with Eucalyptus leaf extract at 45 days after transplanting (13.13), 60 days after transplanting (23.33) and 75 days after transplanting (33.73), head diameter (13.05 cm), head weight (0.65 kg) with yield (24.03 t/ha) and least number of leaves was recorded in *Trichoderma viride* with Garlic bulb extract at 45 days after transplanting (8.93), 60 days after transplanting (14.80) and 75 days after transplanting (23.33), head diameter (8.20 cm), head weight (0.49 kg) with least yield (17.99 t/ha) as compared to control at 45 days after transplanting (7.53), 60 days after transplanting (12.00) and 75 days after transplanting (20.73), minimum head diameter (7.05 cm), head weight (0.38 kg) with lowest yield (14.22 t/ha).

Keywords: Alternaria brassicae; botanical extracts; cabbage; neem leaf extract; T. viride.

1. INTRODUCTION

Cabbage (*Brassica oleraceae* var*. capitata* L.) is a leafy head vegetable belonging to Brassicaceae (Cruciferae) family. It is grouped as cole crops, which is originated from a single wild species *Brassica oleracea* var*. oleracea* (*sylvestris* L.), commonly known as wild cabbage or 'Colewort' (Balliu, 2014). "Cabbage is native of Western Europe and the northern shore of Mediterranean region" (Bose et al*.,* 2001). "The major cabbage producing states in India included West Bengal, Odisha, Gujarat, Madhya Pradesh, Assam, Bihar, Chattisgarh and Uttar Pradesh. In Uttar Pradesh, it is grown in 428 thousand hectare with a production of 348.94 thousand metric tonnes" (NHB, 2021-22).

Cabbage production is affected by many fungal, bacterial and viral diseases at different stages of growth and development like damping off, club root, downy mildew, Sclerotinia rot, black leg, black rot, soft rot and Alternaria blight or Alternaria leaf spot. Among fungal diseases; Alternaria leaf spot is a common disease incited by several species of *Alternaria*. In cabbage it is caused mainly by two species i.e. *Alternaria brassicae* (Berk.) Sacc. and *A. brassicicola* (Schweintiz) Wiltshire, they can survive saprophytically outside of the host and diseased crop debris (Yadav et al*.,* 2014). The pathogen infection in crops in India can reduce yields by 10% to 70% (Singh et al*.*, 2017 and Choudhary et al*.,* 2018). The disease incidence and severity in Uttar Pradesh was 10-40% and 26% respectively (Pandey et al., 2002). The disease infect foliage causing extensive damage to tissue involved in photosynthesis and hence result in yield loss.

"Symptoms of this disease include presence of irregular, often circular brown to dark brown colour leaf spots having concentric rings within the spots. Disease symptoms first appear on older leaves as small necrotic spots that may be surrounded by a yellow halo. Often the circular spots coalesce to form large patches resulting in the leaf blight. In quite a few cases dark coloured small spots are also formed on pods and tender twigs. The round spots might grow to 1⁄2 inch (1 cm) or more in diameter and are usually grey, grey-tan, or near black in colour, leaves curl and die, leading eventually to plant decline. The spots develop in a target, pattern of concentric rings" (Agrios, 2005). "The fungus is primarily seed-borne, but can also come from crop residue. Spores are spread by wind, water splash, human, agricultural tools and equipments. They can also survive in susceptible weeds or perennial crops" (Mamgain et al., 2013). Under *in*

vitro conditions sporulation of *A. brassicae* occurs at optimum temperature of 18-24° C and *A. brassicicola* at 20-30° C.

"Conventionally, different fungicides are used for controlling this disease. Indiscriminate use of higher dose of chemical fungicides affect environment and human health but also increase input cost" (Ahmad and Ashraf, 2016). "Several medicinal and aromatic plants show antioxidant and antifungal properties which not only reduce disease development but also produce harmful residue free products" (Kavita and Dalbeer, 2015).

Now a day's many fungi is used as bio-control agents and they are very good in their performance. Among fungal bio-control agents *Trichoderma viride* is predominant commercially exploited bio-agents (Mohammad and Zahra, 2013). "Use of botanical extracts is considered as cost effective and eco-friendly approach of disease management, without any environmental pollution" (Khalse et al., 2017).

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the laboratory of the Department of Plant Pathology and field experiment was carried out at the Central Research Field, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during *Rabi* season 2023-2024.

2.2 Isolation of the Pathogen

The infected leaf parts were cut into small pieces of 0.5 cm^2 dimension in a manner so that pieces may have some green portion also. Such leaf bits were surface sterilized with 1% sodium hypochlorite (NaOCl) solution for one minute and washed three times with sterile distilled water to remove any traces of sodium hypochlorite adhered with leaf bits (Yadav et al., 2017). Melted PDA was poured in petri plates, the 3-5 leaf bits was transferred on PDA medium contained in Petri plates aseptically with the help of sterilized forceps. These Petriplates were incubated at 25 ±2°C. After 3 days mycelia growth were observed around leaf bits from this colony growth, a portion from the periphery that is, single hyphal tip was separated and transferred to other.

2.3 Purification and Maintenance of the Culture

The culture of *Alternaria brassicae* was purified by hyphal tip method and maintained by periodic sub-culturing on PDA Petriplates and slants. These were incubated at 25 ±2°C. This pure culture was used for further study.

2.4 Characteristics of the Pathogen

The morphological study of *Alternaria brassicae* was made on host and in medium (PDA) by using compound microscope. The taxonomy of *A. brassicae* has been based principally on morphology and sometimes host plant association of each of the species occurring (*A. brassicicola* and *A. brassicae*) has a distinct morphology considering the diversity of conidium shapes and sizes among *Alternaria* sp. All commercial cultivars of brassicae are susceptible to this pathogen (Tewari, 1991).

2.5 Field Preparation

The selected field area was plot marked as per the layout plan. The field was prepared by ploughing soil 2-3 time to a fine tilth level and harrowing during winter season. Field was cleaned by picking debris of previous crop

List 1. Details of treatment

Sr. No.	No. of treatments	Name of Treatments	Concentration
1	T_0	Control (untreated check)	--
2	T_1	*Trichoderma viride* + Ginger leaf extract	5 g/l (S.D.) + 5% (F.S.)
3	T_2	*Trichoderma viride* + Garlic leaf extract	5 g/ l (S.D.) + 5% (F.S.)
4	T_3	*Trichoderma viride* + Neem leaf extract	5 g/l (S.D.) + 5% (F.S.)
5	T_4	*Trichoderma viride* + *Lantana camara leaf extract*	5 g/l (S.D.) + 5% (F.S.)
6	T_5	*Trichoderma viride* + Eucalyptus leaf extract	5 g/l (S.D.) + 5% (F.S.)
7	T_6	*Trichoderma viride* + Calotropis leaf extract	5 g/l (S.D.) + 5% (F.S.)
8	T_7	*Trichoderma viride* + Datura leaf extract	5 g/l (S.D.) + 5% (F.S.)

S.D. – Seedling Dip F.S.- Foliar Spray**

and the soil was pulverized. The total area was divided into 24 plots and planting operation were carried out for raising the crop.

2.6 Preparation of Treatment Suspension

Talcum based formulation of Nidan+ (*Trichoderma viride* 1.5% W.P. 2 X 10^8 cfu/ml) manufactured by Krishi Bio-products and Research Pvt. Ltd. Indore M.P. was purchased from Alopibagh for using as seedling treatment under field conditions. The treatment suspension was prepared by mixing 5 g in 1000 ml of distilled water. The roots of seedlings were dipped in the suspension for 30 minutes and then allow to shade for 15 minutes.

2.7 Transplanting of Seedlings

The experimental plot was laid out as per statistical design and necessary marking of the hills was done for transplanting the seedling. The healthy seedling of about 25-30 days old having uniform size were used for transplantation one these marked hills. The transplanting was done on 22nd December 2023.

2.8 Preparation of Botanical Leaf Extracts

Botanical extracts were prepared by using method of standard procedure given by (Yadav et al., 2017). Matured leaves and other botanicals were collected and sterilized with distilled water, the leaves were homogenized in a pre-chilled pestle and mortar using chilled, sterilized distilled water. Aqueous extract of this botanical (1% w/v) were prepared by mixing 100g fresh leaves botanicals of plant with 100 ml of sterile distilled water and crushing in warring blender. The extract was filtered through four layers of moisture muslin cloth. The filtrate thus obtained was considered as 100% plant extract.

2.9 Observations Recorded

The observations on growth, development and its attributes which were recorded during the course of investigation are as follows.

- **Number of Leaves:** The plant leaves were counted from ground level to the top of the main shoot of five randomly selected plants in each plot of all replications at 45, 60 and 75 days after transplanting.
- **Head Diameter (cm):** The head diameter were measured at the time of harvesting.
- **Head Weight (kg/plant):** The head weight were measured at the time of harvesting.
- **Disease Intensity (%):** Per cent disease intensity were recorded at 45, 60 and 75 day after transplanting (DAT). The initial infections or incidence were recorded in the experimental field at 25 days after transplanting.

Percentage of disease intensity was calculated by using formula given by Wheeler (1969).

Disease intensity (%) = (Sum of all individual disease ratings / (Total number of plant assessed × Maximum disease grade) X 100)

- **Disease Intensity Scale:** Disease intensity were recorded as grades in five randomly selected plants in each plot at different time that is 15 days after the first spray, second spray and third spray as per the scale of **Mayee and Datar (1986)** which is given below:

List 2. Disease intensity scale

Disease rating	Percentage area of leaf infected
0	No infection on leaves
1	<5% leaf area infected
2	5-10% leaf area infected
3	10-20% leaf area infected
4	25-30% leaf area infected
5	>50 % leaf area infected

- **Yield (t/ha):** The matured cabbage heads were harvested and weight of individual heads were recorded according to the treatment and yield per hectare was obtained using this data.
- **Harvesting:** Harvesting of cabbage was done from each plot separately.

3. RESULTS

3.1 Effect of Treatments on Disease Intensity (%) at 45, 60 and 75 Days after Transplanting

The disease intensity (%) at 45, 60 and 75 days after transplanting is depicted in Table 1 and Fig. 1. At 45 days after transplanting reveals that minimum disease intensity (%) was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (17.27%) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (17.87%) and maximum was found in T_2 - *Trichoderma viride* with Garlic bulb extract (19.54%) as compared to T_0 - control (23.35%).

All the treatments were found statistically significant over T_0 control. Among the treatments (T_3, T_4, T_5 and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

At 60 days after transplanting reveals that minimum disease intensity (%) was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (22.66%) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (23.31%) and maximum was found in T_2 - *Trichoderma viride* with Garlic bulb extract (25.67%) as compared to T_0 - control (31.33%).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, T_5 and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

At 75 reveals that minimum disease intensity (%) was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (27.34%) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (28.72%) and maximum was found in T_2 - *Trichoderma viride* with Garlic bulb extract (33.64%) as compared to T_0 - control (45.38 %).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, T_5 and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

3.2 Effect of Treatments on Number of Leaves at 45, 60 and 75 Days after Transplanting

The data of number of leaves shown in the Table 2 and Fig. 2 at 45 days after transplanting reveals that maximum number of leaves was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (14.20) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (13.13) and least was found in T_2 - *Trichoderma viride* with Garlic bulb extract (8.93) as compared to T_0 - control (7.53).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, T_5 and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

At 60 days after transplanting reveals that maximum number of leaves was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (25.47) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (23.33) and least was found in T_2 - *Trichoderma viride* with Garlic bulb extract (14.80) as compared to T_0 - control (12.00).

Table 1. Effect of treatments on disease intensity (%) at 45, 60 and 75 days after transplanting

Sr. No.	Treatments combination	Disease intensity (%)		
		45 DAT	60 DAT	75 DAT
T_0	Control (untreated check)	23.35	31.33	45.38
T_1	*Trichoderma viride* + Ginger rhizome extract	19.28^{ab}	25.35^{ab}	32.98^{ab}
T_2	*Trichoderma viride* + Garlic bulb extract	19.54^{a}	25.67^{a}	33.64^{a}
T_3	*Trichoderma viride* + Neem leaf extract	17.27	22.66	27.34
T_4	*Trichoderma viride* + *Lantana camara* leaf extract	18.33	24.02	30.10
T_5	*Trichoderma viride* + Eucalyptus leaf extract	17.87	23.31	28.72
T_6	*Trichoderma viride* + Calotropis leaf extract	18.89^{c}	24.79^{c}	31.59^{c}
T_7	*Trichoderma viride* + Dhatura leaf extract	19.08^{bc}	25.05^{bc}	32.26^{bc}
SEM (±)		0.13	0.16	0.29
C.D. (5%)		0.39	0.49	0.87

DAT- Days After Transplanting

note: Different letters a, b, c in one column. There was a statistically difference at the 95% confidence level (P<0.05)

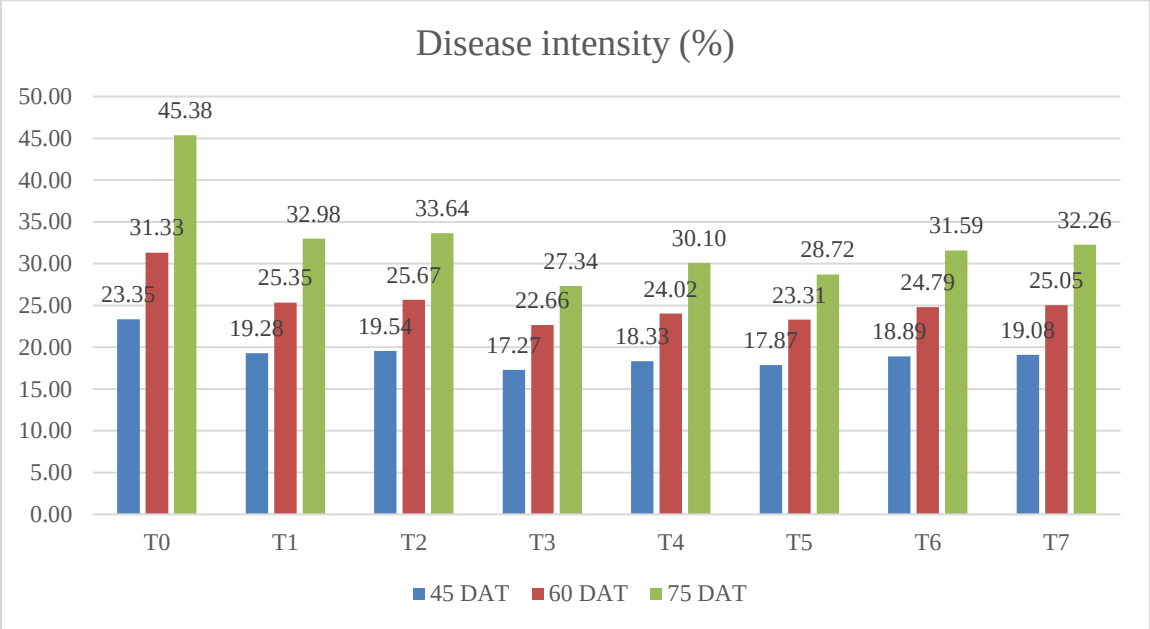

Fig. 1. Effect of treatments on disease intensity (%) at 45, 60 and 75 days after transplanting

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, T_5, T_6 and T_7) were significant to each other however, (T_1 and T_2) and (T_1 and T_7) were non-significant to each other.

At 75 days after transplanting reveals that maximum number of leaves was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (36.27) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (33.73) and least was found in T_2 - *Trichoderma viride* with Garlic bulb extract (23.33) as compared to T_0 - control (20.73).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, T_5 and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

3.3 Effect of Treatments on Head Diameters (cm) of Cabbage

The data of head diameters shown in the Table 3 and Fig. 3 reveals that maximum head diameters was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (14.20 cm) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (13.05 cm) and least was found in T_2 - *Trichoderma viride* with Garlic bulb extract (8.20 cm) as compared to T_0 - control (7.05 cm).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, T_5 and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

3.4 Effect of Treatments on Head Weight (kg) of Cabbage

In the present finding, the data of head weight shown in the Table 4 and Fig. 4 reveals that maximum head weight was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (0.69 kg) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (0.65 kg) and least was found in T_2 - *Trichoderma viride* with Garlic bulb extract (0.49 kg) as compared to T_0 - control (0.38 kg).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4 and T_5) were significant to each other however, (T_1 and T_2), (T_1 and T_7), (T_4 and T_6) and (T_6 and T_7) were non-significant to each other.

3.5 Effect of Treatments on Yield (t/ha) of Cabbage

In the present finding, the data of yield shown in the Table 5 and Fig. 5 reveals that maximum yield was recorded in T_3 – *Trichoderma viride* with Neem leaf extract (25.45 t/ha) followed by T_5 - *Trichoderma viride* with Eucalyptus leaf extract (24.03 t/ha) and least was found in T_2 -

Trichoderma viride with Garlic bulb extract (17.99 t/ha) as compared to T_0 - control (14.22 t/ha).

All the treatments were found statistically significant differ from T_0 control. Among the treatments (T_3, T_4, $_5$ and T_6) were significant to each other however, (T_1 and T_2), (T_1 and T_7) and (T_6 and T_7) were non-significant to each other.

Table 2. Effect of treatments on number of leaves at 45, 60 and 75 days after transplanting

Sr. No.	Treatment combination	Number of leaves		
		45 DAT	60 DAT	75 DAT
T_0	Control (untreated check)	7.53	12.00	20.73
T_1	*Trichoderma viride* + Ginger rhizome extract	9.33^{bc}	16.20^{ab}	25.13^{bc}
T_2	*Trichoderma viride* + Garlic bulb extract	8.93^{c}	14.80^{b}	23.33^{c}
T_3	*Trichoderma viride* + Neem leaf extract	14.20	25.47	36.27
T_4	*Trichoderma viride* + *Lantana camara* leaf extract	12.00	21.20	31.27
T_5	*Trichoderma viride* + Eucalyptus leaf extract	13.13	23.33	33.73
T_6	*Trichoderma viride* + Calotropis leaf extract	10.87^{a}	19.20	28.73^{a}
T_7	*Trichoderma viride* + Dhatura leaf extract	10.13^{ab}	17.67^{a}	26.93^{ab}
SEM (±)		0.28	0.49	0.68
C.D. (5%)		0.85	1.47	2.06

DAT- Days After Transplanting

note: Different letters a, b, c in one column. There was a statistically difference at the 95% confidence level (P<0.05)

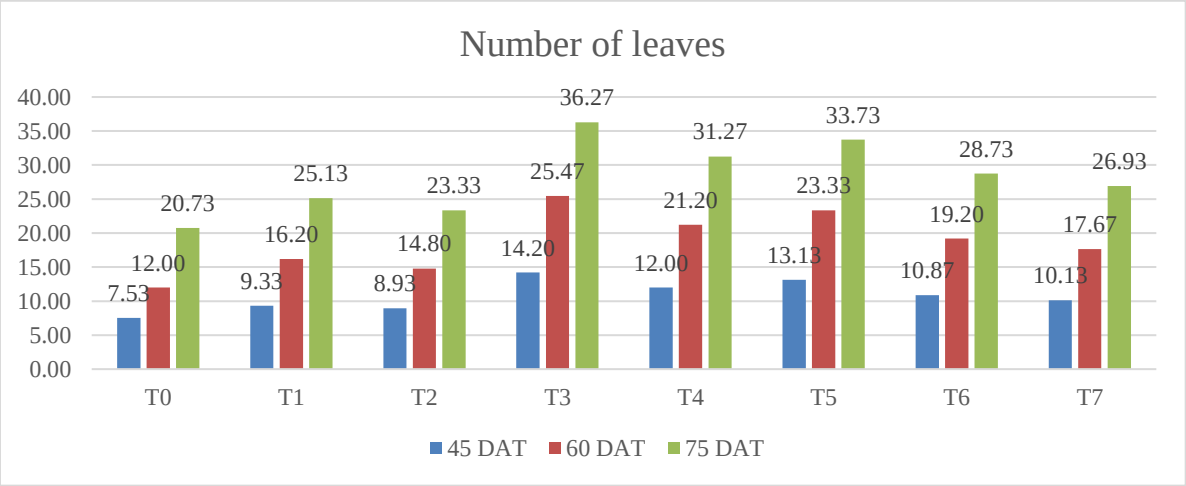

Fig. 2. Effect of treatments on number of leaves at 45, 60 and 75 days after transplanting

Table 3. Effect of treatments on head diameters (cm) of cabbage

Sr. No.	Treatments combination	Head diameter (cm)
T_0	Control (untreated check)	7.05
T_1	*Trichoderma viride* + Ginger rhizome extract	9.05^{bc}
T_2	*Trichoderma viride* + Garlic bulb extract	8.20^{c}
T_3	*Trichoderma viride* + Neem leaf extract	14.20
T_4	*Trichoderma viride* + *Lantana camara* leaf extract	11.90
T_5	*Trichoderma viride* + Eucalyptus leaf extract	13.05
T_6	*Trichoderma viride* + Calotropis leaf extract	10.75^{a}
T_7	*Trichoderma viride* + Dhatura leaf extract	9.90^{ab}
SEM (±)		0.33
C.D. (5%)		0.99

Note: Different letters a, b, c in one column. There was a statistically difference at the 95% confidence level (P<0.05)

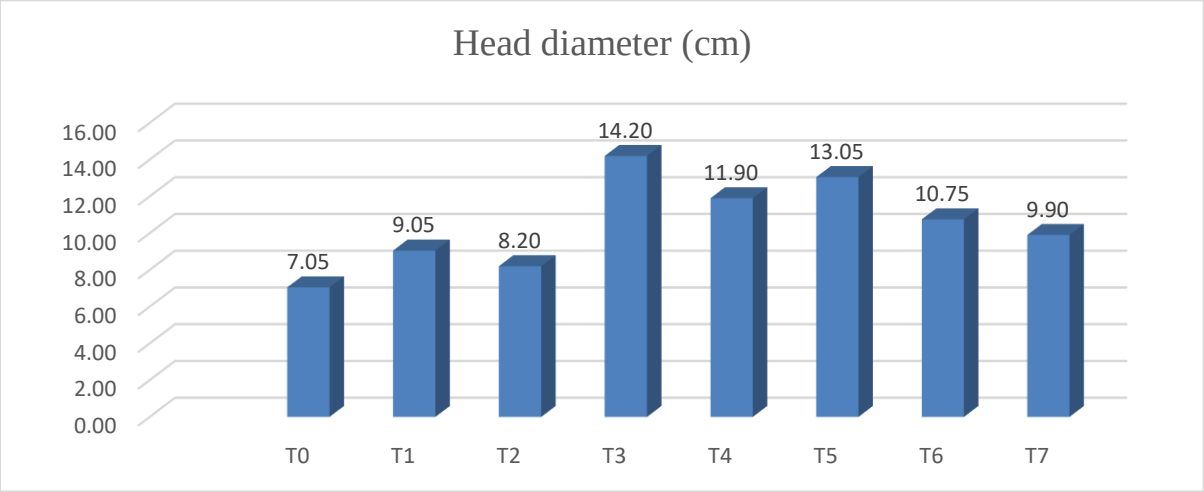

Fig. 3. Effect of treatments on head diameters (cm) of cabbage

Table 4. Effect of treatments on head weight (kg) of cabbage

Sr. No.	Treatments combination	Head weight (kg)
T_0	Control (untreated check)	0.38
T_1	*Trichoderma viride* + Ginger rhizome extract	0.51^{cd}
T_2	*Trichoderma viride* + Garlic bulb extract	0.49^{de}
T_3	*Trichoderma viride* + Neem leaf extract	0.69
T_4	*Trichoderma viride* + *Lantana camara* leaf extract	0.60^{a}
T_5	*Trichoderma viride* + Eucalyptus leaf extract	0.65
T_6	*Trichoderma viride* + Calotropis leaf extract	0.57^{ab}
T_7	*Trichoderma viride* + Dhatura leaf extract	0.54^{bc}
SEM (±)		0.01
C.D. (5%)		0.03

Note: Different letters a, b, c in one column. There was a statistically difference at the 95% confidence level (P<0.05)

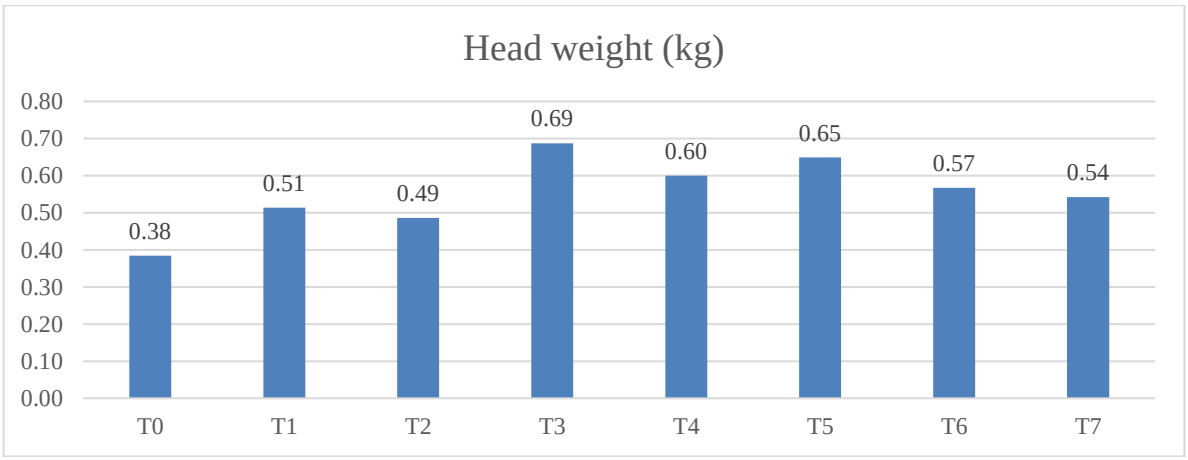

Fig. 4. Effect of treatments on head weight (kg) of cabbage

3.6 Cost of Production

Observations regarding the economics of treatments are shown in the Table 5. Higher gross return value (₹ 509000) and C:B ratio (1:2.32) was observed in treatment *Trichoderma viride* with Neem leaf extract (T_3) as compared to control (T_0) recorded lowest gross return value (₹ 284400) and C:B ratio (1:0.86).

Table 5. Effect of treatments on yield (t/ha) of cabbage

Sr. No.	Treatment combination	Yield (t/ha)
T_0	Control (untreated check)	14.22
T_1	*Trichoderma viride* + Ginger rhizome extract	19.04[bc]
T_2	*Trichoderma viride* + Garlic bulb extract	17.99[c]
T_3	*Trichoderma viride* + Neem leaf extract	25.45
T_4	*Trichoderma viride* + *Lantana camara* leaf extract	22.21
T_5	*Trichoderma viride* + Eucalyptus leaf extract	24.03
T_6	*Trichoderma viride* + Calotropis leaf extract	21.01[a]
T_7	*Trichoderma viride* + Dhatura leaf extract	20.09[ab]
SEM (±)		0.36
C.D. (5%)		1.09

Note: Different letters a, b, c in one column. There was a statistically difference at the 95% confidence level (P<0.05)

Table 6. Cost benefit ratio of the treatments

		Cost benefit ratio					
Sr. No.	**Treatments**	**Total cost of cultivation (`/ha)**	**Total yield (t/ha)**	**Selling (`/t)**	**Gross return (`)**	**Net return (`)**	**Cost benefit ratio**
T_0	Control (untreated check)	152502	14.22	20000	284400	131898	1:0.86
T_1	*Trichoderma viride* + Ginger rhizome extract	162527	19.04	20000	380800	218273	1:1.34
T_2	*Trichoderma viride* + Garlic bulb extract	162527	17.99	20000	359800	197273	1:1.21
T_3	*Trichoderma viride* + Neem leaf extract	153402	25.45	20000	509000	355598	1:2.32
T_4	*Trichoderma viride* + *Lantana camara* leaf extract	153527	22.21	20000	444200	290673	1:1.89
T_5	*Trichoderma viride* + Eucalyptus leaf extract	153652	24.03	20000	480600	326948	1:2.13
T_6	*Trichoderma viride* + Calotropis leaf extract	153652	21.01	20000	420200	266548	1:1.73
T_7	*Trichoderma viride* + Dhatura leaf extract	153653	20.09	20000	401800	248147	1:1.61

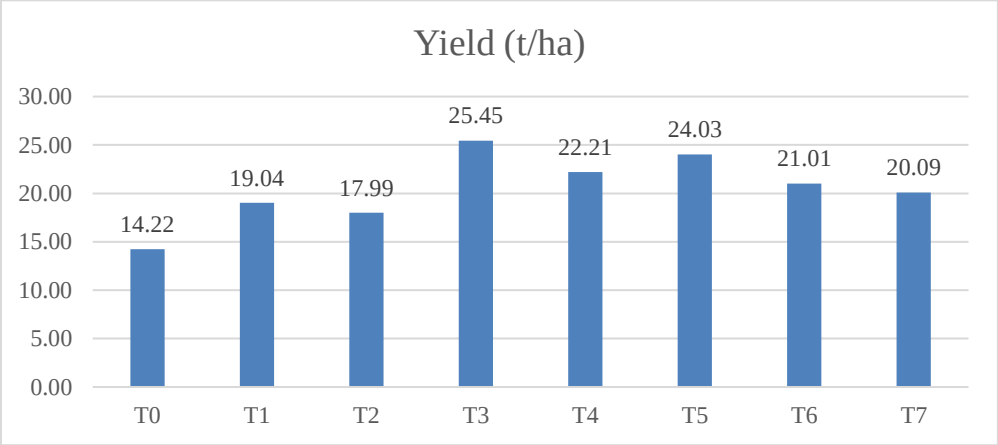

Fig. 5. Effect of treatments on yield (t/ha) of cabbage

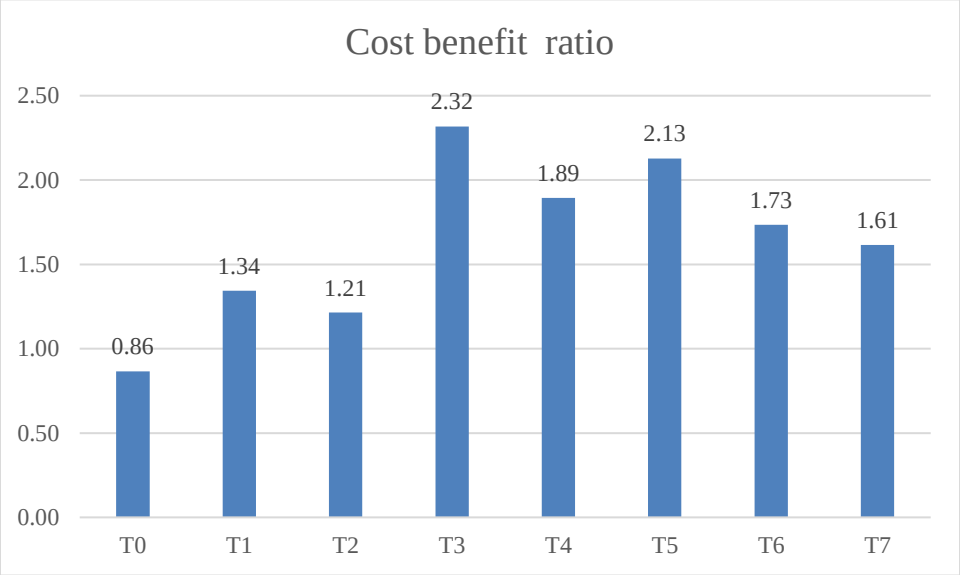

Fig. 6. Effect of treatments on cost benefit ratio of cabbage

4. DISCUSSION

Cabbage (*Brassica oleracea* var. *capitata* L.) is a significant vegetable crop in India. It belongs to the Cruciferae family, which includes around 3,500 species across 350 genera; however, the most economically important crops are found within a single genus. The disease leaf spot of cabbage is prevalent in all the cabbage growing states and is one of the major biotic problems, which limits its production and also quality of produce. There are two species of *Alternaria* which cause serious damage in cabbage: *Alternaria brassicae* and *Alternaria brassicicola*, they can survive saprophytically out side of the host and diseased crop debris. Since, there were wide gaps in the research conducted with respect to this disease.

Considering the economic damage by this pathogen, the present investigation was attempted to find out the per cent disease intensity, number of leaves, head diameter, head weight, yield and cost-benefit ratio by employing *Trichoderma viride* and botanicals extract under field conditions.

Besides chemical control, biological control and botanicals extract are an effective, eco-friendly and alternative approach for any disease management practices.

Among treatments combinations, results indicate that the minimum percentage disease intensity was recorded in the treatment *Trichoderma viride* with Neem leaf extract followed by *Trichoderma viride* with Eucalyptus leaf extract and maximum

was observed in *Trichoderma viride* with Garlic bulb extract as compared to control.

Among treatments combinations, results indicated that the maximum number of leaves, head diameter, head weight, yield and cost-benefit ratio by treatment *Trichoderma viride* with Neem leaf extract followed by *Trichoderma viride* with Eucalyptus leaf extract and minimum was observed in *Trichoderma viride* with Garlic bulb extract as compared to control.

By the statistical analysis, the results of present study, among the treatments, recorded percent disease intensity significantly decreased at 45, 60 and 75 days after transplanting (DAT) with treatment *Trichoderma viride* with Neem leaf extract. The number of leaves was significantly increased at 45, 60 and 75 days after transplanting (DAT) with treatment *Trichoderma viride* with Neem leaf extract. Respectively, head diameter, head weight, yield were significantly increased with this treatment *Trichoderma viride* with Neem leaf extract and aslo found that highest cost benefit ratio as compared to other treatments.

The results of present study, are in agreement with the findings of Sreevarshini et al. (2019) conducted the experiment using botanicals extract during *Rabi* season. The minimum disease intensity was recorded in foliar sprays of *Eucalyptus globulus* @ 10% (30.40%) followed by *Azadirachta indica* @ 15% (31.4%), *Lantana camara* @ 15% (32.40%), *Ocimum sanctum* @ 15% (34.8%), *Cyperus rotundus* @15% (37.4 %), as compared to treated (27.5%) and untreated (43.8%) checks. Maximum fresh head weight was recorded in *Eucalyptus globulus* (0.80 kg) followed by *Azadirachta indica* (0.65 kg), *Lantana camara* (0.64 kg), *Ocimum sanctum* (0.56 kg), *Cyperus rotundus* (0.52 kg), as compared to treated (1.01 kg) and untreated (0.46 kg) checks. Maximum yield was recorded in *Eucalyptus globulus* (26.72 tonnes/ha) followed by *Azadirachta indica* (24.44 tonnes/ha), *Lantana camara* (22.88 tonnes/ha), *Ocimum sanctum* (21.27 tonnes/ha), *Cyperus rotundus* (17.77 tonnes/ha), as compared to treated (33.96 tonnes/ha) and untreated (14.71 tonnes/ha) checks. Sasode et al. (2012) found that the result among crude extract 10 per cent the minimum fungus growth was recorded in neem followed by eucalyptus, tulsi, lantana, datura and pudina. Neem was significantly superior over tulsi, lantana, datura and pudina but at par with eucalyptus. Similar results were also found by Khalse et al. (2017), Yadav et al. (2017) and Bhere et al. (2020).

The probable reason for present findings may be due to the fungal antagonists, antifungal and antibacterial properties such as the application of *Trichoderma viride* reduces the pathogen population in soil by means of mycoparasitism and production of antibiotic which may be reduce the soil borne pathogens in soil. The inhibition of fungal growth due to *Trichoderma* spp. may have been due to secretion of extracellular cell degrading enzymes such as chitinase B-1, 3-glucanase, cellulose and lectin, which may have helped mycoparasites in the colonization of their host. The inhibition of pathogen may also be attributed to the production of secondary metabolites by antagonists such as glioviridin, viridin and gliotoxin (Kalmesh and Gurjar, 2002 and Ghildyal and Pandey, 2008). It's also enhances the nitrogen use efficacy in different crops and assisting to improve photosynthetic activity.

The bio-efficacy of Neem leaf extract over pathogens can be attributed to the fact that Neem has active compounds such as azadirachtin, nimbin, nimbidin, nimbinene and azadirone which are antifungal, antibacterial and anti-insecticidal in nature (Nahak et al. 2015). Neem extract is composed of antimicrobial ingredients such as alkaloids, glycosides, flavonoids, and saponins, which are common antibiotics found in Neem leaf extract that reduced the pathogen growth and showed a promotive effect on growth parameters and yield (Sarawaneeyaruk et al*.* 2015).

5. CONCLUSIONS

From the above study, it is concluded that the *Alternaria brassicae* is a very destructive fungus for cabbage, but with the utilization of advanced techniques it becomes easier to manage this cosmopolitan fungus. Under field conditions, the experiment revealed that *Trichoderma viride with* Neem leaf extract was significantly reduced the per cent disease intensity and increased the yield. The result allows to conclude that the contrary to the problems associated with the use of synthetic chemicals, botanicals are environmentally non pollute, indigenously available, easily accessible, non phytotoxic, systemic ephemeral, readily biodegradable, relatively cost effective and hence constitute a suitable plant protection in the strategy of biological management of disease.

Therefore, it may be recommended for the better management of leaf spot disease of cabbage (*Alternaria brassicae*). The findings of the present experiment are limited to one crop season (2023-2024) under Prayagraj agro-climatic conditions, as such to validate the present findings more such trials should be carried out in future.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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