RESEARCH ARTICLE

Impact of AM Fungi and *Rhizobium* on the Eco-physiological attributes of *Pisum sativum* grown in carpet industry effluent soil

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Abstract

Considering the problem of heavy metals accumulation, released through industrial wastes on the growth and productivity of leguminous crops, a staple diet in the rural population of India, the study was designed to examine the effect of microorganisms (*Rhizobium* and Arbuscular Mycorrhizal Fungi) on the growth, physiology of *Pisum sativum* cultivated in industrial effluents. The experiment had four treatments: two single inoculums of *Rhizobium* and Arbuscular Mycorrhizal Fungi (AMF), one mixed inoculum containing both, and one control.

Plant expansion and the physiological framework under study (fresh weight, dry weight, chlorophyll, and protein activity) are improved by microbial inoculation. However, mixed inoculation showed the maximum value for each variable. Plants treated with both bacteria and AMF also had significantly higher levels of microbial characteristics such as nodule number, mycorrhizal root exploration, and number of AMF spore population. Similarly, micronutrients (B, Cu, Fe, Mn) were also observed at maximum in soil treated with both. Plant heavy metal (As, Hg and Zn) substance was crucially more in soil; however, microbial inoculation importantly reduced HMs absorption.

In combination inoculation, AMF and *Rhizobium* demonstrated superiority, leading to enhanced crop development and physiological features, which resulted in decreased absorption of heavy metals. In addition to addressing the issue of heavy metal stress, this combination of inoculants (symbionts) in soil has been shown to improve micronutrient levels, which boost the productivity of the *Pisum sativum* crop.

Keywords: Arbuscular Mycorrhizal Fungi, Heavy metals, Physiological attributes, *Pisum sativum,* Protein activity, *Rhizobium*.

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Introduction

By establishing symbiotic relationships with *Rhizobium* in root nodules, pea plants obtain the majority of their nitrogen (N_2) through N_2 fixation, whereby *Rhizobium* converts ambient N_2 to ammonia (NH_3), which plants absorb in return for molecules that contain carbon (Dobo, 2022). Approximately 64% of the total N_2 fixed is due to biological activity alone, with the remaining portion coming from abiotic sources (Gebremedhin, 2018). Additionally, *Rhizobium* is crucial to metal phytoremediation because it permits plant growth and enhances soil health when heavy metal inhibitory levels are present (Liu *et al*., 2019). Pea plants develop symbiotic relations with Arbuscular Mycorrhizal Fungi (AMF) as well as to *Rhizobium* (Gough *et al*., 2022). AMF are usually associated with a wide range of trees, shrubs, and crops (Bagyaraj *et al*., 2022).

AMF enhances the stress-related response and facilitates mobility-restricted nutrition and water absorption (Zhu *et al*., 2022). AMF and *Rhizobium* are thought to be the main forces behind the growth and production of legumes due to their contrasting roles in supplying fundamental nutrients (Zhou J *et al*., 2022). Because of the beneficial interactions, plants that are connected with several symbionts grow more than those that belong to a single symbiont. Numerous investigations on legumes treated using both AMF and rhizobia indicate notable gains in plant development when compared to a pure inoculation with either (Afkhami *et al*., 2016; Ashwin *et al*., 2022; Hasan *et al*., 2023, 2024).

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Because soil is a conventional resource which makes soil pollution, especially through heavy metals, is a serious issue for both living and non-living things, including nitrogen-fixing bacteria and AMF. Although plants require small levels of certain heavy metals, large doses are harmful because they produce free radicals that cause oxidative stress. Additionally, the harmful heavy metals can interfere with the host plant's pigments or enzymes, causing them to malfunction (Ahmad *et al*., 2021). When wastewater is used to irrigate croplands throughout an extended period, heavy metals build up in the soil and are transferred to food crops, raising the level above the allowed threshold and making the area hazardous. Agriculture uses both treated and untreated wastewater to supply the increasing need for irrigation water (Ghosh *et al*., 2005; Sharma *et al*., 2007). According to Thebo *et al*., (2017), untreated wastewater is used to irrigate about 11% of the world's total agricultural area. Although the presence of heavy toxic metals in soil has increased due to ongoing irrigation with wastewater from factories, the amount of toxic metal pollution in wastewater is normally low and below the maximum allowed level (Chaoua *et al*., 2019; Zuo *et al*., 2018). The flow of heavy toxic metals from the soil to crops and plants is greatly affected by the pH of soil, soil structure, redox value and organic content of soil, seasons of the ecosystem, overall metal levels, and other variables (Singh *et al*., 2010).

To safeguard public and environmental health from the toxic metals' mobility to the surroundings and accumulation in living organisms, international organizations like the United States Environmental Protection Agency (USEPA), Food and Agricultural Organization (FAO), and World Health Organization (WHO) have established the maximum permissible limits for the heavy toxic metals level in soil, crops and water (Kumari *et al*., 2016). The issue of heavy toxic metal accumulation in soil is usually very common in Uttar Pradesh, India, particularly in areas dominated by Industries. Surprisingly, Bhadohi district of Uttar Pradesh, India, which is situated on the bank of the eastern Gangetic plain, is not left out with the problem of heavy metals due to its wide involvement in carpet manufacturing. The Bhadohi district produces the most handmade carpet weaving, accounting for over 85% of India's carpet exports. When carpet companies release untreated wastewater containing colours like Victoria blue B, Congo red, Auramine O, Tryphan blue and Navy N5RL1, they run the risk of harming aquatic habitats. These dyes may inhibit metabolic processes in plants and cause ecological disturbances by reducing light absorption (G. Singh *et al*., 2015; Yusuf *et al*., 2019). These colours have metabolites that are mutagenic, carcinogenic, and toxic (Affum *et al*., 2020).

The present study used AMF and *Rhizobium* to remove contaminants from the potted pea plant growing in contaminated soils and to assess the variety and amounts of heavy metals in wastewater, soils, and pea plants. This is because wastewater irrigation puts the health of people at risk and adds heavy metals, including copper, zinc, cadmium, chromium, and nickel, to soil-crop interactions (Ahmad *et al*., 2021). With the help of Arbuscular Mycorrhizal Fungi, host plants can support the stabilization of trace elements in the rhizosphere of plants through a mutually beneficial relationship that favors Phytostabilization and phytoextraction (Cabral *et al*., 2015).

Materials And Methods

Study Site

The study regions considered for sample collection are located in the district of Bhadohi in Uttar Pradesh, India. It lies between the parallels of 25° 23′ 42.94′′ North latitude and 82° 34′ 13.08′′ East longitude. Carpet industrial soil samples were acquired from the study site by randomly selecting samples of soil and pea plants

Soil Preparation and Carpet Effluent Soil Application

Soil samples collected from the carpet industry in Bhadohi, were finely powdered, dried in air, and sieved through a 2 mm mesh. Along with the soil sample, some amount of soil was taken from the garden of the Department of Botany, CMP College, Prayagraj. The collected soil sample was mixed with garden soil in a ratio of 3:1 v/v. Mixed soil was autoclaved for 45-minute at 121 degrees celsius.

Preparation of Inoculum

The NBAIM institute of ICAR at Mau, Uttar Pradesh, provided thirty grams of the authorised viable colony of the bacteria *Rhizobium* for the treatment of *Rhizobium*. The seeds of *Pisum* were surface sterilized for 15 minutes using 0.5% sodium hypochlorite (NaClO) and then carefully cleaned. Each pot was then displayed with five sterile seeds as needed.

Trap Culture

The trap culture yielded the consortium of AM fungi employed in the current study. Spore properties were assessed using a compound microscope, and the mycorrhizal relationship was examined using a stereo-binocular microscope.

Experimental Design

The experiment was performed using earthen pots following a complete randomized design for the pea plant with four treatments and five replicates per treatment. Earthen pots (20x34) were filled with 4 kg of garden soil and carpet industry effluent soil. The treatment was as follows: 1. Control, 2. Treatment with Arbuscular Mycorrhizal Fungi (AMF), 3. Treatment with *Rhizobium* (R), 4. Mix treatment of Arbuscular Mycorrhizal Fungi and *Rhizobium* (AMF+ R). Each pot was inoculated with about 150 spores (50 g) of AMF. In each pot 5 germinated seeds of *Pisum sativum* was transplanted. There was a control set up with no treatment given in the plant.

There were five repetitions of each given treatment, along with a control setup. All the setups received water consistently, and no fertilisers were employed to examine the effects of pure *Rhizobium* as well as AMF. The pots were then maintained in the greenhouse of the Department of Botany, CMP Degree College, Prayagraj, and watered as and when necessary. All the selected variables were studied after 60 days of treatment and pot establishment.

Physicochemical Analysis of Soil

Nutrients as well as physiochemical properties of experimental soil sample (Electrical Conductance (EC), pH, total organic carbon, nitrogen, phosphorus and potassium) were analyzed at Motilal Nehru Farmers Training Institute, IFFCO, Phulpur, Prayagraj (Tables.1, 2).

Analysis of Plant Growth Attributes

The measurement of growth parameters was done using the destructive method of sampling. One plant from each replicated treatment was employed to calculate the overall length (root+shoot) of every individual plant using a unit of measuring scale. The fresh weight of each plant was measured separately. An electronic balance was also used to determine the weight of roots. The samples were then dried for a period of 72 hours at 70 degrees celsius in a hot oven, and the dry mass of the vegetation was obtained using an electronic scale.

Table 1: Physio-chemical attributes of soil sample under different set of treatments

Physio-chemical attributes	*Control*	*AMF*	*R*	*AM +R*
pH (H_2O)	7.40	7.70	7.50	7.70
EC (µS cm-1)	0.22	0.33	0.28	0.87
Organic carbon (%)	0.45	0.60	0.55	0.76
Nitrogen (%)	0.37	0.47	0.53	0.65
P_2O_5 (ppm)	106.70	117.50	113.7	123.40
K_2O (ppm)	9.70	11.50	11.00	12.30

Table 2: Micronutrients in soil sample under different set of treatments. Values of all the elements are given in ppm

Elements	*Control*	*R*	*AMF*	*AM+ R*
Boron (B)	0.53	0.40	0.43	0.49
Copper (Cu)	1.10	1.20	1.50	1.80
Iron (Fe)	12.4	15.2	13.0	17.5
Manganese (Mn)	10.0	10.4	10.7	11.0

Analysis of Photosynthetic Pigments

The standard method developed by Lichtenthaler and Welburn (1983) was used for assessing the pigments used for photosynthesis (chl a, chl b, and carotenoid). Using a mortar and pestle, 100 mg of newly harvested foliage was crushed in 80% acetone. The absorbance of this solution was measured using a UV-VIS spectrophotometer at 663, 646, and 470 nm to estimate the amount of photosynthetic pigments.

Biochemical Analysis

Leaves (200 mg) were crushed with 10 ml of $C_2HCl_3O_2$ (20%) using a chilled pestle and mortar to analyze the protein (Bradford, 1976). It was then centrifuged for 15 minutes at 600 rpm. Then the supernatant was extracted. The pellet was agitated in 5.0 ml of 0.1N NaOH, and centrifuged for 15 minutes. Protein extract (0.5 ml) was mixed with 5.0 ml of a basic solution of copper, and the mixture was allowed to sit for 10 minutes after the proteinaceous part was taken out of the precipitate. Following its addition and mixing, the Folin-Ciocalteu reagent gave it a blue color, and the absorbance of the solution was measured at 660 nm using a spectrophotometer (UV- VIS).

Estimation of AMF Spore Population

The AMF spore count in 10-gram air-dried soil was assessed in three replicates for each sample by wet sieving and decanting method (Gerdemann and Nicolson, 1963). The solution of soil was passed through the sieves of 500µm, 200µm, 150µm, 90µm, and 60µm in descending order. AMF spores were placed on filter paper and quantified using a 20X magnification binocular stereoscope.

AM Fungi Identification

The AMF spores were mounted using the PVLG and Melzer+ PVLG as per Phillips and Hayman (1970), at the same time spores were identified at the species level using the species guide of INVAM (http://invam.wvu.edu/), and the synoptic key of Schenck and Perez (1987), and Trappe (1982). The features of their subtending hyphae, size, color, and wall layer were noted to identify the AM fungus.

Heavy Metal Analysis

The plants' heavy metal concentration was also examined using the techniques of Allen *et al.*, (1957). After being cleaned with distilled water, the destructed shoots were dried for 72 hours at 75 degrees celsius in an oven. A powder was created by blending the dry portions in a tri-acid combination (5:1:1 v/v) of $HNO_3/H_2SO_4/HClO_4$. 250 mg of the sample was digested at 80°C. Atomic Absorption Spectrophotometer (AAS) was used to measure the concentration of heavy metals in the treated solution. Following cooling, it was diluted using distilled water and passed through a Whatman 42 filter paper to get filtered.

Statistical Analysis

Using one-way ANOVA, statistical evaluation was conducted independently for each of the factors under study and various treatments using version 23 of the SPSS program (SPSS, Chicago, IL, USA). The multiple range test developed by Duncan (DMRT) was used for assessing whether the treatment differences were significant at $p < 0.05$.

RESULTS

Impact of the Relationship on *Pisum sativum* Characteristics for Growth in Heavy Metal Soil

The findings of the current investigation showed a positive effect of combined inoculation of AM and *Rhizobium* in pots, in contrast to an individual inoculation of growth parameters, and only carpet industrial effluent soil. (Figs. 1 and 2)

Impact of Symbiosis on the Physiological Characteristics of *Pisum sativum* in Heavy Metal-contaminated Soil

Pisum sativum showed higher values for attributes related to physiology (Chl a, Chl b, protein and carotenoid contents) in combined inoculation (AM + *Rhizobium*) as compared to single

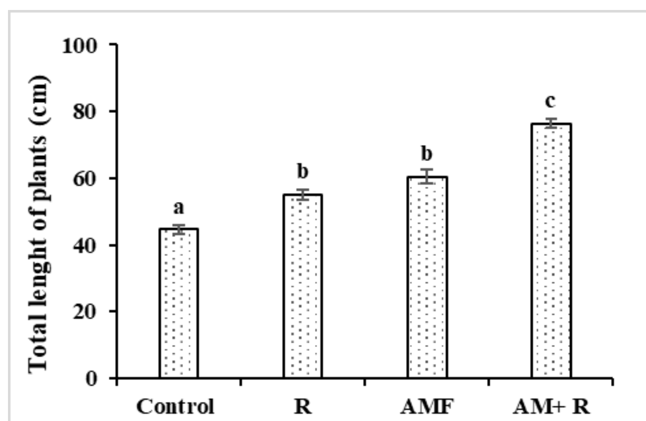

Fig 1: Total length of *P. sativum* plants in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letters are significantly different from each other (P < 0.05). Values are mean ±SE

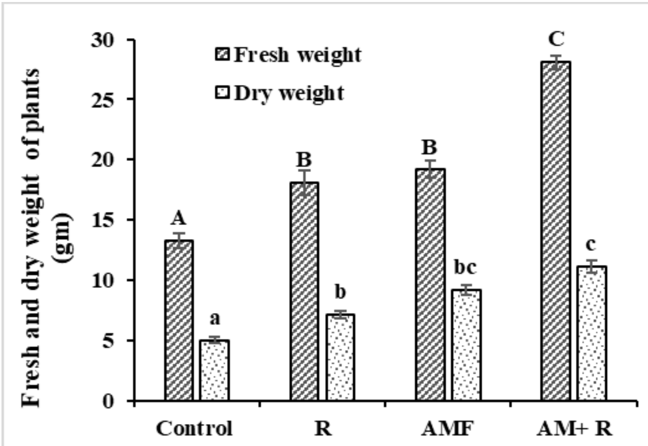

Fig 2: Fresh and dry weight of *P. sativum* in carpet industrial soil under different treatments and combinations (AM+R). Bars affixed with different letters are significantly different from each other (P < 0.05). Capital letter represents fresh weight and a small letter represents dry weight. Values are mean ±SE

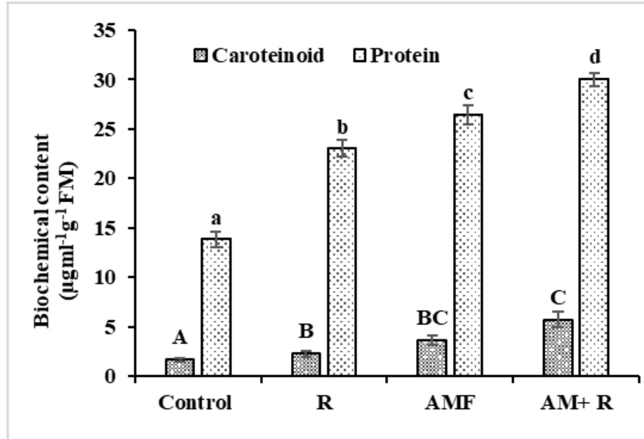

Fig 4: Biochemical content (carotenoid and protein) of *P. sativum* plants in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letters are significantly different from each other (P < 0.05). Capital letter represents carotenoids and small letter represents protein. Values are mean ±SE.

inoculation, followed by only heavy metal soil in pots. (Figs. 3 and 4)

Effect of Symbiosis on Nodulation of *Pisum sativum* in Heavy Metal Soil

In comparison to the control, AMF and *Rhizobium* considerably enhanced the count of nodules in *Pisum sativum* plants. *Pisum sativum* with *Rhizobium* and AMF increased nodule number and had the trend AMF + *Rhizobium* > *Rhizobium* > AMF > Control, which showed *Pisum sativum's* tripartite symbiosis, increased nodulation more than if *Rhizobium* was the only inoculant. (Figs. 5 and 6)

Symbiosis Affecting the Mycorrhizal Root Colonization and Spore Diversity in Heavy Metal Soil

Spore diversity in 20 g of rhizospheric soil and the colonisation of mycorrhizal roots under different treatments of *Pisum sativum* were in the successive sequence: AMF+ *Rhizobium* > AMF > *Rhizobium* > Control. When compared to single inoculation sets, both mycorrhizal parameters were noticeably enhanced in the AMF + *Rhizobium* treatment, and the mycorrhizal population was also relatively higher in AMF + *Rhizobium* as contrasted to the other treatments. (Figs. 7 and 8)

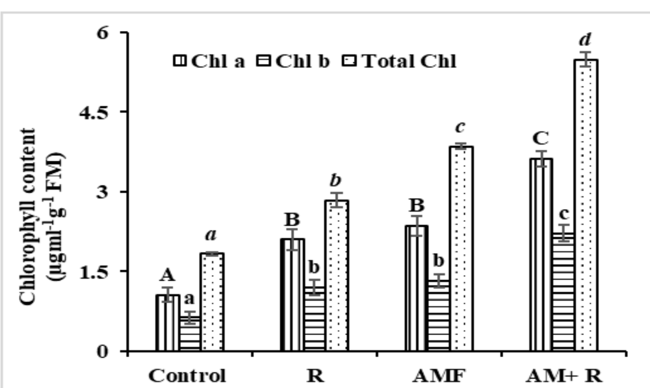

Fig 3: Chlorophyll content of *P. sativum* plants in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letter are significantly different from each other (P < 0.05). Capital letter represents Chl a, and small letter represents Chl b, and small letter (italics) represents total chl. Values are mean ±SE

Symbiosis Impacting Heavy Toxic Metal (HMs) Absorption by *Pisum sativum* Root and Shoot in HMs Contaminated Soil

The outcome of the assembly of HMs (As, Hg, Zn) found in the root and shoot of *Pisum sativum* is shown in Table 3**.** The application of heavy metal soil caused *Pisum sativum* plants' roots and shoots to increase in As, Hg, and Zn significantly. HMs concentration in the root was higher than in the shoot after *Rhizobium* and either of the AMFs were injected into the soil.

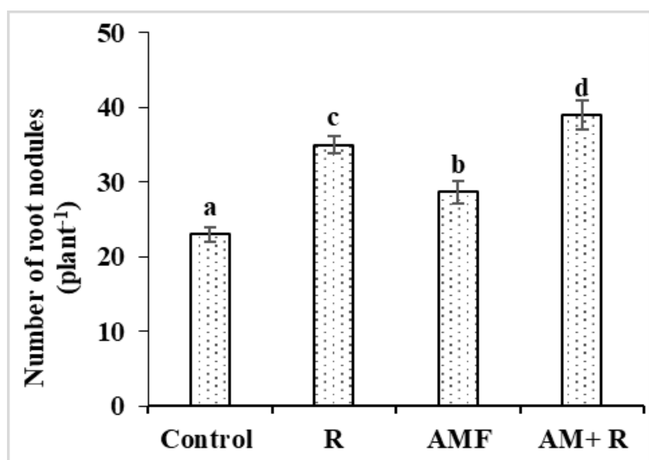

Fig 5: Root nodule number of *P. sativum* plants in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letter are significantly different from each other (P < 0.05). Values are mean ±SE.

Table 3: Effect of microbial inoculation on heavy metal (HM) accumulation in the root and shoot of *P. sativum* plants.

Treatments	*Accumulation of HMs in Root (mg/100 g)*			*Accumulation in HMs Shoot (mg/100 g)*		
	As	*Hg*	*Zn*	*As*	*Hg*	*Zn*
Control	0.40	0.39	4.47	0.36	0.32	3.78
R	0.24	0.30	2.70	0.19	0.20	2.00
AMF	0.17	0.19	2.30	0.10	0.15	1.70

Additionally, a single microbial inoculation reduces the levels of HMs in *Pisum sativum* roots and shoots to a considerable extent.

Nevertheless, the dual inoculation showed a higher level of resistance to these metals in roots and inhibited them from moving to shoots. In heavy metal soil, the greatest response to reduced quantity of HMs in roots and shoots was observed in AMF and *Rhizobium* treatments, as compared to the other treatments. Microbial inoculation increases the micronutrient levels of the soil and maintains physio- chemical effects of the soil (Table. 1 and 2).

Discussion

In the current investigation, considerably more in the growth parameters of *Pisum sativum* has been reported in a pathogen-free environment as well as AMF and *Rhizobium* filled soil. Aggangan *et al*., (2019) have reported that several plants' growth characteristics significantly increased in soil free of pathogens. Adding nutrient-rich AMF and *Rhizobium* to the soil improved the growth characteristics of *Pisum sativum* (Dry weight, fresh weight, and plant length) (Figs. 1 and 2). Because there are enough nutrients available for the other *corps*, similar studies have been published (Ahmad *et al*., 2021; Dar *et al*., 2017; Haris *et al*., 2019). Enhance biomass of legume on application of AMF amount has been documented (Rajpoot *et al*., 2018). *Rhizobium* single application improved the *Pisum sativum* crops' overall growth characteristics (Mohanty *et al*., 2021). Additionally, it is widely known that AMF stimulates plant development by increasing the intake of limiting nutrients (Bagyaraj *et al*., 2022). It has been demonstrated that the extra-radical mycelium of AMF improves intake of nutrients, supporting the growth and development of plants (Lehmann and Rillig, 2015). *Rhizobium* + AMF inoculation enhanced the plant growth metrics under investigation and a similar finding has been reported by Calderon and Dangi, (2024). For other leguminous crops, analogous effects of the *Rhizobium* + AMF beneficial relationship have been documented by Gorgia and Tsikou, (2025).

Compared to other treatments of heavy metal soils, *Pisum sativum* growing in *Rhizobium* + AMF had noticeably higher levels of pigments of photosynthesis (chlorophyll a, chlorophyll b, and carotenoid) (Figs. 3 and 4). Because of the greater magnesium level in the treated pots, the amount of chlorophyll increased (Shakeel *et al*., 2022). Fly ash contains sufficient amounts of magnesium, a necessary and nuclear component of the chlorophyll molecule, and its absorption enhances the amount of chlorophyll pigment in the leaves (Haris *et al*., 2021). Carotenoids are additional pigments that function as chlorophyll's non-enzymatic antioxidants (Kenneth *et al*., 2000). In the current investigation, *Rhizobium* application altered photosynthetic pigments and AMF levels in soil. According to Chaudhary *et al*., (2011), Carotenoid and chlorophyll levels in *Vigna* species treated with *Rhizobium* increased significantly (Kashyap and Siddiqui, 2021). *Pisum sativum* is inoculated with *Rhizobium,* which thrives in soil and increases the production of carotenoids and chlorophyll (Hami *et al*., 2025). Similarly, the plant's connection with AMF markedly increased the host plant's chlorophyll levels. Compared to non-mycorrhizal plants,

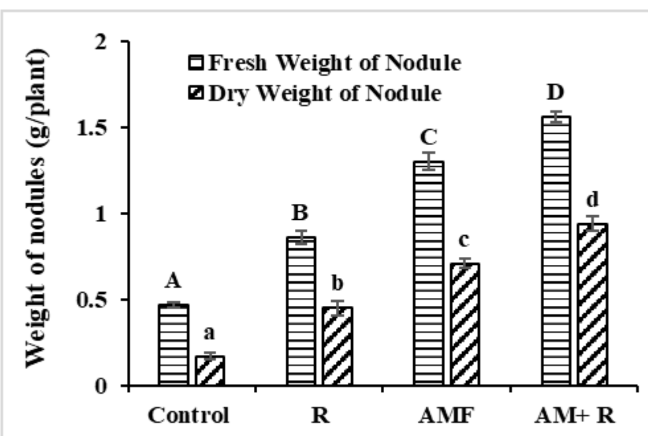

Fig 6: Fresh and dry weight of root nodules of *P. sativum* in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letters are significantly different from each other (P < 0.05). Capital letter represents fresh weight of root nodules and small letter represents dry weight of root nodules. Values are mean ± SE

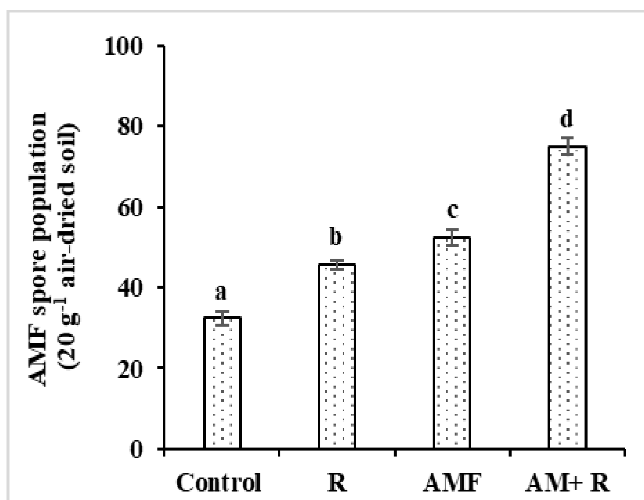

Fig 7: Spore population of AMF in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letters are significantly different from each other (P < 0.05). Values are mean ±SE

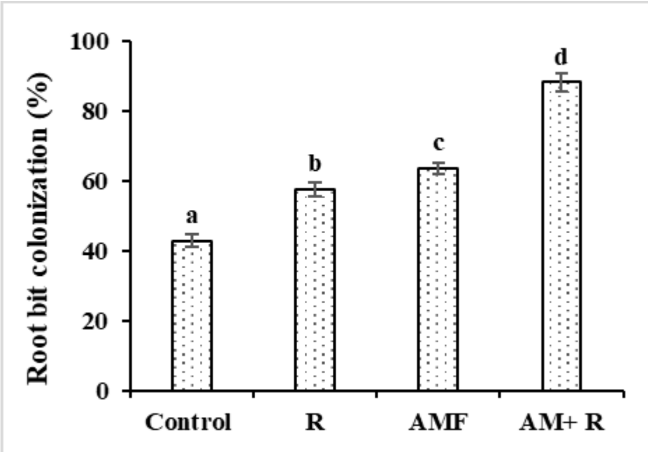

Fig 8: Root bit colonization of AMF in carpet industrial soil under different treatments and symbiosis (AM+R). Bars affixed with different letters are significantly different from each other (P < 0.05). Values are mean ±SE

AMF-inoculated plants exhibited much greater leaf pigment (Al-Ghamdi *et al*., 2012). Additionally, wheat plants introduced by *Glomus mosseae* and *Glomus faciculatum* showed enhanced photosynthetic pigments (Anand *et al*., 2022). According to Krishna *et al*., (2005), *Vitis vinifera* leaves with AMF had higher carotenoid concentrations. Baslam *et al*., (2013) also noted that *Latuca sativa* and *Glomus fasciculatum* inoculated individuals had increased levels of carotenoid content. Additionally, in the performed study, co-inoculation of *Rhizobium* and AMF with *Pisum sativum* plants enhanced photosynthetic activity, as previously reported by Hasan *et al*., in 2023 and 2024.

According to the current study's findings, the protein content of plants (Fig. 4) was considerably raised when AMF and *Rhizobium* were added to the heavy metal soil. *Pisum sativum* plants with AMF + *Rhizobium* had higher protein contents, whereas plants with a single inoculant had lower protein contents (Kavadia *et al*., 2021; Mushtaq *et al*., 2021). Earlier reports have also noted a greater amount of protein in *Rhizobium*-infected plants. Talaat and Shawky, (2014) in *Triticum aestivum*, Tisserant *et al*., (2012) in *Medicago truncatula*, and Stancheva *et al*., (2017) in *Vigna unguculata* also obtained similar results. *Vigna unguiculata* and white clover that received simultaneous inoculation using *Rhizobium* and Arbuscular Mycorrhizal Fungi had higher protein contents than those that received only one treatment (Stancheva *et al*., 2017). *Pisum sativum* cultivated in heavy metal soil, using AMF combined with *Rhizobium* inoculation, enhanced nodulation, root colonization, and AMF spore number (Figs. 7 and 8). According to Xie *et al*., (2020) double inoculation of *Rhizobium* and AMF also increased the nodulation, spore number, and root colonization. Although *Rhizobium* and Arbuscular Mycorrhizal Fungi do not compete with one another for colonization sites, the result was favorable and improved by providing strength for nodule formation and nitrogen fixation (Oruru and Njeru, 2016). When *Rhizobium* and AM fungal species are applied to heavy metal soil, mycorrhizal colonization in peas increases compared to when *Rhizobium* is applied to the soil (Fig. 8). Additionally, dual inoculation was previously found to promote AMF colonization more than AMF treatment alone (Hasan *et al.,* 2023; Oruru and Njeru, 2016).

AMF and *Rhizobium* in soil higher the absorption of HMs in *Pisum sativum* shoots. Similarly, a study performed on mung beans with the use of multiple inoculations of AMF and *Rhizobium* improved the absorption of heavy metals. In our research, the sequence of aggregation of HMs (Chromium and Zinc) in the shoot of *Pisum sativum* was Zn> Cr in the respective treatment of microbes and AMF (Table 3). There have been reports of plants grown on modified soil absorbing heavy metals at a similar rate (Jahan *et al*., 2023; Nayak *et al*., 2015; Singh *et al*., 2012). The quantity of heavy metals that were translocated in the shoot was comparatively smaller than the amount that was retained in the roots of *Pisum sativum* upon intake. The roots may catch and hold a larger percentage of heavy metals than the shoots because they are the first organs to come into contact with them. This may help to explain why roots contain more heavy metals than shoots (Garg and Kaur, 2013). According to Rai *et al*., (2004) *Prosopis juliflora* plants treated with *Rhizobium* acquired comparatively more heavy metals in the roots than in the shoots.

Conclusions

Finally, the study concludes that applying either separately or in pairs, carpet industrial soils containing *Rhizobium* and specific AM fungi greatly enhanced plant growth, biochemical characteristics, photosynthetic pigments, nodulation, and population of mycorrhiza in *Pisum sativum,* compared to the soil in the absence of these modifications. In addition to increasing plant growth, double treatment with *Rhizobium* and AMF lowered the absorption of heavy metals, making it possible for *Pisum sativum* species to withstand extreme metal stress. Employing AMF and *Rhizobium* at the same time produced the most significant enhancement in plant development, physicochemical characteristics, and microbial population. Compared to a single inoculation, a few chosen species of *Rhizobium* and mycorrhizae were superior in stimulating the development of plants and nutrient utilization. Utilizing these symbionts to control the absorption of heavy metal contamination in the plant aerial portion and future prospective uses of AMF in soil as a nourishment enhancer will boost the agricultural production of the *Pisum sativum* crop. Using *Rhizobium* and AMF in agriculture should be part of a long-term research vision that builds on an extensive range of soil features, suitable dosages, and their interactions with microorganisms in the soil.

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Authors' Contributions

APS conceptualized the idea for te study and PKK and VS conceived the experiment and drafted the manuscript. APS and AM reviewed the manuscript and made the needful corrections as well. All authors have read and approved the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

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