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# Prevalence and etiology of okra root rot in low and mid hills of Himachal Pradesh

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**Abstract**
Incidence of okra root rot disease was recorded in different agro-climatic zones of okra growing areas of Himachal Pradesh. The overall disease incidence of okra root rot in Himachal Pradesh ranged from 11.00 to 55.55 percent during 2021-22 whereas 11.66 to 66.66 percent during 2022-23 with an overall range of 12.50 to 61.05. The maximum root rot incidence was observed in Ghumarwin (Bilaspur district) whereas the minimum incidence was in Padhar (Mandi district) during the period of survey. *in vitro* studies revealed the presence of three fungal pathogens associated with okra root rot. *Fusarium solani*, *Fusarium oxysporum* and *Rhizoctonia solani* were retrieved from infected plants. *Fusarium solani* was found major pathogen frequently associated with okra root rot in all the districts surveyed however, two pathogens *F. solani* with *Rhizoctonia solani* or *F. solani* with *F. oxysporum*) were also found occurring together.

**Keywords:** Root rot, disease incidence, *Fusarium solani*

## Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] also known as bhindi or lady's finger belongs to *Malvaceae* family, is an important annual vegetable crop grown as a garden crop or on commercial scale in various tropical, subtropical, and warmer areas of the temperate regions in the world (Kisher *et al.* 2016) [3]. In India, it is grown in almost all parts of country during summer as well as rainy seasons (Kumar *et al.* 2010) [4]. Okra cultivation, especially in tropical and subtropical regions is more intense since it does not need high technological inputs which renders it as an important cash crop (Filgueira 2003) [2]. In Himachal Pradesh, major okra production area includes foothills and mid hills especially in Una, Hamirpur, Bilaspur, Kangra, Mandi, Solan, Sirmour and some parts of Chamba districts. The production of okra is hampered by several diseases caused by fungi, viruses, and nematodes. The economically important diseases *i.e*., fungal diseases viz., damping off (*Rhizoctonia solani*), cercospora leaf spot (*Cercospora malayensis*), fusarium wilt (*Fusarium oxysporum* f. sp. *vasinfectum*), root rot (*Fusarium solani*), powdery mildew (*Erysiphe cichoracearum*), anthracnose (*Colletotrichum capsici and Colletotrichum hibisci*), pod rot (*Botrytis* sp.), charcoal rot (*Macrophomina phaseolina*), alternaria leaf spot (*Alternaria hibiscinum*) are known to occur but root rot is one of the major destructive diseases affecting okra worldwide as well as in Himachal Pradesh. The disease is recognized by poor germination due to seed rotting before emergence and collapse of seedling after emergence at soil level somewhat like damping off symptoms. Root rot seriously affecting the initial plant stand of crop causing greyish discoloration of stem near the soil base, root become soft and resulted into 20-30% losses which may increase up to 80 to 90% (Chauhan *et al.* 1972) [1]. More than one soil-borne fungal species is known to be associated with this disease and causes up to 50 percent yield loss (Saifuddin *et al.* 2014) [8]. In this study, disease survey was carried to know the prevalence of disease in different regions of Himachal Pradesh, so that effective control measures can be adopted to combat the disease.

## Materials and Methods

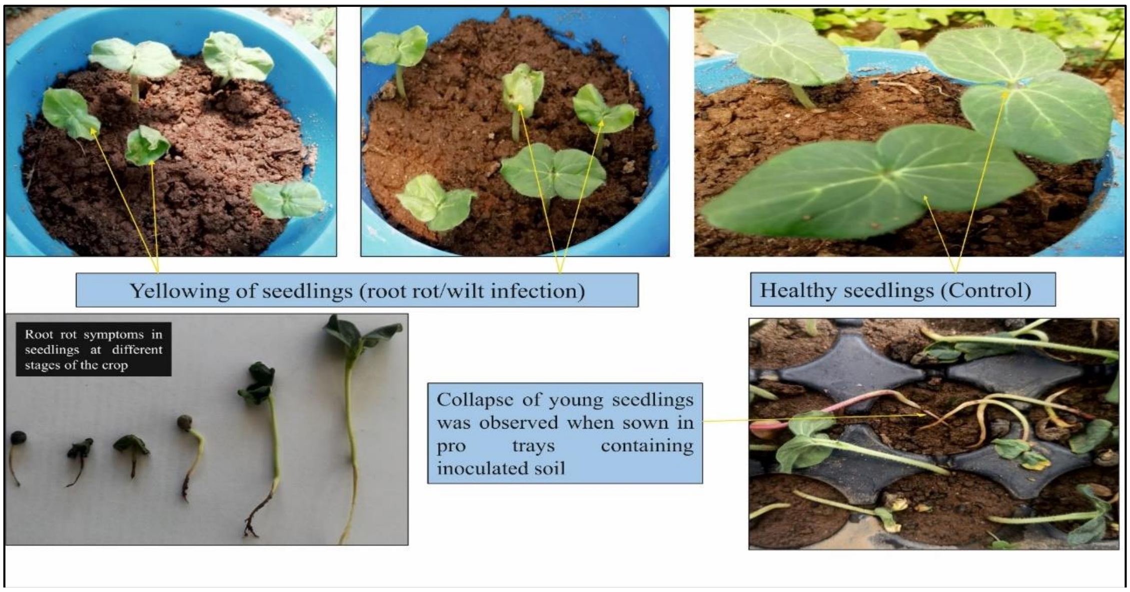
A disease survey was conducted during *Kharif* 2021 and 2022 covering different locations of Himachal Pradesh to record the prevalence and distribution of root rot of okra.

Observations were made by selecting plants from the farmer's fields of each location where an area of $25m^2$ was selected randomly and the numbers of healthy and diseased plants were counted and percent disease incidence was calculated using the formula given by (McKinney, 1923) [5]:

$$\text{Disease incidence (\%)} = \frac{\text{No. of infected seedlings}}{\text{Total no. of seedlings}} \times 100$$

**Isolation of pathogen and pathogenicity test**

The fungal cultures were isolated from diseased tissues using standard methodology on PDA. The diseased samples were washed with sterilized water and cut into small bits of 2-3 mm having half healthy and half diseased portion. These bits were surface sterilized by dipping in 1% sodium hypochlorite solution for 10-15 seconds followed by washing three times in sterilized distilled water under laminar air flow hood. The bits were dried in 2 folds of sterilized filter papers to remove excess moisture and transferred into PDA Petri plates under aseptic conditions and incubated in BOD at 25±1 °C. After 48 hrs. of incubation, growing mycelium was transferred to PDA slants (test tubes) and purified by single spore culture. Fungal colony arising from single spore isolations of each isolate was multiplied on PDA medium and used for further studies. Pathogenicity test was performed on two susceptible okra cultivars 'P-8' in pots under controlled condition by three methods *viz*., a) seed inoculation b) soil inoculation and c) seed-cum-soil inoculation to confirm the pathogenic nature of isolate. The spore suspension of the fungus having $4.0\times10^5$ spores/ml was used as inoculum.




Pathogenicity test of *Fusarium solani* on okra seedlings

Ten apparent healthy and surface sterilized seeds of susceptible okra variety P-8 were sown in each sick pot (6" diameter). Seeds sown in pots having sterilized soil without inoculum served as check. The pots were transferred to the green house and watered daily and observed for the development of disease symptoms. The pathogen was re-isolated from the diseased plant and cultured by standard methods discussed previously. The characteristics of pathogen culture thus obtained was compared with that of corresponding inoculated culture of the pathogen to prove the pathogenicity.

## Results

**Occurrence and distribution of root rot of okra**

Data on the disease incidence of root rot of okra recorded during Kharif 2021 and 2022 in different locations of Himachal Pradesh in major crop growing areas of Mandi, Una, Bilaspur, Hamirpur, Kangra and Chamba districts is presented in Table 1. The disease was observed at all the locations of surveyed areas. The overall disease incidence during 2021-22 varied from 11.00 to 55.55 percent whereas during 2022-23, the overall disease incidence varied from 11.66 to 66.66 percent while, the overall average of root rot incidence ranged between 12.50-61.05 percent at all the locations.

In district Mandi, the disease incidence during 2021-22 ranged from 11.00 to 27.50 percent with a mean of 18.77 percent whereas the disease incidence during 2022-23 ranged from 14.00 to 22.72 percent with a mean of 19.24 percent with an overall average of 19.01 percent; the highest disease incidence (25.00%) was observed in Ghatasni, while the lowest (12.50%) in Padhar. In district Una, the disease incidence during 2021-22 ranged from 12.50 to 40.00 percent with a mean of 19.87 percent whereas the disease incidence during 2022-23 ranged from 16.47 to 47.61 percent with a mean of 23.70 percent with an overall average of 24.70 percent; the highest disease incidence (43.80%) was observed in Amb, while the lowest (14.90%) in Pratapnagar.

In district Bilaspur, the disease incidence ranged from 14.50 to 55.55 percent with a mean of 32.86 percent during 2021-22 whereas during 2022-23, the disease incidence ranged from 12.16 to 66.66 percent with a mean of 32.28 percent with an overall average of 32.56 percent; the highest disease incidence (61.05%) was observed in Silh (Ghumarwin), while the lowest in Chhajoli (13.33%).

In district Hamirpur, the disease incidence during 2021-22 ranged between 15.00-42.85 percent with a mean of 26.85 percent whereas the disease incidence during 2022-23 ranged from 11.66 to 45.45 percent with a mean of 30.41 percent with an overall average of 28.63 percent; the highest disease incidence (44.15%) was observed in Sujanpur, while the lowest in Bharmoti (13.33%).

In district Kangra, the disease incidence during 2021-22 ranged from 27.77 to 42.85 percent with a mean of 39.36 percent whereas the disease incidence during 2022-23 ranged from 22.22 to 43.75 percent with a mean of 36.80 percent with an overall average of 38.08 percent; the highest disease incidence (43.65%) was observed in Maniyara, while the lowest (29.27%) in Panchrukhi.

In district Chamba, the disease incidence during 2021-22 ranged from 19.75-to 42.85 percent with a mean of 27.55 percent whereas the disease incidence during 2022-23 ranged from 18.00 to 29.50 percent with a mean of 23.05 percent with an overall average of 25.40 percent; the highest disease incidence (31.43%) was observed in Saru, while the lowest (20.00%) in Tadoli.

The overall disease incidence ranged from 11.00 to 55.55 percent during 2021-22 whereas 11.66 to 66.66 percent during 2022-23 with an overall range of 12.50 to 61.05 percent disease incidence.

**Pathogen(s) associated with the disease**

Isolations of the pathogens associated with root rot of okra revealed the presence *of Fusarium solani*, *F. oxysporum and Rhizoctonia solani*. Sickle shaped macroconidia were observed in *Fusarium solani* that were almost of the uniform size and it develops pinkish and brownish coloration on agar medium. It covers the 90mm Petri plate in 9-10 days when kept at 25±1 °C. *Rhizoctonia solani* was identified with its characteristic mycelium that has a small constriction at base of branch and always branch at right angle to the parent branch. *Fusarium oxysporum* was recognized by the presence of both macro and micro conidia. Data on number of disease samples analysed and frequency of pathogens associated with the disease has been presented in Table 2. Comparative analysis of the infected plants showed that *Fusarium solani* was frequently associated with root rot of okra. A total of 61 root rot infected plants were analysed from 5 locations in Mandi district and *Fusarium solani* was found associated with 28.52 percent plants and *Rhizoctonia solani* was found present in 23.33 percent plants whereas no recovery of pathogen was observed in 48.15 percent plants. In Una district, 69 plants from 5 locations analysed for detection of pathogen depicted 16.99 percent frequency of *F. solani* and 28.33 percent of *Fusarium oxysporum* whereas no recovery of pathogen was observed in 54.68 percent plants. In Bilaspur district, 107 plants were observed and the infection of *F. solani* was found with 35.52 percent samples and 43.47 percent infection with *F. oxysporum* whereas no recovery of pathogen was observed in 21.01 percent plants. 84 plants from Hamirpur district showed 60.02 percent infection of samples with *F. solani* whereas 23.86 percent infection with *F. oxysporum* whereas no recovery of pathogen was observed in 16.12 percent plants. No other pathogen was found associated with the wilted plants in Una, Bilaspur and Hamirpur districts.

In Kangra district, analysis of 117 diseased plants resulted 24.64 and 63.85 percent isolation frequency of *F. solani* and *Rhizoctonia solani* respectively whereas no recovery of pathogen was observed in 11.51 percent samples. One hundred diseased plants obtained from Chamba district showed 53.95 percent frequency of *F. solani* and 8.50 percent were infected with *Rhizoctonia solani* whereas no recovery of pathogen was observed in 37.55 percent plants.

**Discussion**

These results revealed that *Fusarium* spp. was found associated in all the warmer areas of Himachal Pradesh whereas *Rhizoctonia solani* was found highly associated with the disease in humid areas like Palampur and other locations in Kangra and Chamba as well as in Mandi district. Likewise, *R. solani* was not found in warmer areas of Bilaspur, Hamirpur, and Una districts. Thus, it was concluded that most frequently associated pathogen with root rot of okra in Himachal Pradesh is *Fusarium solani*. Though *Fusarium oxysporum* and *Rhizoctonia solani* were also found associated with the disease, but the frequency of both the pathogens was less than *F. solani*. These results are in accordance with Purba (2004) [7] reported that the most frequently associated pathogen with root rot of okra in Himachal Pradesh was *F. solani*. Though *Rhizoctonia solani* was also associated with the disease but it was met less frequently than *F. solani*. Similarily, Meena *et al.* (2023) [6] also reported root rot caused by *Rhizoctonia solani* is emerging as a significant threat to okra cultivation and observed 31.64 percent maximum disease incidence in Jaipur posing risks to both crop yield and nutritional quality in Rajasthan.

**Table 1:** Prevalence of root rot of okra in Himachal Pradesh

| District | Location | Disease incidence (%) | | Average (%) |
|---|---|---|---|---|
| | | 2021-22 | 2022-23 | |
| Mandi | Jogindernagar | 12.00 | 15.00 | 13.50 |
| | Padhar | 11.00 | 14.00 | 12.50 |
| | Ghatasni | 27.50 | 22.50 | 25.00 |
| | Siyanji | 23.33 | 22.72 | 23.03 |
| | Naun | 20.00 | 22.00 | 21.00 |
| | Mean ± SE | 18.77±2.07 | 19.24±1.12 | 19.01±1.54 |
| Una | Akrot | 15.00 | 18.50 | 16.75 |
| | Mubarikpur | 12.50 | 16.66 | 29.16 |
| | Amb | 40.00 | 47.61 | 43.80 |
| | Pratapnagar | 13.33 | 16.47 | 14.90 |
| | Andora | 18.51 | 19.28 | 18.90 |
| | Mean ± SE | 19.87±2.97 | 23.70±3.12 | 24.70±2.94 |
| Bilaspur | Dangaar | 27.27 | 16.66 | 21.97 |
| | Chhajoli | 14.50 | 12.16 | 13.33 |
| | Naswal | 28.50 | 21.50 | 25.00 |
| | Loharwin | 38.46 | 44.44 | 41.45 |
| | Ghumarwin | 55.55 | 66.66 | 61.05 |
| | Mean ± SE | 32.86±2.93 | 32.28±5.61 | 32.56±4.03 |
| Hamirpur | Putrial | 25.00 | 31.24 | 28.12 |
| | Rangaad | 29.16 | 29.09 | 29.13 |
| | Fatehpur | 22.22 | 34.61 | 28.41 |
| | Bharmoti | 15.00 | 11.66 | 13.33 |
| | Sujanpur | 42.85 | 45.45 | 44.15 |
| | Mean ± SE | 26.85±2.07 | 30.41±2.19 | 28.63±2.06 |
| Kangra | Palampur | 41.66 | 43.75 | 42.71 |
| | Panchrukhi | 27.77 | 30.76 | 29.27 |
| | Maranda | 42.85 | 22.22 | 32.54 |
| | Zamanabad | 41.66 | 42.85 | 42.25 |
| | Maniyara | 42.85 | 44.44 | 43.65 |
| | Mean ± SE | 39.36±1.01 | 36.80±1.50 | 38.08±1.02 |
| Chamba | Saru | 42.85 | 20.00 | 31.43 |
| | Tadoli | 22.00 | 18.00 | 20.00 |
| | Chaned | 25.50 | 23.50 | 25.00 |
| | Parel | 27.64 | 29.50 | 28.57 |
| | Banota | 19.75 | 24.25 | 22.00 |
| | Mean ± SE | 27.55±1.39 | 23.05±0.99 | 25.40±0.83 |
| | Overall range | 11.00-55.55 | 11.66-66.66 | 12.50-61.05 |

**Table 2:** Frequency of fungi associated with root rot of okra at different locations

| District | Location | No. of samples examined | Pathogen associated | | | |
|---|---|---|---|---|---|---|
| | | | *Fusarium solani* (%) | *Fusarium oxysporum* (%) | *Rhizoctonia solani* (%) | No recovery (%) |
| Mandi | Jogindernagar | 15 | 26.67 | - | 13.33 | 60.00 |
| | Padhar | 20 | 35.00 | - | - | 65.00 |
| | Ghatasni | 21 | 47.61 | - | - | 52.39 |
| | Siyanji | 15 | 13.33 | - | 53.33 | 33.34 |
| | Naun | 10 | 20.00 | - | 50.00 | 30.00 |
| | | 61 | 28.52 | - | 23.33 | 48.15 |
| Una | Akrot | 10 | 10.00 | - | - | 90.00 |
| | Mubarikpur | 12 | 25.00 | 16.67 | - | 58.33 |
| | Amb | 15 | 26.67 | 46.67 | - | 26.66 |
| | Pratapnagar | 20 | 15.00 | 45.00 | - | 40.00 |
| | Andora | 12 | 8.30 | 33.33 | - | 58.37 |
| | | 69 | 16.99 | 28.33 | - | 54.68 |
| Bilaspur | Dangaar | 25 | 20.00 | 48.00 | - | 32.00 |
| | Chhajoli | 18 | 55.56 | 27.78 | - | 16.66 |
| | Naswal | 17 | 23.52 | 64.70 | - | 11.78 |
| | Loharwin | 22 | 54.54 | 22.72 | - | 22.74 |
| | Ghumarwin | 25 | 24.00 | 54.16 | - | 21.84 |
| | | 107 | 35.52 | 43.47 | - | 21.01 |
| Hamirpur | Putrial | 12 | 58.33 | 25.00 | - | 16.67 |
| | Rangaad | 18 | 55.55 | 22.22 | - | 22.23 |
| | Fatehpur | 17 | 64.70 | 17.64 | - | 17.66 |
| | Bharmoti | 15 | 53.33 | 26.67 | - | 20.00 |
| | Sujanpur | 22 | 68.18 | 27.78 | - | 4.04 |
| | | 84 | 60.02 | 23.86 | - | 16.12 |
| Kangra | Palampur | 52 | 28.84 | - | 61.54 | 9.62 |
| | Panchrukhi | 14 | 28.57 | - | 57.14 | 14.29 |
| | Maranda | 12 | 25.00 | - | 58.33 | 16.67 |
| | Zamanabad | 22 | 22.27 | - | 68.18 | 9.55 |
| | Maniyara | 27 | 18.51 | - | 74.07 | 7.42 |
| | | 117 | 24.64 | - | 63.85 | 11.51 |
| Chamba | Saru | 22 | 54.54 | - | 13.63 | 31.83 |
| | Tadoli | 21 | 57.14 | - | 9.52 | 33.34 |
| | Chaned | 27 | 66.67 | - | - | 33.33 |
| | Parel | 17 | 52.94 | - | 11.76 | 35.30 |
| | Banota | 13 | 38.46 | - | 7.60 | 53.94 |
| | | 100 | 53.95 | - | 8.50 | 37.55 |

## Conclusion
Root rot of okra emerged as a major disease across all six surveyed districts of Himachal Pradesh (Mandi, Bilaspur, Hamirpur, Una, Kangra, and Chamba) with an overall disease incidence ranging from 12.50% to 61.05%. The highest average incidence was recorded in Kangra (38.08%), followed by Bilaspur (32.56%), while the location-wise peak incidence was observed in Ghumarwin, Bilaspur (61.05%), and Sujanpur, Hamirpur (44.15%). Among the pathogens isolated *Fusarium solani*, *F. oxysporum* and *Rhizoctonia solani*; *F. solani* was the most frequently associated, found in 36.61% of the infected samples, indicating its predominance in all surveyed districts. Therefore, *F. solani* was identified as the principal causal organism and selected for further investigation.

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