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Efficacy of Botanicals against Wilt of Pea caused by *Fusarium oxysporum* f.sp. *pisi* (Van Hall) Snyder & Hansen

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Pea wilt disease, caused by *Fusarium oxysporum* f.sp. *pisi*, is a major threat to pea cultivation, leading to significant yield losses. This study aimed to isolate, identify, and assess the pathogenicity of the fungus, explore its growth conditions on different media, and evaluate the effectiveness of botanical extracts in controlling the pathogen both *in-vitro* and *in-vivo*. Infected pea plants were sterilized and cultured on Potato Dextrose Agar (PDA) at 25±1ÚC. Identification was based on morphological characteristics observed microscopically. Pathogenicity tests confirmed that the pathogen induces yellowing, wilting, root rot, and vascular discoloration. Growth studies revealed optimal fungal growth on PDA, while Rose Bengal Agar was less effective. The pathogen showed maximum growth at 30ÚC, with reduced growth at temperatures below 15ÚC and above 35ÚC. *In-vitro*, Eucalyptus extracts significantly inhibited pathogen growth, with inhibition rates of 61.75%, 68.94%, and 73.45% at 5%, 10%, and 15% concentrations, respectively, after 7 days. In field trials, Dhatura demonstrated the highest efficacy, reducing disease incidence by up to 82.30% compared to untreated controls. The results highlight the successful isolation and identification of *Fusarium oxysporum* f.sp. *pisi,* the determination of its optimal growth conditions, and the potential of botanicals, particularly Dhatura and Eucalyptus, for managing pea wilt disease. Further studies are needed to explore the integration of these botanicals into sustainable disease management strategies.

Keywords: Botanical extract, disease incidence, inhibition, seed treatment

INTRODUCTION

Peas, a key member of the Fabaceae family and the genus *Pisum* (2n=2x=14), include both wild species such as *P. fulvum* and *P. elatius* and cultivated varieties like *P. abyssinicum*. Originating from the Mediterranean region, with secondary centers in Ethiopia and the Near East, peas are among the earliest domesticated food crops. Typically grown as climbing or bushy annual plants, they are primarily self-pollinated. They provide significant amounts of proteins, carbohydrates, calcium, phosphorus, and vitamins A and C. Notably, peas are a cost-effective source of protein and contain essential amino acids, particularly lysine. Furthermore, peas have a symbiotic relationship with soil bacteria that enables them to fix atmospheric nitrogen, reducing the need for synthetic fertilizers. These plants are adaptable to a range of soil types, from light sandy loams to heavy clayey soils, and thrive best in a pH range of 5.5 to 6.5. Cultivars with shorter maturation periods are especially desirable (Devi *et al.* 2021).

Uttarakhand's high humidity fosters various pea diseases, with wilt caused by *Fusarium oxysporum* f.sp. *pisi* being the most severe. This soil-borne fungus survives in the soil for over a decade as hardy spores and can cause substantial yield losses. Early- stage infections kill plants outright, while later infections lead to shriveled grains and significant yield reductions (Sagar *et al.,* 2021). The pathogen has two pathotypes and eight races, with winter crops being particularly vulnerable, often suffering up to 100% yield loss (Sharma *et al.* 2006; Zafar, 2020). Traditionally, synthetic fungicides have been used to manage these diseases, but their

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overuse has led to environmental contamination, resistance development, and residual toxicity. In response, there is growing interest in using plant extracts, which are environmentally friendly and offer an effective alternative. Despite their potential, the use of botanicals for plant disease management remains underexplored. This investigation aims to develop eco-friendly disease management strategies using botanicals, which could reduce fungicide residues and minimize environmental pollution.

MATERIALS AND METHODS

This study was conducted at the College of Horticulture, VCSG UUHF Bharsar, India during *Rabi* season, 2024. The study consisted of three objectives: (i) isolation, identification and pathogenicity test of pathogen from infected plants; (ii) to study the growth of pathogen on different culture media and temperature; (iii) to study the efficacy of Botanicals against pathogen *In-vitro* and *In-vivo* conditions.

Isolation, identification and pathogenicity test of pathogen from infected plants

Infected pea plants exhibiting symptoms of Fusarium wilt were collected from the experimental site at the Vegetable Research and Demonstration Block, College of Horticulture, VCSG UUHF Bharsar, Pauri Garhwal, Uttarakhand. The diseased samples were rinsed, air-dried, and cut into 5mm pieces using a sterilized scalpel. Surface sterilization was performed by immersing the pieces in 0.1% sodium hypochlorite for 30 seconds, followed by thorough washing in sterilized distilled water. The sterilized leaf pieces were then aseptically transferred to Petri plates containing sterile Potato Dextrose Agar medium and incubated at 25±1ÚC. Mycelial growth of the fungus was observed daily. The morphological characteristics of the isolated pathogen were analyzed to confirm its identity as *Fusarium oxysporum* f.sp. *pisi*. Slides were prepared using water and cotton blue stain, and fungal growth was examined under a compound microscope at 40X magnification. Key features such as colony morphology, color, mycelial growth, and conidial dimensions were compared with known characteristics of the target species. A pathogenicity test, following Koch's postulate, was conducted to assess the pathogen's disease-causing ability. Healthy pea plants, grown in sterilized soil, were subjected to various artificial inoculation methods: foliar spray (T2), soil inoculation (T3), seed inoculation (T4), and wound inoculation (T5), with un-inoculated plants as controls (T1). Conidia from a 10-day-old culture were suspended in sterilized water at a concentration of 10conidia/mL for inoculation. Symptoms typical of Fusarium infection appeared within 7-10 days post- inoculation. Re-isolation from diseased tissues was performed, and the recovered isolate was compared with the original culture to confirm the identity of the pathogen.

In vitro cultural characteristics tests Solid media

The cultural characteristics of *Fusarium oxysporum* f.sp. *pisi* were evaluated on five solid media: Potato Dextrose Agar (PDA), Oatmeal Agar, Czapek's Dox Agar, Corn Extract Agar, and Rose Bengal Agar. Each medium was sterilized at 121^{0}C and 15 psi for 15 minutes, and 20 mL was poured into 90 mm Petri dishes. The plates were inoculated with a 5 mm disc of fungal growth and incubated at 25^{0}C. Fungal colony diameter was measured at 2, 4, 6, 8, and 10 days, with each treatment replicated four times.

Different temperature

Potato Dextrose Agar (PDA) was used to study the effect of temperature on *Fusarium oxysporum* f.sp. *pisi*. Petri plates with four replicates were incubated at 15^{0}C, 20^{0}C, 25^{0}C, 30^{0}C, and 35^{0}C for 7 days. Mycelial growth was recorded after incubation.

Determination of the efficacy of botanicals against pathogen in in-vitro and in-vivo conditions.

Seven different botanicals namely- Tulsi, Ashwagandha, Dhatura, Garlic, Ginger, Eucalyptus, Neem with a control was tested on different per cent concentration ie., 5, 10 and 15% by poison food technique and mycelial growth was recorded at different concentration at 7 day interval.

Botanical preparation

Fresh leaves of Tulsi, Ashwagandha, Dhatura, Garlic, Ginger, Eucalyptus, and Neem were washed, air- dried, and ground with distilled water in a 1:1 (W/V) ratio. The homogenized mixture was filtered, and the solution were mixed with 95, 90 and 85 mL of sterilized Potato Dextrose Agar (PDA), respectively. Each Petri plate was then poured with 20 mL of molten PDA. After the medium solidified, a 5 mm mycelial disc taken from a three-week-old fungal culture was inoculated onto the center of each plate. The plates were subsequently incubated at 25±2ÚC, with control plates prepared in the same manner but without the addition of botanicals. After 7 days of incubation, radial colony growth was measured to assess the efficacy of each botanical treatment. The effectiveness of the botanicals was expressed as the percent inhibition of mycelial growth in comparison to the control, which was calculated using Vincent's (1947) formula. This method allowed for a systematic comparison of the antifungal activity of the botanical treatments under controlled conditions.

Poisoned food technique

The *in-vitro* evaluation of botanicals against the isolated pathogen was performed using the poisoned food technique. To prepare the botanical concentrations, 5, 10 and 15 mL of plant extract stock solution were mixed with 95, 90 and 85 mL of sterilized Potato Dextrose Agar (PDA), respectively. Each Petri plate was then poured with 20 mL of molten PDA. After the medium solidified, a 5 mm mycelial disc taken from a three-week-old fungal culture was inoculated onto the center of each plate. The plates were subsequently incubated at 25±2^{0}C, with control plates prepared in the same manner but without the addition of botanicals. After 7 days of incubation, radial colony growth was measured to assess the efficacy of each botanical treatment. The effectiveness of the botanicals was expressed as the percent inhibition of mycelial growth in comparison to the control, which was calculated using Vincent's (1947) formula. This method allowed for a systematic comparison of the antifungal activity of the botanical treatments under controlled conditions.

Observation recorded

i. Size of fungal colony (in mm): The size of fungal colony was observed by radial growth of fungal colony with the help of measuring scale from two different directions and the mean of the observation considered as mycelial growth of the colony.

Per cent mycelium inhibition: Per cent inhibition in growth was calculated in relation to growth in control using the following formula of Vincent (1947).

$$i = \frac{C-T}{C} \times 100$$

Where,
I = Per cent inhibition
C = Mycelial growth of fungus in control
T = Mycelial growth of fungus in treatment

In-vivo evaluation of different botanicals against Fusarium oxysporum f.sp. pisi

A field experiment was conducted during the Rabi season of 2024 at the Vegetable Research and Demonstration Block in Uttarakhand, situated at 29^{0}N latitude and 78^{0}E longitude in the Western Himalayan zone. The experiment employed a Randomized Complete Block Design to evaluate the efficacy of seven botanical treatments against *Fusarium oxysporum f.*sp*. pisi* under in-vivo conditions. The botanicals were applied as seed treatments, a well-established method for controlling seed-borne diseases. Pea seeds of the variety Arkel were treated with various botanicals using liquid formulations in 100 mL Erlenmeyer flasks to ensure uniform coating. Following treatment, the seeds were air-dried and then mixed mechanically. The botanicals used in the experiment were sourced from Ranichauri, the MAP Demonstration Block, and locally from Bharsar.

Observations recorded

The observations were recorded taken five randomly selected plants from each treatment in each replication and their average was worked out to record the data. The observations were recorded on following characters:

i.Percent Disease Incidence (PDI)
Percent Disease Incidence or Wilt incidence was calculated with the assistance of following formula and also the marking table given by Wheeler (1969).

$$\text{Percent disease incidence} = \frac{\text{No.of infected plants}}{\text{Total No.of plants}} \times 100$$

ii. Percent Disease reduction over control
Percent Disease reduction over control was calculated by a standard formula:

$$\text{Percent disease reduction over control} = \frac{\text{(PDI in control plot) (PDI in treatment plot)}}{\text{PDI in control plot}} \times 100$$

iii.Yield (g/plot and q/ha)

Harvesting of seeds was made at mature stage for calculating total yield per plant. The total yield per plant was multiplied with total number of plants per plot to obtained yield per plot in grams.

RESULTS AND DISCUSSION

Isolation and identification of the pathogen

The investigation focused on pea plants displaying typical wilting symptoms of *Fusarium oxysporum f.sp. pisi.* Infected plants were collected from the field and examined microscopically in the lab. A pure culture of the pathogen was isolated and maintained on Potato Dextrose Agar (PDA) slants through periodic sub-culturing. The pathogen's identification was based on its morphological and microscopic traits. On PDA, *Fusarium oxysporum f.sp. pisi* formed a cottony white mycelium with stroma in shades of purple-red, bluish-grey, and yellowish-tan. The colonies grew to about 81 mm in 7 days and had smooth to irregular margins. The pathogen produced two types of conidia: microconidia, which were small, oval, single-celled, and dispersed in the mycelial mat, and macroconidia, which were sickle-shaped, hyaline, multicellular with 3 to 5 septa, and had sharply curved, tapering ends.The morphological features of the fungus matched those reported by Kumari *et al*. (2016) and Merzoug *et al*. (2014), confirming the pathogen's identity and its role in Fusarium wilt.

Pathogenicity test

The efficacy of various inoculation methods for inducing Fusarium wilt in pea plants was systematically assessed, with results summarized in Table 1. Each method demonstrated a significant deviation from the control group, with notable differences in the incubation periods for symptom development. The shortest incubation period was observed with seed inoculation (T_4), at 16.25 days, while the longest was with wound inoculation (T_5), at 19.75 days. Soil inoculation (T_3) and foliar inoculation (T_2) had similar incubation periods, at 18.50 days and 16.50 days, respectively. Artificial inoculation of healthy pea plants confirmed the pathogenicity of *Fusarium oxysporum* f.sp. *pisi*. Symptoms appeared within 6 to 10 days post- inoculation, with seed inoculation leading to the earliest symptoms. The initial signs of infection included yellowing of the basal leaves, which progressively spread upwards, eventually causing wilting. Affected plants also showed significant discoloration in the root and stem tissues, indicating the pathogen's impact. These findings align with previous studies. Ashwathi *et al.* (2017) reported similar symptoms in coriander, where Fusarium infection caused comparable wilting and tissue discoloration. Hami *et al.* (2021) also documented similar incubation periods in chili seedlings infected with various Fusarium species, reinforcing the present study's results on the variability in symptom onset based on the inoculation method

Symptoms observed

The progression of *Fusarium oxysporum* f.sp. *pisi* in pea plants reveals a distinct pattern of disease development, beginning with basal leaf yellowing that gradually spreads upwards. The symptoms are observable from the seedling stage through to maturity. Early signs include premature yellowing and drooping of leaves, which can progress to complete wilting of foliage, even as the plant may continue to survive. Upon examining

Table 1: Effect of different inoculation methods on symptoms development of *F. oxysporum* f.sp. *pisi*

Treatments	Treatment details	Incubation period (days) ±S.E.(m)	Type of symptoms
T1	Control	0.00±0.00	No symptoms
T2	Foliar inoculation	16.50*±0.29	Yellowing of leaves
T3	Soil inoculation	18.50*±0.29	Yellowing of leaves
T4	Seed inoculation	16.25*±0.25	Yellowing of leaves
T5	Wound inoculation	19.75*±0.48	Yellowing of leaves
SE(d)		0.43	
C.D.(0.05)		0.92	

*Significant at 5% level of significance as compared with T1 (control)

Table 2. Effect of different media on mycelial growth (mm) of *F. oxysporum* f.sp. *pisi*

Treatments	Treatment details	Day 7(mm) ± S.E.(m)
T1	Potato dextrose agar	81.08±0.10
T2	Oat meal agar	69.52±0.29
T3	Czapek's dox agar	65.97±0.30
T4	Corn extract agar	58.44±0.07
T5	Rose bengal agar	35.17±0.09
SE(d)		0.28
C.D.(0.05)		0.60

the roots, one finds brownish to blackish lesions, indicative of internal disease progression. The infection contributes to root and stem softening and rotting. Ultimately, these symptoms lead to severe wilting and a yellowish-brown discoloration, particularly noticeable in the final stages of the disease.

These observations highlight the profound impact of *Fusarium oxysporum* f.sp. *pisi* on both the external and internal tissues of pea plants, culminating in significant wilt and degradation of plant tissues.

Cultural studies

Growth of Fusarium oxysporum f.sp. pisi on different solid media

The growth patterns of *Fusarium oxysporum* f.sp. *pisi* were assessed on five different culture media, showing clear differences in mycelial expansion by the 7th day. The fungus grew the most on Potato Dextrose Agar (T1), reaching 81.08 mm, followed by Oat Meal Agar (T2) with 69.52 mm and Czapek's Dox Agar (T3) at 65.97 mm. Corn

Table 3: Effect of different temperature on mycelial growth (mm) of *F. oxysporium* f.sp. *pisi*

Treatments	Treatment details(°C)	Day 7(mm) ± S.E.(m)
T1	15	27.31±0.09
T2	20	49.72±0.12
T3	25	66.29±0.09
T4	30	89.28±0.13
T5	35	21.88±0.12
SE(d)		0.15
C.D.(0.05)		0.33

Extract Agar (T4) showed moderate growth at 58.44 mm, while Rose Bengal Agar (T5) had the least growth at 35.17 mm (Table 2). The strong growth on Potato Dextrose Agar is likely due to its nutrient richness, aligning with findings from Tejashwini *et al.* (2023) and Vare *et al.* (2021). These results highlight PDA as the most effective medium for growing *F. oxysporum* f.sp*. pisi*, with varying performance across other media.

Growth of F. oxysporum f.sp. pisi on different temperatures

The effect of temperature on the mycelial growth of *Fusarium oxysporum* f.sp*. pisi* was evaluated by incubating the fungus at five different temperatures. After 7 days, the results showed that 30 ^{0}C (T4) was the optimal temperature, with the fungus achieving the highest radial growth of 89.28 mm. Growth decreased at 25 ^{0}C (T3) with 66.29 mm, 20 ^{0}C (T2) with 49.72 mm, and 15 ^{0}C (T1) with 27.31 mm. The lowest growth was recorded at 35 ^{0}C (T5), with only 21.88 mm (Table 3). The peak growth at 30 ^{0}C is consistent with the known optimal temperature for *Fusarium oxysporum* f. sp. *pisi*, as it supports the pathogen's metabolic processes most effectively. The reduced growth at 15 ^{0}C and 35 ^{0}C suggests these temperatures are less suitable, likely due to impaired enzymatic activity. These findings align with previous studies by Chaudhary *et al.* (2018) and Kurmi *et al.* (2022), which also emphasized the criticalrole of temperature in fungal growth.

Evaluation of botanicals (in-vitro)

Effects of botanicals on mycelial growth of pathogen

An *in-vitro* study was conducted to assess the efficacy of various botanical treatments against *Fusarium oxysporum* f.sp*. pisi* at different concentrations. Mycelial growth was measured on the 7th day post-inoculation, revealing significant inhibition across treatments compared to the control (T0), with varying effects depending on the concentration used. At 5%, Eucalyptus (T7) showed the highest inhibition, with mycelial growth reduced to 30.29 mm, followed by Ashwagandha (T3) at 45.91 mm and Tulsi (T2) at 50.91 mm. The least effective was Garlic (T5), with 68.61

Table 4 : Effect of botanicals on mycelial growth (mm) of *F. oxysporum* f.sp. *pisi* at different concentrations

Treatments	Treatment details	5%±SE.(m)	10%±SE.(m)	15%±SE.(m)
T1	Control	79.20±0.19	80.00±0.09	80.07±0.15
T2	Tulsi	50.91*±0.38	35.81*±0.18	31.51*±0.13
T3	Ashwagandha	45.91*±0.06	40.82*±0.29	37.80*±0.42
T4	Dhatura	53.62*±0.31	47.58*±0.17	22.47*±0.31
T5	Garlic	68.61*±0.12	61.11*±0.23	50.10*±0.19
T6	Ginger	57.77*±0.21	48.91*±0.25	34.14*±0.18
T7	Eucalyptus	30.29*±0.24	24.85*±0.38	21.26*±0.31
T8	Neem	63.76*±0.22	56.31*±0.35	50.94*±0.43
SE(d)		0.33	0.37	0.40
C.D.(0.05)		0.71	0.78	0.86

*Significant at 5% level of significance as compared with T_1 (control)

mm of growth. At 10%, Eucalyptus again led with 24.85 mm, while Garlic remained the least effective at 61.11 mm. At 15%, Eucalyptus continued to show the most significant inhibition at 21.26 mm, while Neem (T8) showed the highest growth at 50.94 mm, indicating lower efficacy. Overall, Eucalyptus consistently emerged as the most potent inhibitor, while Neem and Garlic showed lower effectiveness. These results highlight the potential of botanical extracts, particularly Eucalyptus, as effective antifungal agents against *Fusarium* species, supporting findings from similar studies (Table 4).

Percent mycelium inhibition of F. oxysporum f.sp. pisi

In an *in-vitro* evaluation of botanical treatments against *Fusarium oxysporum* f.sp. *pisi*, the effectiveness of various concentrations (5%, 10% and 15%) was assessed on the 7th day post-inoculation. The results demonstrated significant variability in inhibition based on the botanical used and its concentration. At a 5% concentration, Eucalyptus (T7)exhibited the highest inhibition rate of 61.75%, while Garlic (T5) proved to be the least effective with only 13.36% inhibition. At 10%, Eucalyptus continued to lead with 68.94% inhibition, followed by Tulsi (T2) at 55.23%. Garlic's efficacy remained low at 23.61%. At a 15% concentration, Eucalyptus achieved a 73.45% inhibition rate, with Dhatura (T4) also showing strong antifungal activity at 71.94%. In contrast, Neem (T8) demonstrated the least effectiveness

Table. 5: Effect of botanicals on percent mycelial inhibition of *F. oxysporum* f.sp. *pisi* at different concentrations

Treatments	Treatment details	5%±SE.(m)	10%±SE.(m)	15%±SE.(m)
T1	Control	0.00±0.00 (0.00)	0.00±0.00 (0.00)	0.00±000 (0.00)
T2	Tulsi	35.71*±0.58 (36.68)	55.23*±0.25 (47.99)	60.64*±09(51.13)
T3	Ashwagandha	42.03*±0.17 (40.40)	48.97*±0.31 (44.39)	52.79*±0.59 (46.58)
T4	Dhatura	32.30*±0.32 (34.62)	40.52*±0.22 (39.52)	71.94*±0.39 (57.99)
T5	Garlic	13.36*±0.18 (21.43)	23.61*±0.32(29.06)	37.43*±0.13 (37.71)
T6	Ginger	27.05*±0.21 (31.33)	38.86*±0.32 (38.55)	57.36*±0.20 (49.21)
T7	Eucalyptus	61.75*±0.26(51.78)	68.94*±0.51 (58.11)	73.45*±0.38 (58.96)
T8	Neem	19.50*±0.25 (26.19)	29.61*±0.48 (32.95)	36.39*±0.43 (37.09)
SE(d)		0.41 (0.26)	0.47 (0.29)	0.47 (0.28)
C.D.(0.05)		0.87 (0.55)	1.01 (0.62)	1.01 (0.61)

( ) Value parenthesis is angular transformed

*Significant at 5% level of significance as compared with T_1 (control)

with only 36.39% inhibition (Table 5). Throughout the study, Eucalyptus consistently emerged as the most effective inhibitor at all tested concentrations. Garlic, on the other hand, exhibited the least antifungal activity. These findings are in line with previous research, which underscores the potent antifungal properties of Eucalyptus and Dhatura. This study highlights the potential of these botanicals, particularly Eucalyptus, in developing effective antifungal strategies against Fusarium species, suggesting their broader application in sustainable agricultural practices.

Effects of botanicals on per cent disease incidence on 30 and 60 DAS

30 DAS: Table 6 highlights significant variations in disease incidence across treatments 30 days after sowing. Dhatura (T4) exhibited the lowest disease incidence at 13.71%, followed by Ashwagandha (T3) at 15.15% and Eucalyptus (T7) at 21.60%. In contrast, the control (T1) showed the highest incidence at 76.38%, with Neem (T8) recording 33.78%. All treatments significantly reduced disease incidence compared to the control, with Dhatura demonstrating the highest effectiveness in managing Fusarium wilt.

At 60 DAS: As shown by the data presented in Table 6, all the treatments were successful in reducing the percent disease incidence when these results were compared to control treatment outcomes. It ranged between 14.18% and 80.12%. The minimum disease incidence was seen in treatments (T4), Dhatura (14.18%), followed by (T3), Ashwagandha (14.25%) and (T7), Eucalyptus (25.65%) whereas maximum incidence was found in Control (80.12%) followed by (T8), Neem. All the treatments were found significant as compared with control.

Table 6 : Effect of botanicals on per cent disease incidence on 30 and 60 DAS

Treatments	Treatment details	Doses (%)	Per cent Disease Incidence	
			30DAS±S.E.(m)	60DAS±S.E.(m)
T1	Control	-	76.38±0.20 (60.90)	80.12±0.07 (63.50)
T2	Tulsi	15	32.50*±0.25(34.75)	34.19*±0.60(35.77)
T3	Ashwagandha	15	15.15*±0.09(22.90)	14.25*±0.19(22.17)
T4	Dhatura	15	13.71*±0.08(21.72)	14.18*±0.41(22.11)
T5	Garlic	15	24.06*±0.33(29.36)	27.96*±0.39(31.91)
T6	Ginger	15	30.52*±0.07(33.52)	32.57*±0.16(34.79)
T7	Eucalyptus	15	21.60*±0.25(27.68)	25.65*±0.06(30.41)
T8	Neem	15	33.78*±0.28(35.52)	45.86*±0.48(42.61)
S.E.(d)			0.32 (0.21)	0.48 (0.32)
C.d. (0.05)			0.70 (0.46)	1.03 (0.68)

( ) Value parenthesis is angular transformed

*Significant at 5% level of significance as compared with T_1 (control)

Table. 7: Effect of botanicals on per cent disease reduction over control on 30 and 60 DAS

Treatments	Treatment details	Doses (%)	Per cent Disease Reduction	
			30DAS±S.E.(m)	60DAS±S.E.(m)
T1	Control	-	0.00±0.00 (0.00)	0.00±0.00 (0.00)
T2	Tulsi	15	57.45*±0.41 (49.26)	57.33*±0.72 (49.19)
T3	Ashwagandha	15	80.17*±0.16 (63.53)	82.21*±0.25 (65.03)
T4	Dhatura	15	82.05*±0.15 (64.91)	82.30*±0.50 (65.10)
T5	Garlic	15	68.50*±0.38 (55.84)	65.10*±0.51 (53.77)
T6	Ginger	15	60.05*±0.13 (50.78)	59.35*±0.17 (50.37)
T7	Eucalyptus	15	71.72*±0.38 (57.85)	67.99*±0.05 (55.52)
T8	Neem	15	55.77*±0.45 (48.29)	42.76*±0.56 (40.82)
S.E.(d)			0.40 (0.24)	0.59 (0.37)
C.d. (0.05)			0.87 (0.52)	1.29 (0.81)

( ) Value parenthesis is angular transformed
*Significant at 5% level of significance as compared with T_1 (control)

Table. 8: Effect of different treatments on total yield (g/plot) and (q/ha)

Treatments	Treatment details	Yield(g/plot)±S.E. (m)	Yield(q/ha)±S.E. (m)
T1	Control	253.16±0.30	25.32±0.03
T2	Tulsi	507.06*±1.58	50.71±0.16
T3	Ashwagandha	681.18*±0.35	68.12±0.04
T4	Dhatura	707.18*±0.91	70.72±0.09
T5	Garlic	590.96*±0.39	59.10±0.04
T6	Ginger	542.69*±0.86	54.27±0.09
T7	Eucalyptus	640.55*±0.01	64.06±0.00
T8	Neem	422.61*±0.18	42.26±0.02
S.E.(d)		1.10	
C.d. (0.05)		2.39	

*Significant at 5% level of significance as compared with T1 (control)

Effect of botanicals on percent disease reduction over control on 30 and 60 DAS

At 30 days: The data presented in Table 7 indicate that all tested botanicals significantly reduced disease incidence compared to the control. The efficacy of the botanicals varied, with disease reduction percentages ranging from 55.77% to 82.05%. The highest disease reduction was observed with the seed treatment using Dhatura (T4), which achieved an 82.05% reduction, while the lowest was recorded with the Neem treatment (T8), at 55.77%. All botanical treatments demonstrated statistically significant effectiveness in reducing disease incidence compared to the control.

At 60 days: Table 7 shows notable differences in disease reduction among botanical treatments compared to the control over 30 and 60 days. Dhatura (T4) achieved the maximum disease reduction at 82.30%, closely followed by Ashwagandha (T3) with a reduction of 82.21%. Eucalyptus (T7) and Garlic (T5) also performed well, reducing disease incidence by 67.99% and 65.10%, respectively. Ginger (T6) and Tulsi (T2) showed moderate reductions at 59.35% and 57.33%, while Neem (T8) was the least effective with a 42.76% reduction. *In-vivo* assessments demonstrated that all treatments significantly decreased disease incidence compared to the control, which had the highest incidence rates of 76% at 30 days and 80.12% at 60 days. Notably, Dhatura consistently resulted in the lowest disease incidence, with 13.71% at 30 days and 14.18% at 60 days, indicating its superior effectiveness. These results are consistent with Dubey (2020), which identified Eucalyptus, Garlic and Tulsi as effective treatments, while Neem was less effective. This study highlights the potential of Dhatura and other botanicals in managing Fusarium wilt, emphasizing their role in integrated disease management approaches.

The findings support the use of these botanicals as practical options for sustainable agricultural practices.

Effects of different treatments on total yield (g/plot) and (q/ha)

Table 8 demonstrates significant differences in yield among the various botanical treatments. Dhatura (T4) achieved the highest yield at 707.18 g/plot, which corresponds to 70.72 q/ha. This was closely followed by Ashwagandha (T3), yielding 681.18 g/plot, or 68.12 q/ha. Eucalyptus (T7) produced a yield of 640.55 g/plot, equivalent to 64.06 q/ha, while Garlic (T5) resulted in 590.96 g/plot, or 59.10 q/ha. In contrast, the control treatment yielded the lowest amount, with 253.16 g/plot, translating to 25.32 q/ha. Statistical analysis confirmed that all treatments significantly improved yield compared to the control. The outstanding yield performance of Dhatura highlights its potential for enhancing agricultural productivity. These results suggest that incorporating Dhatura into agricultural practices could offer substantial benefits in terms of yield, positioning it as a valuable option for boosting crop production.

DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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