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EPIDEMIOLOGY OF RUST DISEASE ON PEA (*PISUM SATIVUM*) IN MID HILL CONDITIONS OF HIMACHAL PRADESH, INDIA

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ABSTRACT

Pea is third most important pulse crop of the world which is being cultivated all over the globe over the land area of two million hectares. Despite of its being grown in large area, this crop is infected by numerous pathogens including rust disease. This rust is disease of pea is caused by *Uromyces viciae fabae* affect the pea crop all over the mid-hill conditions of Himachal Pradesh. Therefore, the present study was conducted in mid-hill regions lies in District Mandi of Himachal Pradesh out to know the epidemiology of rust disease on pea (*Pisum sativum*). A survey of total thirteen study sites was carried out and effects on different plant characteristics like plant height, number of leaves, pods (number of pods and seeds per pod), leaf length and length of pods was evaluated. Results revealed that rust disease on pea crop was observed from seven study areas. Disease symptoms appeared as rust sori of aecia, uredia and telia which poses severe infection on entire plant. Variable degrees of disease severity and incidence of pea rust was observed in different study areas where infection was observed. An increase in disease severity and incidence was observed with the growth of pea crop. The disease severity (DS) was found in the range of 1.4–46.3% whereas, diseases incidence (DI) was observed in the range of 3.3–47.5%. Analysis of results revealed that infected plants showed significant decline in plant height, number of leaves, pods (number of pods and seeds per pod) and leaf length as compare to healthy plants. The plant height of infected plants was observed in the range of 17.8-16.3cm, whereas, number of leaves, pods (number of pods and seeds per pod) and leaf length were observed in the range of 87-65.6, 16-14, 11-7 and 4-3cm respectively. However, no significant difference was recorded in length of pods in infected and healthy plants. It is necessary to use suitable preventive and curative control measures to avoid heavy losses in final yield. Besides the use of chemical pesticides, the use of mycorrhizal fungi now days is proving beneficial to enhance overall growth performance of the plants for sustainable agricultural production.

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INTRODUCTION

Pea (*Pisum sativum* L.) a common leguminous crop of the family Fabaceae, is third most important pulse crop of the world. It is cultivated all over the globe over two million hectares of land (McKay *et al.*, 2003). India contributes as key portion in the world pea production.

India hold second rank in in the area as well as production of pea all among all countries of the world (Singh *et al.*, 2020). The Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra and Himachal Pradesh are among the major pea producing states of India. It is the 5th leading pea producing state of India which produced 294.96 thousand metric tonnes during the year 2017-18 (FAO, 2014; Singh *et al.*, 2020; Mondor, 2020; Aishwarya *et al.*, 2022). It is a legume crop which improves soil fertility by providing nitrogen to the successive crop (nitrogen fixation by *Rhizobium leguminosarum*) without the added expense of supplemental fertilizer. Despite of being cultivated broadly in India, it is commonly attacked by numerous pathogens (Sharma, 1999). Rust of pea caused by *Uromyces viciae fabae* (Pers.) de Bary is one of the most important diseases. This rust pathogen attacks number of host plants belonging to family Leguminoseae (Butler, 1918; Upadhyay *et al.*, 2019; Gautam *et al.*, 2022). This rust is also a destructive disease of pea in Himachal Pradesh especially in mid-hill conditions. Here it initiated its infection from early leafy stage and lasts up to plant maturity. Hence, it declines the overall performance of the plant.

However, it is reported to be destructive from other states of India (Arthur and Cummins, 1962; Gaumann, 1998; Upadhyay *et al.*, 2019). The rust pathogen infects stems, pods and lower surface of leaves of pea plants and produce minute, whitish, slightly raised spots as initial symptoms which later enlarge and rupture the epidermis to produce reddish brown, irregular pustules. The yellowish-white aecial cups are produced on leaflets and on pods, singly or in small groups containing abundant, powdery urediospores. These pustules turn dark brown to black when overwintering teliospores are produced (Xue, 2003). In severe infections, the affected plant dries without forming any seeds in pods or with small shriveled seeds. The plant has a dark brown to blackish appearance, visible in affected patches if totally infected (Beniwal *et al.*, 1993).

Himachal Pradesh is a hilly state of India with a total area of 55,673 km^2. More than 90% population of the state depends directly on agriculture and horticulture. The variable geographical and climatic conditions of the state divided it in to various agro-climatic zones which favor the cultivation of different agriculture and horticulture crops. There are four agroclimatic zones in Himachal Pradesh in which Mid hill zone extends from 651-1800 meters above sea level. It has a mild temperate climate which occupies about 32% of the total geographical areas and about 37% of the cultivated area (Gulati *et al.*, 2004; Samant *et al.*, 2007). Himachal Pradesh, occupies 5thposition in pea production in India with total production of 294.96 thousand metric tons per year (Upadhyay *et al.*, 2019). It is one of the commercial crop grown in mid hill regions of district Mandi, Himachal Pradesh. Despite of being major crop grown in all areas of Himachal Pradesh, a rust disease caused by *Uromyces viciae fabae* affect this crop all over the mid-hill conditions of the state, which posed major effects on different plant characteristics and of course on yield. Therefore, the present study was undertaken to study epidemiology of rust disease on pea (*Pisum sativum*) in mid hill conditions of Himachal Pradesh.

MATERIALS AND METHODS

Survey and Sampling

A survey of mid-hill regions lies in district Mandi of Himachal Pradesh was carried out to know the area covered under the cultivation of pea (*Pisum sativum*) and the status of pea rust diseases in mid- hill conditions of Himachal Pradesh. Total thirteen different areas namely, Baggi, Chachyot, Chalehad, Chatter, Dadour, Dhanotu, Dugrai, Kummi, Lohara, Malhanu, Ratti, Seri and Surandhi were surveyed between November 2020 to March, 2021 to observe the prevalence of pea rust diseases in these areas (Figure 1). Local farmers involved in cultivation of pea crop were also consulted to enhance the related information of pea crop and its diseases.

Samples of pea plants showing typical rust disease symptoms were collected from different locations of surveyed areas, placed in labeled paper bags and brought to the laboratory for further analysis. Field notes were also prepared to locate initial foci of infection and to identify the stage of rust disease. The observations were recorded with respect to time of appearance, symptomatology, incidence and severity of the disease.

Field Observations

During the field survey, 5–10 diseased and healthy plants were selected randomly to study the effect of rust disease on different morphological characteristics. The mean of all values for diseased and healthy plants was calculated and treated as average value. The following plant characteristics were observed.

Figure 1. Map of study area showing survey and sampling sites.

Plant Height

The plant height (in cm) of 5–10 randomly selected diseased and healthy plants from fields was measured from the base of the plant to the top of the plants with the help of Centimeter scale.

Number of leaves per plant

Total number of leaves in randomly selected plant was counted to check the difference between healthy plant and diseased plant.

Number, average length of pods and number of seeds per pod

Pods of ten randomly selected diseased and healthy plants were collected, counted and reported on per plant basis. Similarly, ten pods were randomly selected from main shoot in each surveyed site, their length was measured with cm scale and average length of pod was calculated. For number of seeds per pod, seeds of 10 selected pods from respective branches were threshed, counted and average number reported on pod basis.

Isolation and Identification of Fungi

Pea plants showing typical disease symptoms were collected from different study areas. The collected plant samples were analyzed for various disease symptoms on plant parts, rust sori and infection stage. Microscope slides were prepared from diseased samples by mounting the rust powder in a drop of distilled water and lacto phenol cotton blue mount mixture. The spore characteristics were observed from such prepared slides. In addition, thin hand sections through infected tissues were also prepared and observed under microscope. The fungal specimens were identified and their distributional records were checked in the standard literature (Bilgrami and Rizwi, 1991; Cummins and Hiratsuka, 2003; Jamaluddin *et al.*, 2004). Illustrations were prepared and photographed under a light microscope fitted with a digital camera.

Statistical Analysis

The information of rust diseases on pea obtained after filed surveys was analyzed for disease incidence and disease severity to find out the epidemiology of the disease in the area under mid- hill conditions of Himachal Pradesh. Disease incidence (DI) (Mayer and Datar, 1986) and severity (DS) (Mahrotra and Aggarwal, 2003) during the present study was calculated as per the formula given below:

$$\text{Disease incidence (DI)} = \frac{\text{No. of infected plants}}{\text{Total no. of plants assessed}} \times 100$$

$$\text{Disease severity (DS)} = \frac{\text{Sum of all numerical rating}}{\text{Number of leaves examined} \times \text{maximum grade}} \times 100$$

RESULTS

The results after completing survey revealed that pea is one of the major commercial crop being cultivated in all study sites. Of the total thirteen study sites surveyed, rust disease on pea crop was observed only from Chachyot, Chatter, Kummi, Lohara, Malhanu, Seri and Surandhi. In remaining study areas namely, Baggi, Chalehad, Dugrai, Dadour, Ratti and Dhanotu, no symptoms of rust disease on pea were observed.

Symptomatology of diseased plants was studied under natural conditions. Initial symptoms were observed at the pod formation stage of pea crop as scattered yellow spots which get enlarged and rapidly grow further. First symptom appeared on the upper surface of the lower most leaves as yellowish cup shaped aeciospores which enlarge and eventually coalesced. Under suitable environmental conditions the pathogen traverses upward and similar reddish mass appears on the upper surface of the leaves. As the infection progressed the lower surface of the infected leaves also get covered with fungal growth. The uppermost leaflets and stem were also found infected. The infection gradually spreads to stem. Although, the entire plant was prone to infection but initially the symptoms appeared on the lower portion of the leaves just above the ground level. The severely infected plants were observed to give a reddish color appearance. The non-green parts of pea plants were found free from infection (Figure 2).

Figure 2. *Uromyces viciae-fabae*on pea (*Pisum sativum*). A-B= Aecia on lower side of pea plant, C-D = Aecia and Uredia on lower side of leaves, E= Telia on upper side of plant leaves, F= Telia on lower side of pea plant.

Microscopic examination of hands sections and mount of slides revealed that the peridium of aecium was short, whitish and cup shaped. The aeciospores were round to angular or elliptical, yellow in colour with fine warts and measure 14–22 µm in diameter. The uredospores were round to ovate, light brown echinulate with 3-4 germ pores and measure 20–30 × 18–26 µm The teliospores were sub globose to ovate, thick walled, with straightened apex, smooth, single celled, pedicellate and about 25–38 × 18–27 µm in size (Figure 3). Based on present study and available literature, this rust pathogen is believed to be autoecious in nature with aeciospores, urediospores and teliospores found on a similar host plant. The comparison of present findings with previously published studies, this rust pathogen was identified as *Uromyces fabae (Uromyces viciae-fabae*) was first reported by Persoon in 1801.

Disease Severity and Incidence

Of the total areas surveyed, the disease was found occurring in seven areas with various degrees of severity and incidence. After analysis of results, an increase in disease severity and incidence was observed with the growth of pea crop. Three stages of life cycle of rust fungi namely, aecial, uredial and telial were observed during the survey. The initiation of disease was observed in the month of January. Among all surveyed locations, initial infection was observed first in Chachyot, Surandhi and Malhanu. The

percentage diseases severity and incidence was observed maximum in Chachyot (12.5%) with percent disease incidence of 4.6% in January followed by Kummi (7.88%) with PDI of 4.2%, Seri (6.6%) with PDI of 3.2% and Malhanu (5.76%) with percent disease incidence of 4.4%. Similarly, percentage diseases severity was observed maximum in Malhanu during the month of February (30.7%) with percent disease incidence of 23.9% followed by Surandi (29.3%) with percent disease incidence of 25.1% and Kummi (27.9%) with percent disease incidence of 23.2%. In the month of March, maximum percentage diseases severity was again observed in Malhanu (46.3%) with 31.1 % percent diseases incidence followed by Kummi (37.9%) with PDI of 35.3% and Surandhi (32.1%) with PDI of 47.5% (Table 1; Figure 4 and 5).

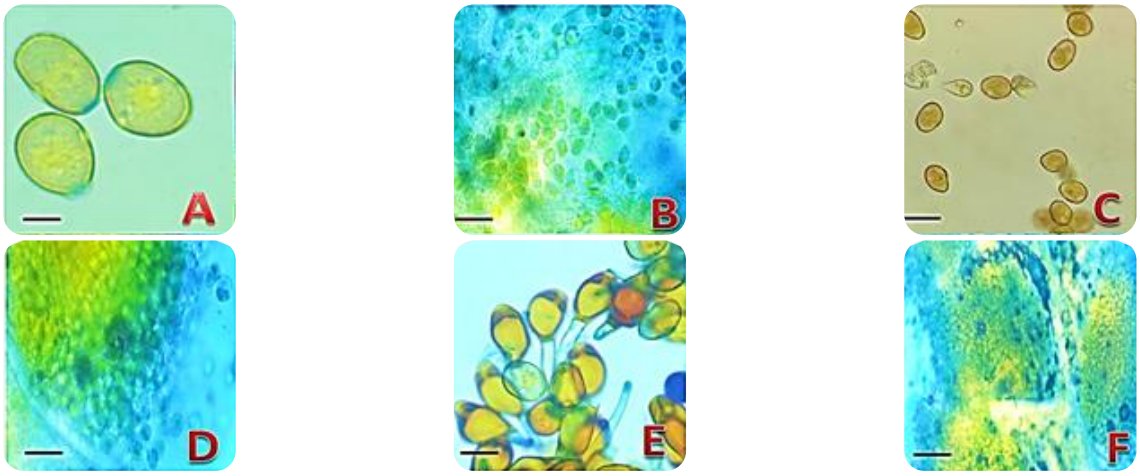

Figure 3. *Uromyces viciae-fabae* on pea (*Pisum sativum*). A) aeciospores, B) cut section of aeciospores, C) uredospores, D) cut section of uredospores E) teliospores and F) cut section of teliospores, Scale bar: A–F = 20 µm.

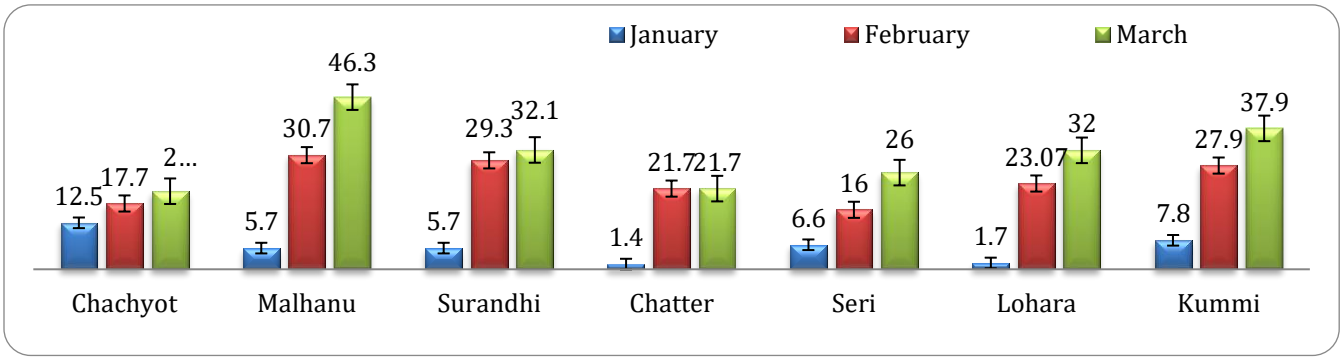

Figure 4. Percentage (%) disease severity (DS) of rust disease on pea.

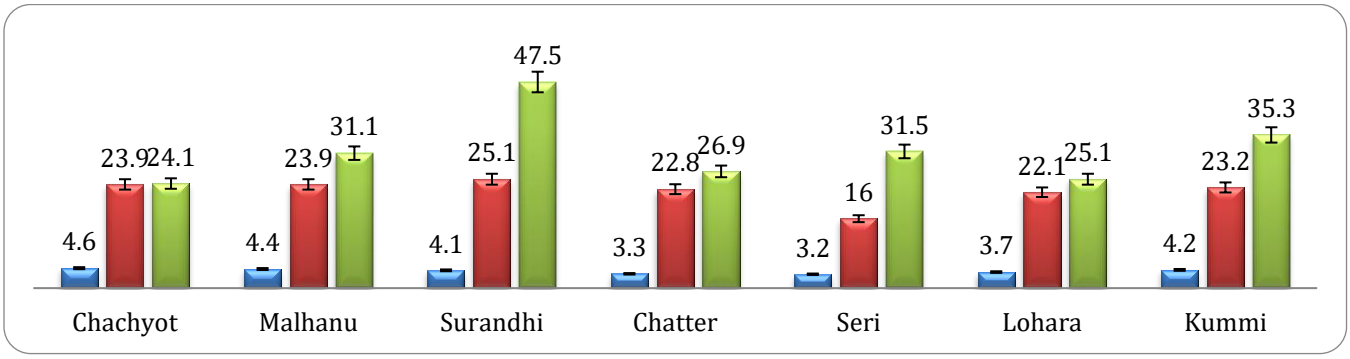

Figure 5. Percentage (%) disease incidence (DI) of rust disease on pea.

Table 1. Disease severity (DS) and diseases incidence (DI) of rust disease on pea.

Study Areas	Disease Severity (%)			Disease Incidence (%)		
	January	February	March	January	February	March
Chachyot	12.5	17.73	21.06	4.6	23.9	24.1
Malhanu	5.76	30.7	46.3	4.4	23.9	31.1
Surandhi	5.73	29.3	32.1	4.1	25.1	47.5
Chatter	1.4	21.7	21.7	3.3	22.8	26.9
Seri	6.6	16.0	26	3.2	16	31.5
Lohara	1.7	23.07	32	3.7	22.1	25.1
Kummi	7.88	27.9	37.9	4.2	23.2	35.3

Effects on Rust Disease on Morphological Properties

Analyses of results revealed that infected plants showed significant variations in plant height, number of leaves, pods (number of pods and seeds per pod) and leaf length as compare to healthy plants. However, no significant difference was recorded in length of pods in infected and healthy plants. The detailed results of variations in morphological characteristics of infected and healthy plants are presented in Table 2.

Plant Height

A variation in plant height of healthy and infected plants was observed. In healthy plants, highest plant height was recorded in samples collected from Lohara (18.7cm) followed by Chatter (18.5cm), Chachyot (18.1cm), Surandhi (18.06cm), Malhanu (17.9cm), Seri (17.2cm) and lowest in Kummi (17.1cm). However, plant height was found highest Chatter (17.8cm) followed by Chachyot (17.3cm), Malhanu (17.2cm), Surandhi (17.1cm), Lohara (16.9cm), Kummi (16.8cm) and Seri (16.3cm) in rust infected plants.

Number of Leaves per Plant

A minor difference in average number of leaves per plant was observed between healthy and infected plants. While, highest average number of leaves per plant was observed in Lohara (87), it was followed by Malhanu (72), Seri (70.3), Chatter (69.6), Kummi (67), while, lowest in Chachyot & Surandhi (65.6 each). Similarly, the average number of leaves in healthy plant was found highest in Lohara (90.3), it was followed by Malhanu (73), Seri (71.6), Chatter (70.3), Kummi (69.6), Chachyot (68.3) and Surandhi (66.3).

Table 2. Effect of *Uromyces vciae-fabae* on the morphological attributes of pea.

Plant Characteristics	Plant height (cm)		No. of leaves/ plant		No. of pods		Length of pods (cm)		No. of grains/ pod		Leaf length (cm)	
	H	I	H	I	H	I	H	I	H	I	H	I
Chachyot	18.1	17.3	68.3	65.6	17.3	15.3	7.8	5.6	7.6	7.3	5	3
Chhater	18.5	17.8	70.3	69.6	16.6	14	8.5	6.6	11.3	11	4.8	3.3
Kummi	17.1	16.8	69.6	67	17	16	7.8	6	12.3	11	4.3	3
Lohara	18.7	16.9	90.3	87	17	15	8.3	7	10	7	4.8	3.5
Malhanu	17.9	17.2	73	72	16.6	15	7.6	6.6	8.3	7.6	5	3.9
Seri	17.2	16.3	71.6	70.3	16.3	14.3	7.6	7	11.6	11	5.2	4
Surandhi	18.06	17.1	66.3	65.6	15.6	14.6	7.8	5.6	10.6	9	5.4	3.8

H=healthy, I= infected

Number of Pods

While comparing average number of pods between infected and healthy pea plants, a moderately significant variation was observed. When the highest average number of pods was observed at Kummi (16) in case of infected plants, it was followed by Chachyot (15.3), Loahra & Malhanu (15 each), Surandhi (14.6), Seri (14.3) and Chatter (14); it was found highest at Chachyot (17.3) which was followed by Lohara & Kummi (17 each), Malhanu &Chatter (16.6 each), Seri (16.3) and Surandhi (15.6) in healthy plants.

Average Length of Pods

The results revealed great variation in average length of pods both in healthy and infected plants. While, highest

pod length in healthy plants was found in Chatter (8.5cm); it was followed by Lohara (8.3cm), Chachyot, Kummi & Surandhi (7.8 cm each) and lowest in Malhanu & Seri (7.6 cm each) whereas, in infected plants, pod length was observed maximum in Lohara & Seri (7 cm each), followed by Chatter & Malhanu (6.6 cm each) and Chachyot & Surandhi (5.6 cm each) and Kummi (6).

Number of Grains per Pod

While analyzing the results of effects of rust on number of grains per pod, it was observed that the healthy pods collected from Kummi showed highest average numbers of grains (12.3), which was followed by Seri (11.6), Chatter (11.3), Surandhi (10.6), Lohara (10), Malhanu (8.3) and Chachyot (7.6). When we analyzed infected pods, maximum number of grains per pod were observed in pod samples collected from Chatter, Kummi, Seri (11 each), followed by Surandhi (9), Malhanu (7.6) and Chachyot (7.3).

Leaf Length

The rust fungi showed a great effect on leaf length in infected plants as compared to healthy ones. Highest leaf length of infected plants was observed in plants collected from Seri (4cm), followed by Malhanu, Surandhi, Lohara, Chatter, Kummi and Chachyot where, average leaf length was observed in the range of 3.9-3 cm. Similarly, in healthy plants, highest leaf length was observed in Surandhi (5.4cm), followed by Seri (5.2cm), Malhanu & Chachyot (5cm each), Lohara (4.8 cm) and Kummi (4.3 cm).

DISCUSSION

Pea rust is worldwide in distribution found on various plant genera belonging to the family Leguminosae. The agro-climatic conditions of Himachal Pradesh are quite favorable for producing quality peas and also favour the growth and development of different diseases of this crop including pea rust. In a survey carried out by Chauhan *et al.* (1991) to study the prevalence and distribution of pea rust in Himachal Pradesh, suggested the occurrence of the different stages of pea rust disease caused by *Uromyces-vciae-fabae*. Similar studies on epidemiology and control of rust disease of pea were carried out by Singh and Tripathi (2004); Mishra *et al.* (2009); Bal and Kumar (2012). The appearance of earliest rust symptoms as development of aecia on pea leaves were recorded in the month of January (6.5 ℃ with 67% humidity and 102 mm rainfall) and February (8.6 ℃ with 66% humidity and 140 mm rainfall) in various surveyed locations revealed that the climate during these months in district Mandi favors primary infection and disease development. Similar observations on development of aecia as earliest symptoms of pea rust in February or even later were also observed by Singh (1973). These observations along with results of present study revealed that the months of January and February were very favorable for the primary infection and disease development. Occurrence of pea rust occurs severe form in all the major pea growing area of India during January was also observed by Kumar *et al.* (1994) and Upadhyay *et al.* (2019). Based on detailed study as well as published literature, *Uromyces fabae* produces aeciospores, urediospores and teliospores found on a similar host plant (autoecious in nature).

The results of present study revealed that pea rust affects morphological properties of pea. Plant height, number of leaves, pods (number of pods and seeds per pod) and leaf length was observed to be greatly variable in infected plants when compared to healthy ones. Similar observations on effects of pea rust (*U. fabae*) on pea were studied very earlier by Thatcher (1939) which revealed that this rust pathogen causes the secretion of some metabolites from infected host cells. This aspect on effects of pea rust on pea crops were investigated by Barilli *et al.* (2009); Barilli *et al.* (2014); Singh *et al.* (2014) and Osuna-Caballero *et al.* (2022) where they highlighted the effects of *U. fabae* on growth characteristics of this crop. The increased permeability of infected cells, synthesis of proteins and change in protein and several enzymes in susceptible plants was observed in bean leaves infected with *U. fabae* (Staples and Stahmann, 1964; Staples, 1968; Hahn *et al.*, 1997; Singh *et al.*, 2012; Barilli *et al.*, 2014; More *et al.*, 2020). Because of such harmful effects, it becomes necessary to use suitable preventive and curative control measures to avoid heavy losses in final yield. Apart from chemical control, use of mycorrhizal fungi as potential bio-fertilizers is proving beneficial now days to increase overall growth performance of the plants (Manjula *et al.*, 2022). Therefore, the use of such environmental friendly measures should be promoted for sustainable agricultural production.

AUTHORS' CONTRIBUTION

All authors contributed equally to this research.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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