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Impact Of Mycorrhizal Fungi and *Bradyrhizobium japonicum* on the Productivity of Soybean KDS-726 Variety from Naldurg, Maharashtra, India

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ABSTRACT

A systematic probe of Indian and regional literature shows there were no cultivar-specific evidence for KDS-726 rainfed kharif conditions. Most studies use other soybean cultivars and report yield responses but arbuscular mycorrhizal fungi (AMF) and *Bradyrhizobium japonicum* individually not found any data trials hence a pot culture experiment was investigated. The simultaneous application of *B. japonicum* and AM fungi improved growth, yield and AMF colonisation. The presence of AM fungus in *Glycine max* L. KDS-726. Vesicular, arbuscular and hyphal types of root colonisation was observed. *B. japonicum +Gigaspora margarita* had the highest percentage of root colonization (RC) (88±2.33%) while lowest in *Glomus macroaggregatum* (40±1.01%). The highest amount of root length colonisation (RLC) was found in *B. japonicum+Glomus macroaggregatum* (44.3±3.02%) while the lowest in *B. japonicum* (17.0±4.20%). *B. japonicum+Glomus macroaggregatum* had the highest percentage of spore density (172.83±0.19/100g of soil) while lowest in *Gigaspora margarita+B. japonicum* had the (101.52±101.21/100 g of soil) after 90 days. An increase in the level of AMF inoculation significantly promoted the growth. The height of the shoot, length of the root, number of leaves, number of root nodules, number of pods, fresh weight of the shoot and root and dry weight of the shoot and root were studied and found highest biomass production in the combination of *B. japonicum+Glomus macroaggregatum* followed by *B. japonicum+Glomus margarita*. The study expresses the variation controls and the correlation between *B. japonicum +Glomus macroaggregatum* spore density and biomass productivity.

Keywords: Soybean variety KDS-726, Rhizosphere soil, *Bradyrhizobium japonicum,* AMF species Interaction, AMF root colonization and spore density, Biomass production

INTRODUCTION

A field experiment was conducted to study the impact of inoculation with DTB4 and DTR30 along with AMF (*Glomus clarum, Funneliformis mosseae*, and *Gigaspora margarita*) on the growth and yield of drought-stressed (*Glycine max*, L.), Nade *et al.* (2024) findings imply that using a mixture of bioinoculants may help soybean productivity. According to Sheteiwy *et al.* (2021), AMF and *B. japonicum* treatments may help soybeans become more drought-tolerant. Tarnabi *et al.* (2020) and Gao *et al.,* (2020) observed that under drought stress and well-watered locations, AMF and B. japonicum treatments enhanced bacterial numbers and the activity of the enzymes (phosphatase and dehydrogenase). When compared to untreated plants, soybeans treated with AMF and *B. japonicum* developed and produced more in drought (restrained irrigation) and adequately-watered circumstances, regardless of the impacts of drought. Kamau *et al.* (2020) examine the impact of mycorrhizal and rhizobium inoculation on the growth of soybeans in the acidic soils of Gatanga, Kenya. The essential role of mycorrhizal fungi complicates their cultivation and commercialisation, while the limited shelf life of rhizobium at ambient temperatures prevents its use by farmers with limited resources. Ashwin *et al.* (2023) studied the association of arbuscular mycorrhizal fungi in legume roots and nodules. Legumes engage in tripartite symbiotic relationships with rhizobia. Ozede and Babalola (2021) studied the Rhizobium and Arbuscular Mycorrhizal Fungal Species and Improved Soybean yield under drought stress conditions. Results revealed that co-inoculation of rhizobia and mycorrhizal fungi can be harnessed biotechnologically to offer a solution to food insecurity. *Rhizobium* and Mycorrhizal Fungal Species Improved soybean yield under drought stress conditions revealed that co-inoculation of rhizobia and mycorrhizal fungi can be harnessed biotechnologically to proffer a solution to food insecurity, as studied by Igiehon and Babalola (2021). According to Allam *et al.* (2021)

Rhizobium and mycorrhizae are used in rhizobiophage-containing soil to enhance nodulation and growth. Because it has the power to increase or decrease the advantageous effects of individual species, the relationship between leguminous plants and rhizosphere microorganisms is crucial. With a reduction percentage of 20–28%, mycorrhizal inoculation enhanced the negative impact. Plants are also that received mycorrhizal inoculation had higher levels of total chlorophyll, carotenoids and legumes.

Although numerous studies document the individual benefits of arbuscular mycorrhizal fungi and *B. japonicum* on soybean productivity, there is a lack of cultivar-specific evidence for KDS-726 under Naldurg's soil, rainfed conditions. Previous Indian studies are restricted to other varieties and rarely employ factorial co-inoculation designs with phosphorus management. Furthermore, critical indicators such as nutrient uptake, mycorrhizal colonization, soil biological activity and economic viability are under reported. Thus, the unique gap lies in evaluating the synergistic impact of AMF and *Bradyrhizobium* on KDS-726 soybean in Naldurg.

MATERIALS AND METHODS

Study site

Naldurg is located at 17.82°N 76.3°E, 438 km from Mumbai.50 km from Solapur city.It has an area of 7550 km2 and average elevation of 566 metres (1856 feet). The temperature ranges from 10.1 °C to 43.1 °C, and the average yearly rainfall is 760mm.

Pot experiment

A pot experiment was conducted to investigate the interaction between the Soybean cultivar KDS-726 plant and the Synergistic Effect of *Bradyrhizobium* and Mycorrhiza in the rhizosphere, as well as the effect of *Bradyrhizobium* cultures. The soybean root modulating rhizobial cultures (*Bradyrhizobium japonicum*) were isolated from the Naldurg region in India. Study: The pure, white, creamy bacterial colonies were selected and marked on yeast extract mannitol agar medium with Congo red (Hi-Media) and incubated at 25 ± 3 °C for 2-3 days or until a pure colony appeared. AM inoculum and assessment of AMF propagules. In this study, *Gigaspora margarita, Glomus macroaggregatum* and *Acaulospora undulata*, and these natural mycorrhizal fungi cultures were identified from the treatments active in this investigation using experimental pots. The bioassay method (Sharma *et al.*, 1996) was also used to determine the infectious propagules (IP) in the inoculum, which were expre ssed as the IP number per g of soil inoculum. Rhizosphere soil of Soybean cultivars kDS-726 examination of a Naldurg site revealed that it influences water retention, nutrient retention, and soil aeration

Treatments and design of the study; *Bradyrhizobium* inoculant preparation and seed treatment

The experiment occurred at the Pot Experiment Research centre in Botany, Naldurg, using Soybean (*Glycine max*) as the test crop. The research should be an on-pot study utilizing a completely randomized design (CRD). The experiments were carried out in 12-inch diameter pots and separated into 7 pots. The soybean was grown for the 2024 rainy season. Inside the pots, the treatments consisted of this technique used by Kamau *et al.* (2020). Ensures reliable early colonization despite cracking soil and episodic wet-dry cycles & found higher initial root contact hence further boosts colonization and P uptake under P-fixing soil and intermittent moisture. Selected AM species are found dominant of this localities hence chosen for this investigation.

Inoculant combinations are as follows-

i. Soybean control
ii. Soybean along with *Glomus macroaggregatum* (Gm).
iii. Soybean treated with *Bradyrhizobium japonicum* (Bj).
iv. Soybean treated with *Bradyrhizobium japonicum* + *Acaulospora undulata* (Bj+Au).
v. Soybean treated with *Bradyrhizobium japonicum* + G*igaspora margarita* (Bj+Gm).

Mycorrhizal status

A mixture of three AM species, *Acaulospora undulata*, *Glomus macroaggregatum*, and *Gigaspora margarita*, was employed to inoculate the treatments by placing 10 grams of it beneath the seeds in the pot planting experiments. A total of 250 g of soil and sand was provided per pot for the treatments and *Glomus macroaggregatum* is a dominant species used as control. The *Bradirhizobium* inoculant for soybeans was utilized in the treatments. Each treatment consisted of three half-liter planting pots, 20 cm in diameter with one

containing sterilized soil and the other holding non-sterilized soil collected from Naldurg. The soil was kept in a hot air oven at 100°C C for 48 hours. A total of seven plots were formed by applying seven treatments, which were the same as those used in the on-pots trials. AM inoculation at 50 g of basic soil included a mixture of AM inoculum with 1000 IP (a blend of native AMF cultures, *Acaulospora undulata, Glomus macroaggregatum*, and *Gigaspora margaritata* containing root fragments, along with hyphal and mycelial mass per pot, which was applied using the layering technique just beneath the seeds. *Bradyrhizobial* cultures were cultivated in YEM broth and used as a seed treatment inoculation (Naomi *et al.*, 2020).

Root colonization

The soybean KDS-726 variety was collected from the Naldurg area study sites of the Dharashiv district in the monsoon season. The study of secondary root of the Soybean was washed with clean water and soil remains and kept in FAA solution (Formalin-Acetic Alcohol). Throughout the study of root assessment, the root was washed 3-4 times to remove the FAA from the root. If 20-30 segments of the root are cut into 2-3 cm in length, the root is boiled in 10% KOH. The root sample was sterilized with sterilized distilled water till to the brown colour of the boiled root changed to colourless. The root was to be found in the 5% of HCL for 3-4 min to enhance the root staining ability. Later, the HCL treatment root was washed with sterile distilled water 5-6 times and placed into 0.05% trypan blue stain overnight (12 hours). To type the slide, initially, remove the additional stain 4-5 times and wash it with purified water. The roots were observed in the complex microscope and the results and photographed with a OnePlus Nord mobile camera. (Phillips *et al.,* 1970), The mycorrhizal infections, like arbuscular, hyphae and vesicle colonization, were verified and calculated % root colonization and % root length colonization by using the formula and photography.

$$\%\ \text{Root Colonization} = \frac{\text{Total no of root segments colonized}}{\text{Total no of root segments examined}} \times 100$$

Isolation of AM fungal Spores from Soil

The spore total was determined using a mycorrhiza inoculant obtained from the Soybean collected from the Naldurg study sites of the Osmanabad district in the monsoon season. Numerous techniques have been presented to recover AM fungi spores from the soil. AM fungi spores originate from this is wet sieving and decanting methods, which remove the clay, sand, and organic matter segments while retaining spores and other similar-sized soil particles on sieves of various sizes with stainless steel mesh in descending order (35, 63, 125,150, 212 and 355µm). Study was using for the isolation, 100g of soil was weighed and added to 1000 mL of water in a conical flask. Before the flask was surprised well in a whirlpool mixture and permitted to settle for a few seconds, and was immediately transferred to a series of sieves. The container was washed twice with water and then further through the sieve series. This separation was collected in individual jars by washing them with water. Previously, the sieved isolated spores were placed on a gridded Petri plate and examined experimentally in the lab using a 400X binocular microscope (Lawrence and Mayo LM-52-3521). The number of AM fungal spores was determined and expressed as a specific number of spores per 100 g of the soil sample for analysis. These separate spores were chosen with a micropipette and were prepared in Poly Vinyl Lacto Glycerol (PVLG) to create permanent slides and capture images using a mobile camera.

Identification of spores

Using the INVAM International Collection of Vesicular Arbuscular Mycorrhizal morphotaxonomic criteria and mycorrhizal guides, the identification of AM fungal spores was approved by (Schencket *et al.*, 1990 and Rodrigues *et al.,* 2009). Spore density and spore diversity were recorded. Giving to Schenck and Pérez (1990), Walker (1983); Schußler (2000); Mosse and Bowen 1968; Koske *et al.,* 1986; Muthukumar *et al.,* (2005); the investigating by Bukhari and Rodrigues (2006) and culture database known by International Collection of Vesicular Arbuscular Mycorrhizal (http://invam.wvu.edu/the-fungi) fungi Glomalean spores were identified.

Biomass Productivity

After 90 days of treatment growth parameters such as height of the shoot, length of the root, number of leaves, number of root nodules, number of pods, fresh weight of the shoot and root and dry weight of the shoot and root were studied were recorded. Biomass was measured using the harvest method. The length of the shoot was measured from the surface of the soil. The plant's root length was measured by uprooting the plant. A digital balance was used for the measurement of the fresh weight

of the shoot and root. For dry weight measurements, plant materials were oven-dried at 80^0C for 24 to 48 hours until a constant weight was achieved, then cooled and weighed. (Semegnew *et al.*, 2019)

Statistical Analyses

All data were statistically analysed and the importance of variances was determined by using SPSS (Rahman and Muktadir, 2021).

RESULTS

Root colonization and Root length colonization:

The results in percentage (%) of the root colonization and percentage (%) of root length colonization were analysed from *Glomus macroaggregatum* and *Bradyrhizobium japonicum* experiments (Table 1). The highest proportion of ro ot colonisation was discovered through a study. Th e study found that *B. japonicum* + *Glomus macroag gregatum* had the highest percentage of root coloni sation (88±2.33%), whereas *B. japonicum* had the l owest percentage (40±1.01%). The highest root length colonization was the maximum 161.33±3.02 % of the *B. japonicum*+ *Glomus macroaggregatum,* the lowest was in *Glomus macroaggregatum* (72±4.20). Root colonization by vesicular, arbuscular and hyphal fungi was recorded in this table and is that in (**Table 1** and **Figure 1**).

Table 1: AMF Root colonization and Root length colonization in pot experiments of variety soybeans KDS-726.

Sr./No.	Treatments	AMF Root colonization(n*=25)		
		RC %	RLC %	Types of Colonization
1.	Control	19.0±2.0	12.0±30.10	Hyphal
2.	*Glomus macroaggregatum*	37.0±1.01	17.0±4.20	Vesicles, Arbuscules
3.	*Bradyrhizobium japonicum*	40.0±1.01	20.0±4.20	Vesicles
4.	*B. japomicum+Acaulospora undulata*	48±2.20	25.6±4.10	Vesicles, Hyphal
5.	*B. japonicum+Glomus macroaggregatum*	88.0±2.33%	40.3±3.02	Vesicles & Arbuscules
6.	*B. japonicum+Gigaspora margarita*	72±1.12	44.0±2.11	Arbuscules & Hyphal
	SE	10.26	5.28	-

Values are means of three replications, ±-Standard error, **RC**- root colonization**, RLC**- Root length colonization

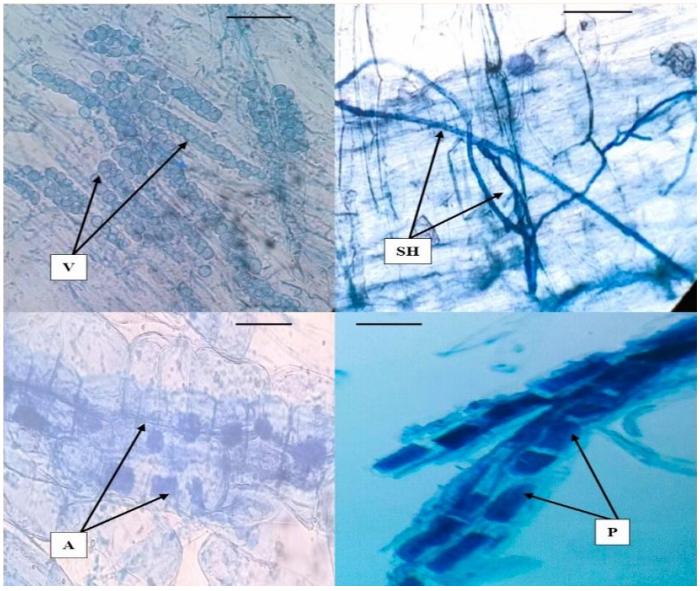

Figure 1: Showing Soybean KDS-726 variation controls the AMF root colonization (X=100). Scale bar = 40 µm. V= Chain of vescicle; SH= Swelling hyphae; A= Paris type of Arbuscules

AM fungi spore density

The study found that the spore density of AM fungus spores in the rhizosphere soil varied from 117.66±0.00 to 172.83±0.19/100g. *B. japonicum* + *Gl. macroaggregatum* had the maximum spore density (172.83 ± 0.19/100 g soil), and *B. japonicum* + *Gi. margarita* had the minimum spore density (101.52 ± 1.21/100g soil). Morphological classification, counting, percentage calculations, and root colonisation examination were all part of the analysis of AM fungal spores. Although *Glomus macroaggregatum* has been detected in other species, the data also indicated that these spores, which are regularly found, include *Acaulospora undulata*, *Glomus microaggregatum*, and *Gigaspora margarita* (**Table 2** and **Figure 2**).

Table 2: AMF Spore density of rhizosphere soil of soybean after 30, 60 and 90 days.

Sr. No.	Treatments	Parameters		
		30 days	60 days	90 days
1	Control	30±1.5	54±1.6	77±0.9
2	*Glomus macroaggregatum*	70 ± 8.24	99.44 ± 3.11	117.91 ± 0.36
3	*Bradyrhizobium japonicum*	113 ± 7.56	158.33 ± 4.16	138.88 ± 1.12
4	*B.japomicum+Acaulospora undulata*	128 ± 9.35	136.11 ± 2.14	112.5 ± 0.95
5	*B.japonicum+Glomus macroaggregatum*	103 ± 7.57	147.22 ± 3.01	172.83 ± 0.19
6	*B.japonicum+Gigaspora margarita*	112 ± 6.93	135.55 ± 1.84	101.52 ± 1.21
	SE	14.81	15.75	13.30

Values are means of three replications; ± - Standard error

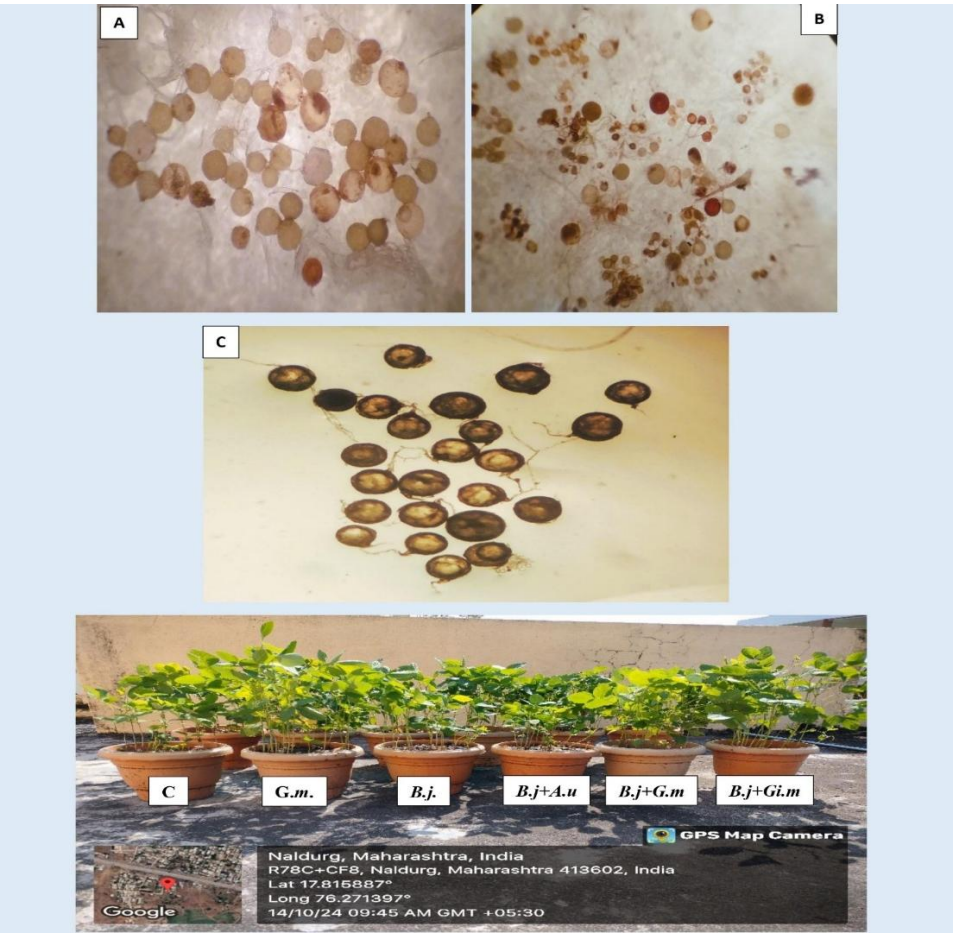

Figure 2: Diversity of AM fungal spores isolated from the pot experiments of Soybean (*Glycine max* L.) KDS-726 (X = 400). **A** = *Acaulospora undulata*; **B** = *Glomus macroaggregatum*; **C** = *Gigaspora margarita*; **C** - *control*; ***G.m.*** - *Glomus macroaggregatum*, ***B.j.*** - *Bradyrhizobium japonicum*; ***B.J.*** + ***A.u.*** (*Acaulospora undulata*); ***B.j.*** + ***G.m*** (*Glomus macroaggregatum*); ***B.j.*** + ***Gi.*** (*Gigaspora margarita*)

Biomass production

The height of the shoot, length of the root, number of leaves, number of root nodules, number of pods, fresh weight of the shoot and root and dry weight of the shoot and root were studied in pot experiments (**Table 3** and **Figure 3**).

Table 3: Growth responses of AMF species and *Bradyrhizobium japonicum* on biomass production of soybean after 90 days.

Parameters	Control	*Gm*	*Bj*	*Bj+Au*	*Bj +Gm*	*Bj+Gim*
Height of shoot (cm)	19±0.10	39±0.20	40±0.95	41±0.45	51±0.18	50±.012
Length of root (cm)	08±2.0	20±0.41	19±0.50	22±0.43	27±0.46	26±0.10
Number of leaves	10±4.0	15±4.0	10±03	11±01	15±01	14±03
Number of nodules	10±3.0	17±2.0	16±05	18±02	27±02	25±02
Number of pods	07±03	12±3.0	15±00	14±03	18±05	15±01
Fresh weight of shoot(g)	14.12±0.50	20.71±0.23	20.75±.02	18.21±0.14	23.41±6	20.96±02
Fresh weight of root(g)	1.1±0.42	1.7±0.12	1.7±0.20	1.2±0.16	1.9±0.13	1.5±0.11
Dry weight of shoot(g)	1.13±0.32	1.45±0.16	1.20±0.15	2.02±0.20	2.45±0.42	2.33±0.31
Dry weight of root(g)	0.235±0.15	0.459±0.17	0.422±0.16	0.449±0.21	0.591±0.01	0.520±0.14
SE	2.13	4.10	4.18	4.29	5.40	5.25

Gm*. -** *Glomus macroaggregatum;* ***Bj. *- Bradyrhizobium japonicum;* ***Bj.+Au -*** *Acaulospora undulata;* **Bj.+*Gm*. -** *Glomus macroaggregatum;* ***Bj +Gim*** *- Gigaspora margarita.* Values are means of three replications, ± - Standard error

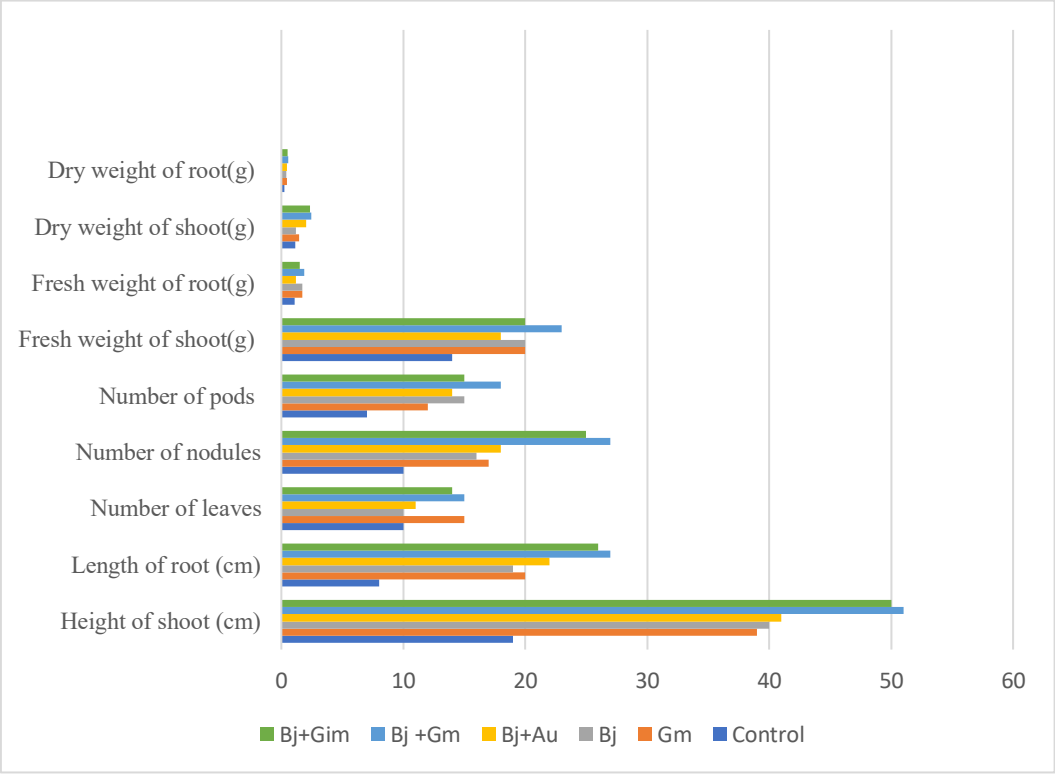

Figure 3: Growth responses of AMF species and *Bradyrhizobium japonicum* on biomass production of soybean

Height of Shoot and Root Length

In this study height of the shoot was maximum when the plant was treated with AMF + *B. japonicum* + *Glomus macroaggregatum* (51±0.18cm) which was followed by the plant treated with Control (19±0.10cm), *G. macroaggregatum* control (39±0.20cm) and *B. japonicum*+*Gigaspora* (50±.02cm). Root length was found to be minimum in the control (non-mycorrhizal) plant (8±2.0cm) and the *G. macroaggregatum* (19±0.50cm).

Number of leaves

As compared to the control (10±4 leaves), all the treated plants showed an equivalent number of leaves in *G. macroaggregatum*+*B. japonicum* (15±1), *A. undulata* + *B. japonicum* (11±1) and a relatively smaller number of leaves in *G.macroaggregatum* (14±4).

No of Nodules

In the number of nodules, *B. japonicum* + *Gi. margarita* (25±02), followed by the *G. macroaggregatum* -treated alone plant (17±02), *B. japonicum* + *G. macroaggregatum* (27±2), *B. japonicum* + *Aculospora undulata* (18±5).

Fresh weight of shoot and root

In the case of fresh weight shoot, *B. japonicum* + *Glomus macroaggregatum* (23.41±6g) had the maximum fresh weight of the shoot, followed by *B. japonicum* + *Aculospora undulata* (18.21±05g) and then *G. macroaggregatum* treated alone, plant (20.71±0.23g) and in *G. macroaggregatum* + *Gi. margrita* (20.96±02g).

The weight of roots was observed in the control and *B. japonicum* + *Gi. margarita* (1.5±0.11g) is minimum and *B. japonicum* + *A. undulata* (1.2±0.16g), *B.japonicum* + *G.macroaggregatum* (1.09±0.13g) and *Bradyrhizobium japonicum* (1.7±0.20g).

Dry weight of the shoot and root

The dry weight of the shoot was found to be maximum in *B. japonicum* + *Acalospora undulata* (2.02±02g), followed by the *Glomus macroaggregatum* treated plant (1.45±0.1g), and *G.macroaggregatum* + B. *japonicum* (2.45±0.2g), control (1.13±0.32g), *B.japonicum* + *Gigaspora margarita* (2.33±0.32g) and *B. japonicum* + *A. undulata* (2.02±0.20g).

The dry weight of roots is *G. macroaggregatum* (0.459g) than the control (0.232g), very much less in *B. japonicum* + *A. undulata* (0.449g), followed by *G.macroaggregatum* + *B. japonicum* (0.591g) and minimum in *B.japonicum* + *Gi. margarita* (0.520g).

DISCUSSION

Both arbuscular mycorrhizal fungi (AMF) and *Bradyrhizobium* benefit crops like soybean, but they act through different biological mechanisms, which is why treatment performance differs depending on soil, crop variety and environmental conditions. AMF and *Bradyrhizobium* are not independent actors they form a mechanistic partnership where P fuels N-fixation, N fuels C supply and shared signaling + stress protection integrates the symbioses.

It was reported that the co-inoculated treatments with fertiliser application had the highest root number plant−1 (9.0 ± 0.6, 8.7 ± 1.9 and 4.7 ± 0.8), biomass was higher in treatments infected with *Rhizobium* and Mycorrhiza The only mycorrhiza-inoculated treatments in the greenhouse, however, showed reduced dry biomass in comparison to the control (16.67% for V1, 42.20% for V2, and 22.18% for V3). Also, 27.01% and 66.99% for V1, 42.20% and 70.33% for V2, and 36.84% and 80.20% for V3 were the results of combined inoculation of AMF + Rhizobium and AMF + Rhizobium + fertiliser, respectively. (Dobe,2022). Wangiyana *et al.* (2022) examined the productivity and potential of East Lombok, Indonesia, which was enhanced by the response of multiple soybean varieties (V1 = Detap, V2 = Biosoy-2, and V3 = Dena-1) to co-inoculation with Rhizobium and mycorrhiza biofertilizers in dryland areas. Arbuscular mycorrhizal fungi's environmental reaction to regional soybean production; Climate change, fertilizer shortages, and reduced land for cultivation have increased attention to the potential help provided by soil-borne organisms. The most prevalent AMF species in the investigated area are *Glomus fuegianum* and *Acaulospora scrobiculata. G. fuegianum* abundance was negatively linked to precipitation seasonality and positively linked to mean annual rainfall and mycorrhizal colonization of soybean roots by Faggioli et al (2022). According to Nader *et al.* (2024). When irrigating soybeans (*Glycine max*, L.) during critical growth stages, arbuscular mycorrhizal fungi reduce the negative effects of drought stress. In the soybean

rhizosphere, bioinoculant inoculation enhanced the activities of Dehydrogenase and phosphatase. After applying *B. japonicum*, dehydrogenase activity increased by 23.13 and 33.47%, *B. subtilis* by 23.04 and 33.39%, AMF by 22.40 and 32.84%, *B. japonicum* + *B. subtilis* by 22.66 and 33.06%, *B. japonicum* + AMF by 20.10 and 30.84%, and *B. subtilis* + AMF by 15.67 and 27.01% when compared to 100% NPK and 50% NPK, respectively and mixture treatment by 19.05 and 29.93%. According to the results of this study, a combination of bioinoculants could benefit soybean plants' resistance to drought stress, especially during critical growth stages, and that soybean growth, productivity. A pot culture experiment using a completely randomized design (CRD) was used to examine the effects of *Bradyrhizobium japonicum* and Arbuscular Mycorrhizal Fungi on the growth, yield, and odor of soybeans when applied together. Compared to single inoculation, dual inoculation of AM fungus and *B. japonicum* enhanced soybean plant growth, yield, AMF colonization, and nodulation. The growth was greatly aided by an increase in the amount of AMF inoculation. *Bradyrhizobium japonicum* was isolated from native soil and used to treat soybean seeds of cultivar MAUS 158. B. japonicum-treated seeds were placed in plastic bags with varying concentrations of AMF inoculation, 0, 20, 25, 30, 35, 40 and 50 g at the time of sowing, and a control without inoculation was maintained Shweta *et al.*, 2022).

CONCLUSION

Mycorrhizal fungi significantly affect with treated plants. Treatments of combination gave significant response for the root AMF colonization & spore density. As a result, the interaction between *B. japonicum* and *G. macroaggregatum* is the most prevalent, exhibiting the highest relative abundance of biomass production and soybean yield. Hence need to be the combined treatments for better surveillance of AMF status. Dual inoculation of AMF and *Bradyrhizobium* is a low-cost, eco-friendly strategy that improves legume productivity and soil fertility, our further research upgrade the AMF strain compatibility, stress tolerance and farmer adoption practices.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

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