Microbiology Research Journal International

Volume 34, Issue 6, Page 1-10, 2024; Article no.MRJI.116718
ISSN: 2456-7043, NLM ID: 101726596
(Past name: British Microbiology Research Journal, Past ISSN: 2231-0886, NLM ID: 101608140)

Bioefficacy of Indigenous Isolates of Biocontrol Fungi and Bacteria against *Macrophomina Phaseolina* Causing Root Rot Disease in Green Gram

Irfan Ahmad [a*] and Mujeebur Rahman Khan [a]

[a] Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh-202002, U.P., India.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/mrji/2024/v34i61447

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc. are available here: https://www.sdiarticle5.com/review-history/116718

Original Research Article

Received: 09/03/2024
Accepted: 14/05/2024
Published: 17/05/2024

ABSTRACT

Green grams are the most valuable pulse crops in terms of plant-based protein, dietary fiber, and various phytochemicals. Although green gram is found susceptible to the soil-borne fungus *Macrophomina phaseolina* (Tassi) Goid, it leads to severe root-rot disease and causes a significant reduction in crop yield. Thus, the study aims to determine the bioefficacy of indigenous isolates of biocontrol fungi and bacteria *viz., T. asperelloides* AMUTASPD-51, *T. asperellum* AMUTASPM-51, *T. asperellum* AMUTASPM-52, *T. asperellum* AMUTASPM-53, *T. atroviride* AMUTATROV-31, *T. harzianum* AMUTHZ-71, *T. harzianum* AMUTHZ-72, *T. harzianum* AMUTHZ-73, *T. harzianum* AMUTHZ-74, *T. hamatum* AMUTHM-31, *T. viride* AMUTVR-61, *T. viride* AMUTVR-62, *T. virens* AMUTVNS-41, *T. longibrachiatum* AMUTLONB-41, *Pochonia chlamydosporia* AMUPC-31, *Purpureocillium lilacinum* AMUPL-31, *Aspergillus niger* AMUAN-41, *Bacillus subtilis* AMUBS-80 and

**Corresponding author: E-mail: ahmadirfan8923@gmail.com;*

Cite as: *Ahmad, I., & Khan, M. R. (2024). Bioefficacy of Indigenous Isolates of Biocontrol Fungi and Bacteria against Macrophomina Phaseolina Causing Root Rot Disease in Green Gram. Microbiology Research Journal International, 34(6), 1–10. https://doi.org/10.9734/mrji/2024/v34i61447*

Pseudomonas fluorescens AMUPF-80 against *Macrophomina phaseolina* AMUMP-2 by using dual inoculation technique for seven days incubation at a temperature under *in-vitro* condition. All species of *Trichoderma* fungus showed high biocontrol potential to suppress the radial growth of *M. phaseolina* AMUMP-2 over control. Among the biocontrol fungi and bacteria, *T. viride* AMUTVR-61 resulted in the highest radial inhibition of *M. phaseolina* AMUMP-2 by 95.0% over control. The *T. harzianum* AMUTHZ-72 was second most effective in decreasing the radial growth by 94.2% of the pathogens, followed by *T. harzianum* AMUTHZ-71 (92.8%), *T. asperellum* AMUTASPM-53 (86.1%), and *T. harzianum* AMUTHZ-74 (83.7%) over control. However, *B. subtilis* AMUBS-80 was found to be the least effective, suppressing radial inhibition of *M. phaseolina* AMUMP-2 by 21.7% over control. The present study indicates that *T. viride* AMUTVR-61 and *T. harzianum* AMUTHZ-72 were the most significant indigenous biocontrol fungi against *M. phaseolina* AMUMP-2. Furthermore, its application led to a substantial decrease in the soil-borne pathogen population that affects plant health, especially green gram, and adverse environmental and human effects.

Keywords: Biocontrol agents; M. phaseolina AMUMP-2*; Trichoderma spp.; Aspergillus spp; green gram.*

1. INTRODUCTION

Pulses are an essential source of plant-based protein and staple food for the Indian people. India is one of the largest producers and consumers of pulses in the world [1]. Besides providing a healthy diet to humans, it contributes to improved soil fertility and agro-biodiversity [2]. Among the pulses, green gram or mung bean, *Vigna radiata* (L.) is the third most crucial pulse crops in India next to chickpea and pigeon pea [3, 4]. It is a key component in the symbiotic relationship between nitrogen-fixing rhizobium and leguminous plants. This relationship helps conserve the nitrogen components in soil and improve soil fertility for non-leguminous crops [5, 6]. Green gram is a nutritionally rich, high-quality protein, carbohydrates, amino acids, vitamins, micronutrients, and low-fat content food crop [7, 8]. It is widely grown under semi-arid and sub-tropical climates and is cultivated in almost all parts of India [9]. The crop is grown mainly in the Kharif season [10].

Various biotic and abiotic factors have been reported to affect the growth and production of green grams so far [11, 12]. The biotic factors include powdery mildew, mung bean yellow mosaic virus, cercospora leaf spot, anthracnose, root-rot, leaf crinkle virus, web blight, rust, and bacterial leaf blight are the most distressing agents that cause more significant reduction in crop yield [13]. The root-rot fungus, *M. phaseolina*, is a highly potent and destructive pathogen that causes significant damage to the host plant at all stages of growth, including during flowering and pod formation in green gram [14, 15, 6]. It is a necrotrophic seed and soil-borne fungus that causes root-rot disease in green gram [16, 17]. The pathogen propagules invade urdbean and mungbean seeds and affect the germination and viability rate of the seed [18,19]. The pathogen deteriorates the stored seed quality ranging from 2% to 36% in various South Asian countries such as Bangladesh [20], Pakistan [21], India [22], and Thailand [23]. Thus, the soil-borne pathogens cause great reductions in the yield of green gram crops, ranging from 20% to 60% across various regions in India [7].

Microbial antagonistic microorganisms have the potential to offer a cost-effective and environmentally friendly approach to controlling soil-borne phytopathogens [24, 25, 6, 26, 27]. Several biocontrol fungi and bacteria, such as *Trichoderma* species [15, 6], *P. chlamydosporia* [28], *P. lilacinum* [29]*, A. niger* [30], *B. subtilis* [31] and *P. fluorescens* Kumari et al., [32] have been evaluated for controlling root-rot pathogens. *Trichoderma* species have evident greater effectiveness against *M. phaseolina* in field as well as laboratory conditions [15, 6, 26]. *A. niger* has been proven as a highly effective microbial antagonist against the root-rot fungus *M. phaseolina* [15, 33]. *T. atroviride*, *T. asperellum*, *T. harzianum*, *T. hamatum*, *T. koningii*, *T. polysporum* and *T. viride* are found to be effective in suppressing the mycelial growth of *M. phaseolina* in mung beans [15, 6, 34].

Trichoderma spp. exhibits mycoparasites (hindering fungal colonization), secreting lytic or cell wall-degrading enzymes (like cellulases, glucanases, proteases, chitinases, chitinases, as well as toxins, hormones, and antibiotic compounds), and nutrient competent [35,36]. Therefore, the present study aimed to evaluate the efficacy of biocontrol fungi and bacteria *viz*., *T. asperelloides* AMUTASPD-51, *T. asperellum* AMUTASPM-51, *T. asperellum* AMUTASPM-52,

T. asperellum AMUTASPM-53, *T. atroviride* AMUTATROV-31, *T. harzianum* AMUTHZ-71, *T. harzianum* AMUTHZ-72, *T. harzianum* AMUTHZ-73, *T. harzianum* AMUTHZ-74, *T. hamatum* AMUTHM-31, *T. viride* AMUTVR-61, *T. viride* AMUTVR-62, *T. virens* AMUTVNS-41, *T. longibrachiatum* AMUTLONB-41, *P. chlamydosporia* AMUPC-31, *P. lilacinum* AMUPL-31, *A. niger* AMUAN-41, *B. subtilis* AMUBS-80 and *P. fluorescens* AMUPF-80 to manage root-rot fungus caused by *M. phaseolina* AMUMP-2 in green gram. This study also showed the isolation of native biocontrol fungi and bacteria from soil-borne pathogens to substitute chemical fungicides for soil-borne pathogens. This study enlightens the incorporation of plant and microbial-based materials in the disease management module rather than using synthetic agrochemicals in soil fertilization and crop protection.

2. MATERIALS AND METHODS

2.1 Isolation and Identification of Root-rot Fungus

The root-rot fungus, *Macrophomina phaseolina* AMUMP-2 was isolated from the infected roots of the green gram. The infected root sample was cut into small pieces (2-5mm) and surface sterilized by dipping in 1% sodium hypochlorite (w/v) for 30 seconds and then rinsed twice with distilled water. The pieces were dried on sterilized absorbent tissue paper and placed onto a petri dish containing solidified potato dextrose agar (PDA). The inoculated plates were kept at 28±2°C in an incubator for a week. After incubation, the fungus colonies were examined under a microscope and compared to *Macrophomina phaseolina* characteristics. Hence, the root-rot fungus was examined based on its morphological and cultural characteristics.

2.2 Isolation and Identification of Biocontrol Fungi and Bacteria

The biocontrol fungi, *viz*., *Trichoderma* species, *P. chlamydosporia*, *P. lilacinum* and *Aspergillus niger* were isolated from several green gram field soil using serial dilution method on *Trichoderma* selective medium, Corn Meal Agar, and *Aspergillus* selective medium, respectively. The soil sample of 10g was collected separately from each sample and mixed with 90 ml of double distilled water (DDW) in a 100 ml Erlenmeyer flask. The flask containing soil solution was homogenized using a shaker for 10 min. After that, the flask was stand in a laminar flow for 10 min to settle down heavy particles. For soil dilution, 1 ml of the soil solution was pipetted into a culture tube containing 9 ml DDW, shaken, and marked as 10^{-2} dilution. This process was repeated until 10^{-4} or 10^{-6} dilution level was achieved. For isolation of *Trichoderma* species, *P. chlamydosporia*, *P. lilacinum* and *Aspergillus* species, 100µl of dilution 10^{-4} was spread on solidified *Trichoderma* selective media (TSM), Corn Meal Agar (CMA) and *Aspergillus* selective media (ASM), respectively. The plates were sealed with parafilm tape and incubated at 28±2°C for ten days. *Trichoderma* colonies from TSM, *P. chlamydosporia,* and *P. lilacinum* colonies from CMA and *A. niger* colonies from ASM were sub-cultured on solidified PDA under sterilized conditions. The plates were incubated at 28±2°C for ten days. After incubation, the isolates of *Trichoderma* species, *P. chlamydosporia, P. lilacinum* and *A. niger* were processed for morphological identification based on colony size, mycelium, conidiation colour, pattern and colour of the medium. The microscopic characteristics such as conidiophores, conidia, phialides, or mycelial structures were examined under 40× magnifications.

The biocontrol bacteria *viz., B. subtilis* and *P. fluorescens* 100µl (10^{-6}) dilution from were spread onto solidified Nutrient Agar (NA) medium in Petri plates under a flame in a Laminar flow. The inoculated Petri plates were sealed with parafilm tape and incubated for 24 h at 37.8°C in a BOD incubator. After incubation, streaking with a single colony was done on NA medium in Petri plates. The colonies were examined for colour, size, shape, gram response, and cell shape to confirm *B. subtilis* and *P. fluorescens* (Brown, 1939).

2.3 *In vitro* Efficacy of Biocontrol Fungi and Bacteria against Root-rot Fungus

The efficacy of nineteen indigenous isolates of biocontrol fungi and bacteria *viz., T. asperelloides* AMUTASPD-51, *T. asperellum* AMUTASPM-51, *T. asperellum* AMUTASPM-52, *T. asperellum* AMUTASPM-53, *T. atroviride* AMUTATROV-31, *T. harzianum* AMUTHZ-71, *T. harzianum* AMUTHZ-72, *T. harzianum* AMUTHZ-73, *T. harzianum* AMUTHZ-74, *T. hamatum* AMUTHM-31, *T. viride* AMUTVR-61, *T. viride* AMUTVR-62, *T. virens* AMUTVNS-41, *T. longibrachiatum* AMUTLONB-41, *P. chlamydosporia* AMUPC-31, *P. lilacinum*

AMUPL-31, *A. niger* AMUAN-41, *B. subtilis* AMUBS-80 and *P. fluorescens* AMUPF-80 against *M. phaseolina* AMUMP-2 was evaluated under *In vitro* condition by following the dual culture plate method [37]. The biocontrol fungi, bacteria and test pathogen (*M. phaseolina* AMUMP-2) of 5 mm diameter disc were taken from seven days old cultures and placed oppositely towards the periphery of the Petri plates containing PDA media. The antagonistic activity of biocontrol fungi and bacteria was observed against the test fungus by measuring the per cent inhibition of mycelial growth of the pathogenic using equation no. 1. The dual culture plates were maintained in five replications and incubated at 28±2°C in a BOD for five days.

$$PI = \{(C - T)/C\} \times 100 \ldots\ldots \quad \text{Eq. (1)}$$

where,
I = Per cent inhibition
C = Control (radial growth)
T = Treatment (radial growth)

2.4 Statistical Analysis

The table data were presented in mean values of five replications of each treatment using MS Excel 2021. The data on the colony diameter (mm) of pathogen and biocontrol fungi and bacteria were analyzed through single-factor ANOVA. The single-factor ANOVA to mycelial growth inhibition (%) was evaluated in terms of Fisher's least significant difference (LSD), coefficient of variation (CV), and standard error of the mean (SEM) at the probability level, *P≤0*.05. The data on percent growth inhibition is presented as a box plot with one-way ANOVA and represents the Tukey test using Origin-Pro software, 2024. The statistical significance between the treatments was determined by the Tukey HSD test at the probability level, *P*≤ 0.05, using R software [38].

3. RESULTS

3.1 Antagonistic Effects of Biocontrol Fungi against Root-rot Fungus *In vitro*

The result of the present study revealed that the nineteen indigenous isolates of biocontrol fungi and bacteria *viz., T. asperelloides* AMUTASPD-51, *T. asperellum* AMUTASPM-51, *T. asperellum* AMUTASPM-52, *T. asperellum* AMUTASPM-53, *T. atroviride* AMUTATROV-31, *T. harzianum* AMUTHZ-71, *T. harzianum* AMUTHZ-72, *T. harzianum* AMUTHZ-73, *T. harzianum* AMUTHZ-74, *T. hamatum* AMUTHM-31, *T. viride* AMUTVR-61, *T. viride* AMUTVR-62, *T. virens* AMUTVNS-41, *T. longibrachiatum* AMUTLONB-41, *P. chlamydosporia* AMUPC-31, *P. lilacinum* AMUPL-31, *A. niger* AMUAN-41, *B. subtilis* AMUBS-80 and *P. fluorescens* AMUPF-80

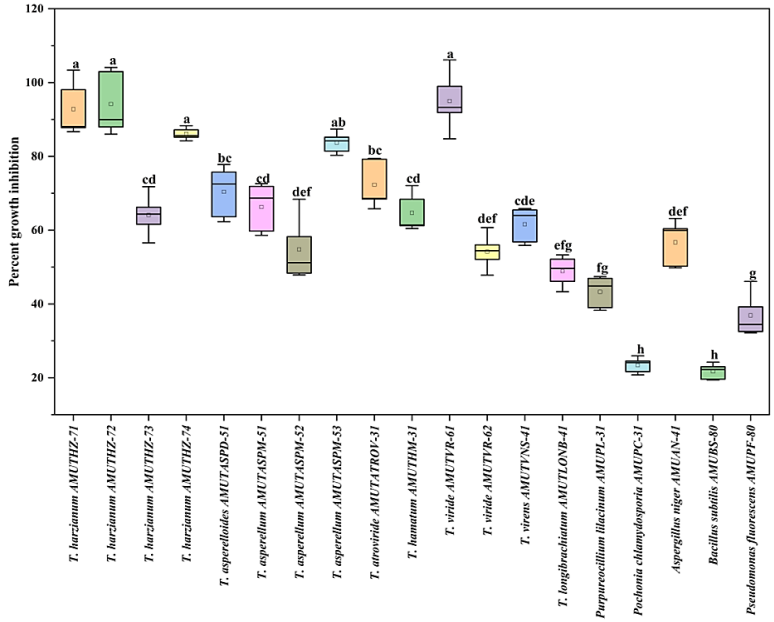

Fig. 1. *In-vitro*, the effect of biocontrol fungi and bacteria on the percent growth inhibition of *Macrophomina phaseolina* AMUMP-2. Different alphabets are indicated significantly different at *P*≤0.05 according to Tukey test. Error bars show standard deviation

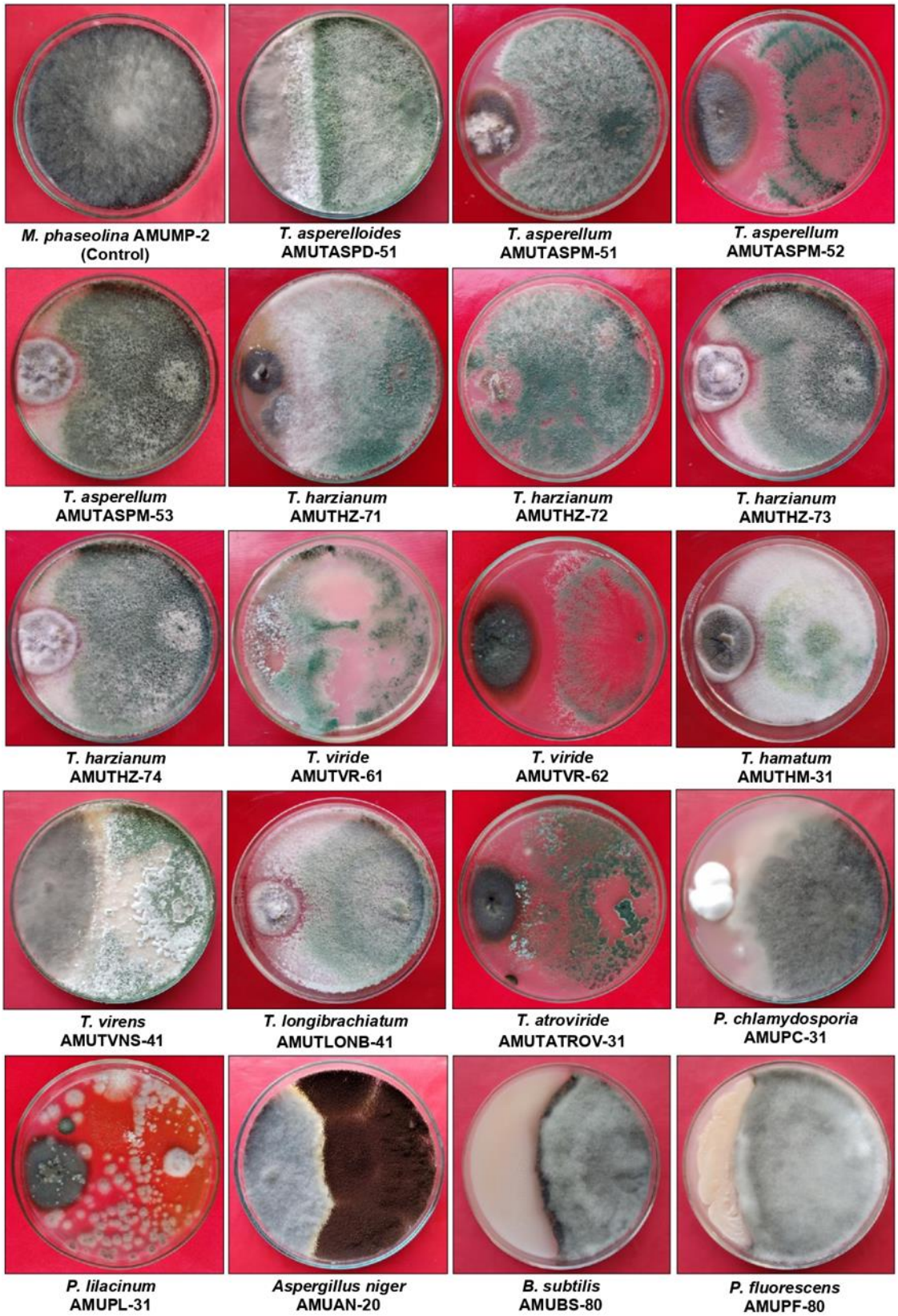

Fig. 2. Antagonistic effect of biocontrol fungi and bacteria against *Macrophomina phaseolina* AMUMP-2 *In-vitro*

Table 1. *In vitro*, the effect of biocontrol fungi and bacteria on the colonization of *Macrophomina phaseolina* AMUMP-2

Biocontrol agents		Colony Diameter (mm) *Macrophomina phaseolina* AMUMP-2	Growth inhibition (%)
Control		90.0^{a}	-
Aspergillus niger AMUAN-41		39.0^{efg}	56.7^{def}
T. asperelloides AMUTASPD-51		26.6^{hi}	70.4^{bc}
T. asperellum AMUTASPM-51		30.3^{ghi}	66.3^{cd}
T. asperellum AMUTASPM-52		40.7^{ef}	54.8^{def}
T. asperellum AMUTASPM-53		12.8^{kl}	86.1^{a}
T. atroviride AMUTATROV-31		24.9^{ij}	72.3^{bc}
T. harzianum AMUTHZ-71		6.5^{kl}	92.8^{a}
T. harzianum AMUTHZ-72		5.2^{l}	94.2^{a}
T. harzianum AMUTHZ-73		32.3^{fghi}	64.1^{cd}
T. harzianum AMUTHZ-74		15.4^{jk}	83.7^{ab}
T. hamatum AMUTHM-31		31.8^{fghi}	64.7^{cd}
T. viride AMUTVR-61		4.5^{l}	95.0^{a}
T. viride AMUTVR-62		41.2^{ef}	54.2^{def}
T. virens AMUTVNS-41		34.6^{fgh}	61.6^{cde}
T. longibrachiatum AMUTLONB-41		46.0^{de}	48.9^{efg}
Pochonia chlamydosporia AMUPC-31		68.9^{b}	23.4^{h}
Purpureocillium lilacinum AMUPL-31		51.0^{cd}	43.3^{fg}
Bacillus subtilis AMUBS-80		70.5^{b}	21.7^{h}
Pseudomonas fluorescens AMUPF-80		56.8^{c}	36.9^{g}
LSD *P*≤0.05		5.23	7.33
CV		11.41	9.28
SEM		17.32	33.87
ANOVA			
Treatment	Df	19	18
	Sum Sq	50255	43682
	Mean Sq	2645	2426.8
	F value	152.7**	71.63**
Residuals	Df	80	46
	Sum Sq	1386	2575
	Mean Sq	17.3	33.9

*Each values are means of five replicates. Values followed by different alphabets within column are significantly different at P≤0.05 according to Tukey test. **F values are significant at P≤0.05*

showed inhibitory effects against *M. phaseolina* AMUMP-2 (Fig. 2). The indigenous isolates of biocontrol fungi and bacteria effectively suppressed the mycelial growth of test pathogens compared to the untreated control (Fig. 2). Among biocontrol fungi and bacteria, *T. viride* AMUTVR-61 showed higher mycelial inhibition of 95.0% of the test pathogen over untreated control (*P*≤0.05; Table 1, Fig. 1). Next in order was *T. harzianum* AMUTHZ-72, which showed mycelial inhibition of 94.2%, followed by *T. harzianum* AMUTHZ-71 and *T. asperellum* AMUTASPM-53 exhibited a percent inhibited the test pathogen by 92.8% and 86.1% compared to the control (*P*≤0.05; Table 1, Fig. 1). Similarly, *T. harzianum* AMUTHZ-74 was also significantly suppressed the mycelial growth of *M. phaseolina* AMUMP-2 by 83.7% followed by *T. atroviride* AMUTATROV-31 (72.3%) and *T. asperelloides* AMUTASPD-51 (70.4%) over control (*P*≤0.05; Table 1; Fig. 1). The treatment of *Bacillus subtilis* AMUBS-80 showed relatively lower effectiveness, as indicated by an inhibition zone of 21.7% against the test pathogens (*P*≤0.05; Table 1; Fig. 1).

4. DISCUSSION

Green gram is one of the important pulse crops, but its productivity is considerably affected by biotic and abiotic factors in India compared to other countries [3,4]. The root-rot fungus *Macrophomina phaseolina* is one of the most economically significant pathogens of green

gram that has a negative impact on plant yield and production [39,15,7,6]. The pathogen, *M. phaseolina* infects leaves, pods, and roots, resulting in defoliation or blighted appearance of leaves [13,19]. The present study found that all indigenous isolates of biocontrol fungi and bacteria significantly suppressed the mycelial growth of *M. phaseolina* AMUMP-2 *in vitro*. The dual inoculation test revealed biocontrol fungi and bacteria, *T. viride* AMUTVR-61 and *T. harzianum* AMUTHZ-72 showed maximum suppression of the colonization *M. phaseolina* pathogen followed by *T. harzianum* AMUTHZ-71 and *T. asperellum* AMUTASPM-53. Similarly, Khan et al. [6] determined that *T. harzianum* and *T. viride* were significantly inhibited by 70-73% colonization of *M. phaseolina* AMUMP-2. *T. hamatum* significantly decreased the *M. phaseolina* AMUMP-2 mycelial growth by 76.3% [6, 26]. Similarly, several other researchers reported an inhibitory effect of *T. hamatum*, *T. virens*, *A. niger*, and *T. longibrachiatum* against *M. phaseolina* in terms of its radial growth suppression [40, 6, 34].

The plates that were dual inoculated with both *Trichoderma* spp. and the pathogen showed significant competition [24]. The inhibitory effect may suppress the pathogens through various mechanisms, including mycoparasitism [41], antibiotics [42, 35], and competition for nutrients, space [43] and induce systemic resistance [44]. Another treatment of *T. virens* AMUTVNS-41, *T. longibrachiatum* AMUTLONB-41, *P. chlamydosporia* AMUPC-31, *P. lilacinum* AMUPL-31, *A. niger* AMUAN-41, *B. subtilis* AMUBS-80 and *P. fluorescens* AMUPF-80 significantly decreased the radial growth of *M. phaseolina.* Likewise, *T. harzianum, T. virens, T. fasciculatum, T. asperellum, T. viride, P. chlamydosporia*, *P. lilacinum*, *B. subtilis*, and *P. fluorescens* exhibited a significant antagonistic impact against the *M. phaseolina* [28, 31, 29, 32, 6, 34]. The results of the experiments revealed that the biocontrol fungi and bacteria, *Trichoderma* spp., *P. lilacinum*, *P. chlamydosporia*, *A. niger*, *B. subtilis* and *P. fluorescens* exhibited mycoparasitism and antibiosis as potential mechanisms for parasitizing and suppressing pathogens. These mechanisms have the potential to control dry root rot disease effectively.

5. CONCLUSION

The present study concludes that indigenous isolates of biocontrol fungi and bacteria significantly suppress the mycelial growth of *Macrophomina phaseolina* AMUMP-2 *in vitro*. The dual inoculation test revealed that biocontrol fungi, *T. viride* AMUTVR-61, *T. harzianum* AMUTHZ-72, *T. harzianum* AMUTHZ-71, *T. asperellum* AMUTASPM-53, and *T. harzianum* AMUTHZ-74 showed maximum percent of colony growth inhibition. Biocontrol fungi and bacteria are effective alternatives to synthetic fertilizers and fungicides. The soil microbiome rich in *Trichoderma* and *Aspergillus* species is the best biological agent in maintaining soil fertility, promoting plant growth, and reducing soilborne pathogen colonization. The multifaceted effects of biocontrol fungi attract researchers' attention to the improvement of soil nutrient management practices and crop production. Besides the biocontrol potential of beneficial microbes, they help attain economic sustainability, increase renewability, conserve biodiversity, and promote environmental safety at both farmers' and commercial levels.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. McDermott J, Wyatt AJ. The role of pulses in sustainable and healthy food systems. Annals of the New York Academy of Sciences. 2017;1392(1):30-42. Available:https://doi.org/10.1111/nyas.13319
2. Food and Agriculture Organization of the United Nations. International year of pulses. Pulses and biodiversity; 2016. chrome.extension://efaidnbmnnnibpcajpcglclefindmkaj.https://www.fao.org/fileadmin/user_upload/pulses-2016/docs/factsheets/Biodiversity_EN_PRINT.pdf
3. Kumar M, Kumhar DR, Meena AK, Choudhary K. Management of dry root rot [*Macrophomina phaseolina* (Tassi.) Goid] of mungbean (*Vigna radiata* L.) through bioagents and bio-fertilizer *In vivo*. Legume Research-An International Journal. 2021; 44(Of):849-853. Available:https://doi.org/10.18805/LR-4154
4. Pratap A, Gupta S, Rathore M, Basavaraja T, Singh CM, Prajapati U, Singh P, Singh Y, Kumari G. Mungbean. In The beans and the peas. Woodhead Publishing. 2021;1-32.

5. Dudeja SS, Duhan JS. Biological nitrogen fixation research in pulses with special reference to mungbean and urdbean. Indian Journal of Pulses Research. 2005;18(2):107.
6. Khan MR, Haque Z, Rasool F, Salati K, Khan U, Mohiddin FA, Zuhaib M. Management of root-rot disease complex of mungbean caused by *Macrophomina phaseolina* and *Rhizoctonia solani* through soil application of *Trichoderma* spp. Crop Protection. 2019;119:24-29. Available:https://doi.org/10.1016/j.cropro.2019.01.014
7. Pandey AK, Burlakoti RR, Kenyon L, Nair RM. Perspectives and challenges for sustainable management of fungal diseases of mungbean [*Vigna radiata* (L.) R. Wilczek var. *radiata*]: A review. Frontiers in Environmental Science. 2018; 6:53. Available:https://doi.org/10.3389/fenvs.2018.00053
8. Nasir M, Sidhu JS, Sogi DS. Processing and nutritional profile of mung bean, black gram, pigeon pea, lupin, moth bean, and Indian vetch. Dry beans and pulses: Production, processing, and nutrition. 2022;431-452.
9. Mallaiah B, Krishna Rao V. Integrated management of dry root-rot of greengram [*Vigna Radiate* (L.) Wilczek] incited by *Macrophomina Phaseolina* (Tassi.) Goid. Management. 2016;1:2.
10. Kumar N, Hazra KK, Nadarajan N. Efficacy of pre and post-emergence herbicides in rainy season green gram (*Vigna radiata*). Indian Journal of Agricultural Sciences. 2017;87(9):1219-1224.
11. Nair RM, Pandey AK, War AR, Hanumantharao B, Shwe T, Alam AKMM, Pratap A, Malik SR, Karimi R, Mbeyagala EK, Douglas CA, Rane J, Schafleitner R. Biotic and abiotic constraints in mungbean production-Progress in genetic improvement. Frontiers in Plant Science. 2019;10:1340. Available:https://doi.org/10.3389/fpls.2019.01340
12. Mukhtar T, Tariq-Khan M, Aslam MN. Bioefficacy of *Trichoderma* species against Javanese root-knot nematode, *Meloidogyne javanica*, in green gram. Gesunde Pflanzen. 2021;73(3): 265-272. Available:https://doi.org/10.1007/s10343-021-00544-8
13. Singh J, Mishra KK, Chaubey AK. Important disease of green gram (*Vigna radiata* L. Wilczek) and their management (p. 382). CRC Press. CRC Press; 2020.
14. Dhingra OD, Sinclair JB. Isolation and partial purification of a phytotoxin Produced by *Macrophomina phaseolina*. Journal of Phytopathology. 1974;80(1):35-40. Available:https://doi.org/10.1111/j.1439-0434.1974.tb02726.x
15. Shahid S, Khan MR. Biological control of root-rot on mungbean plants incited by *Macrophomina phaseolina* through microbial antagonists. Plant Pathology Journal. 2016;15(2):27-39. Available:https://doi.org/10.3923/ppj.2016.27.39
16. Dhingra OD, Sinclair JB. Biology and pathology of Macrophomina phaseolina. Imprensa Universitaria. 36.570 Minas Gerais-brazil. Universidade Federal de Viçosa. 1978;166.
17. Rajput LS, Kumar S, Nataraj V, Shivakumar M, Pathak K, Jaiswal S, Mandloi S, Agrawal N, Ratnaparkhe MB, Kumawat G, Maheshwari HS. Recent advancement in management of soybean charcoal rot caused by *Macrophomina phaseolina*. In *Macrophomina phaseolina*. Academic Press; 2023;55-74.
18. Kar AK, Sahu KC. Deterioration of seed quality in mung bean by *Macrophomina phaseolina* (Tassi) Goid. and its management. Seed Research. 2009; 37(1/2):139-142.
19. Basandrai AK, Pandey AK, Somta P, Basandrai D. *Macrophomina phaseolina*-host interface: Insights into an emerging dry root rot pathogen of mungbean and urdbean, and its mitigation strategies. Plant Pathology. 2021;70(6):1263-1275. Available:https://doi.org/10.1111/ppa.13378
20. Ali M.Z, Khan MAA, Rahaman AKMM, Ahmed MAFMS, Ahsan AFMS. Study on seed quality and performance of some mungbean varieties in Bangladesh. International Journal of Experimental Agriculture. 2010;1(2):10-15.
21. Haider A, Ahmed S. Study on seed quality and performance of some mungbean varieties in Pakistan Journal of Biology, Agriculture and Healthcare. 2014;23:161-165.
22. Ashwini C, Giri G. Control of seed borne fungi in greengram and black gram through

bio-agents. International Journal of Applied Biology and Pharmaceutical Technology. 2014;5:168-170.

23. Rahman S, Vearasilp S, Srichuwong S. Detection of seed borne fungi in mungbean and black-gram seeds. Sustainable Technology Development in Crop Production. 1999;1–3.
24. Harman GE. Overview of mechanisms and uses of *Trichoderma* spp. Phytopathology. 2006;96(2):190-194. Available:https://doi.org/10.1094/PHYTO-96-0190
25. Thombre BB, Kohire OD. Integrated management of *Macrophomina* blight of mungbean (*Vigna radiata* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. Indian Phytopathology. 2018;71(3):423-429. Available:https://doi.org/10.1007/s42360-018-0055-6
26. Iqbal U, Mukhtar T. Evaluation of biocontrol potential of seven indigenous *Trichoderma* species against charcoal rot causing fungus, *Macrophomina phaseolina*. Gesunde Pflanzen. 2020; 72(2):195-202. Available:https://doi.org/10.1007/s10343-020-00501-x
27. Khan MR, Ahmad I, Ansari MSA, Shah MH. Root-knot nematodes in cereal and pulse crops, and their management by novel biological and biotechnological approaches. In Novel Biological and Biotechnological Applications in Plant Nematode Management. Singapore: Springer Nature Singapore. 2023;289-311.
28. Akhtar MS, Siddiqui ZA. Effect of phosphate solubilizing microorganism and rhizobium on the growth, nodulation, yield and root rot disease complex of chickpea under field conditions. African Journal of Biotechnology. 2009;8:3489-3496.
29. Habiba RN, Ali SA, Sultana VIQAR, Ara JEHAN, Ehteshamul-Haque SYED. Evaluation of biocontrol potential of epiphytic *fluorescent Pseudomonas* associated with healthy fruits and vegetables against root rot and root knot pathogens of mungbean. Pakistan Journal of Botany. 2016;48(3):1299-1303.
30. Khan MR, Anwer MA. Molecular and biochemical characterization of soil isolates of *Aspergillus niger* aggregate and an assessment of their antagonism against *Rhizoctonia solani*. Phytopathologia Mediterranea. 2007;46(3):304-315.
31. Deshmukh MA, Gade RM, Belkar YK, Koche MD. Efficacy of bioagents, biofertilizers and soil amendaments to manage root rot in greengram. Legume Research. 2016;39(1):140-144.
32. Kumari P, Meena M, Gupta P, Dubey MK, Nath G, Upadhyay RS. Plant growth promoting rhizobacteria and their biopriming for growth promotion in mung bean (*Vigna radiata* (L.) R. Wilczek). Biocatalysis and Agricultural Biotechnology. 2018;16:163-171.
33. Khan IH, Javaid A. *In-vitro* screening of *Aspergillus* spp. for their biocontrol potential against *Macrophomina phaseolina*. Journal of Plant Pathology. 2021;103(4):1195-1205. Available:https://doi.org/10.1007/s42161-021-00865-7
34. Choudhary A, Ashraf S, Musheer N. The antagonistic effect of locally isolated *Trichoderma* spp. against dry root rot of mungbean. Archives of Phytopathology and Plant Protection. 2021;54(15-16): 1204-1210. Available:https://doi.org/10.1080/03235408.2021.1896872.
35. Vinale F, Sivasithamparam K, Ghisalberti EL, Woo SL, Nigro M, Marra R, Lombardi N, Pascale A, Ruocco M, Lanzuise S, Manganiello G, Lorito M. *Trichoderma* secondary metabolites active on plants and fungal pathogens. Open Mycology Journal. 2014;8(1):127-139. Available:https://doi.org/10.2174/1874437001408010127
36. Caulier A, Rapetti-Mauss R, Guizouarn H, Picard V, Garçon L, Badens C. Primary red cell hydration disorders: Pathogenesis and diagnosis. International Journal of Laboratory Hematology. 2018;40(Suppl. 1):68-73. Available:https://doi.org/10.1111/ijlh.12820.
37. Dennis C, Webster J. Antagonistic properties of species groups of *Trichoderma*: Production of volatile and nonvolatile antibiotics. Transactions-British Mycological Society. 1971;57:41-IN4.
38. R Development Core Team. A language and environment for statistical computing; 2014. Available:http://www.r-project.org. R Foundation for Statistical Computing.
39. Ikram N, Dawar S. Effect of *Prosopis Juliflora* (Sw.) DC. in the control of root rot fungi of cowpea (*Vigna unguiculata* L.) and mung bean [*Vigna radiata* (L.) Wilczek].

Pakistan Journal of Botany. 2013;45(2): 649-654.

40. Singh R, Maurya S, Upadhyay RS. Antifungal potential of *Trichoderma* species against *Macrophomina phaseolina*. Journal of Agricultural Technology**.** 2012;8(6):1925-1933.
41. Weindling R. *Trichoderma lignorum* as a parasite of other soil fungi. Phytopathology. 1932;22(8):837-845.
42. Ajith PS, Lakshmidevi N. *Zygosporium masonii*: A new fungal antagonist against *Colletotrichum capsici* incitant of anthracnose on bellpeppers. Journal of Agricultural Technology. 2012;8(3):931–939.
43. Hjeljord LG, Stensvand A, Tronsmo A. Effect of temperature and nutrient stress on the capacity of commercial *Trichoderma* products to control *Botrytis cinerea* and *Mucor piriformis* in greenhouse strawberries. Biological Control. 2000; 19(2):149-160. Available:https://doi.org/10.1006/bcon.2000.0859
44. Vinale F, Sivasithamparam K, Ghisalberti EL, Marra R, Woo SL, Lorito M. *Trichoderma*-plant-pathogen interactions. Soil Biology and Biochemistry. 2008;40(1): 1-10. Available:https://doi.org/10.1016/j.soilbio.2007.07.002

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/116718