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Integrated effects of rhizobial inoculant with vermin-compost (vc) on groundnut (*Arachis hypogaea* L.) in pot condition

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ABSTRACT

The study was conducted to evaluate the integrated effects of rhizobial inoculant and vermicompost on the growth, nodulation, and yield of groundnut (*Arachis hypogaea* L.) under pot conditions at the Soil Science Division, BINA, Mymensingh during 2024. The experiment comprised five treatments: T_1 (control: I_0 + VC_0), T_2 ($N_{60}P_{60}K_{75}S_{60}$), T_3 (I_1 + $P_{60}K_{75}S_{60}$), T_4 (VC_{10} + $P_{60}K_{75}S_{60}$), and T_5 (I_1 + VC_{10} + $P_{60}K_{75}S_{60}$), arranged in a randomized complete block design with three replications. Results revealed significant differences ($p < 0.05$) among treatments for growth, nodulation, and yield parameters. The combined application of rhizobial inoculant and vermicompost (T_5) produced the highest number of effective nodules per plant (96.67), nodule weight (0.60 g plant^{-1}), number of pods per plant (10.83), and yield (17.4 g pot^{-1}), representing a 91.84% increase over the uninoculated control. The enhanced performance of T_5 indicates a strong synergistic interaction between Rhizobium inoculation and vermicompost, resulting in improved nitrogen fixation, nutrient availability, and plant vigor. These findings demonstrate that integrating biofertilizers with organic amendments can effectively improve the productivity and sustainability of groundnut cultivation while reducing dependence on chemical fertilizers.

Keywords: Groundnut, Inoculant, Vermicompost, Nodulation, Yield performance

INTRODUCTION

In Asian countries, legumes have made a perfect contribution to both the promotion of ecosystems in agricultural production and sustainable intensive farming (Schultze *et al.*, 2018).

Groundnut yield and quality have been increased thanks to animal manures and beneficial bacteria (Chuong *et al.*, 2021). Nearly all agricultural soils lack of enough nitrogen to support plant growth (Buri *et al.*, 2010). The co-application of vermicompost, and Rhizobia inoculation is the primary strategy that gets beyond these drawbacks (Prasanthi *et al.*, 2019). Rhizobia inoculation has successfully produced favorable results by supporting atmospheric nitrogen for legumes (Mmbaga *et al.*, 2014). The productivity and quality of legumes as well as the crop soil's nutrition in the degraded soil may be improved with the addition of vermicompost (Tairo *et al*, 2013). In agricultural cultivation, organic fertilizer and rhizobia inoculation have been used (Bikale *et al.*, 2019).

Due to its various advantages, the oil-seed legume peanut (*Arachis hypogaea* L.) has been referred to as a multifunctional plant (Akram *et al.*, 2018; Lusas, 1979). Previous studies have reported on the nutritional and therapeutic effects of this plant (Akram *et al*, 2018; Akhtar *et al.*, 2014). Because peanut oil contains 50% monounsaturated fatty acids (MUFAs), 33% paraformaldehyde (PFA), and 14% saturated fatty acids, it has been deemed heart-friendly (Akhtar *et al.,* 2014; Arya *et al.*, 2016).

Globally, the use of chemical fertilizers has raised the threats to the environment and society. Fertility and soil bacteria have also been impacted. The usage of these chemical fertilizers has also a negative impact on agricultural output and human health (Rai *et al.*, 2014). Vermicompost is a natural materials prepared by collaborations between smaller microorganism and earthworms. It is a completely balanced with low C:N proportion (Ramasamy *et al.*, 2011). Earthworm which excretes beneficial soil organisms and secretes polysaccharides, proteins and different nitrogenous compound into the dirt and thus enhance soil fertility and raise crop productivity (Hatti *et al.,* 2010; Rekha *et al.,* 2013). In addition to having organic nitrogen, phosphorus, and potassium, vermicompost is also thought to be a good source of micronutrients like iron, manganese, copper, zinc, molybdenum, and iodine. Most importantly is that these nutrients are released from vermicompost in amounts that are suitable for the needs of the plant due to microbial activity in the soil and the compost's decomposition (Argaw *et al.*, 2017). One of the innovative approaches and promising technologies that can help lower the need for inorganic N fertilizers while increasing soil fertility and cutting production costs is rhizobia-legume symbiosis. It is estimated that nodulated legumes, such as pulses and oilseeds, fix nitrogen (N_2), which adds 21.45 million tons of nitrogen to agricultural systems worldwide each year (Herridge *et al.*, 2008). One more environmentally friendly and sustainable method to boost crops' capacity for nitrogen fixation is to inoculate them with rhizobia.

Therefore, the present study was undertaken to investigate the integrated effects of rhizobial inoculant with vermicompost on groundnut in pot condition.

MATERIALS AND METHODS

Experimental site

The research work relating to the study of the effect the effects of rhizobial inoculant with vermicompost on groundnut in pot conditionat the Soil Science Division, BINA, Mymensingh during 2024.

Description of soil

The soil of the experimental pot belongs to the Agro Ecologieal Zone-9 (Old Brahmaputra Floodplain). The region has broad ridges and basins. Relief is irregular, especially near the old and present river channels. Soils of the area are predominantly silt loams to silty clay loams on the ridges and clay in the basins. Organic matter content is low on the ridges and moderate in the basins, topsoils moderately acidic but subsoils neutral in reaction. General fertility level is low.

Description of the groundnut variety

Binachinabadam-4 is a high yielding groundnut variety (maximum: 3.5 tons/ha, average 2.6 tons/ha) released in 2008. Duration: 140-150 days in winter and 100-120 days in summer season.

Pod and kernels are medium bold sized. It can tolerate cercospora leaf spot, collar root and rust diseases and also performs better under drought and saline conditions.

Climate

Mymensingh Sadar experiences a monsoonal humid subtropical climate, categorized as Köppen Cwa. This means it has a distinct wet season (monsoon) from May/June to August, a dry season, and generally hot, humid conditions.

Preparation of the pot

Plastic pot containing 5 kg sterilized sand was used in the pot. Sand was poured into pot-which was sterilized through washing by detergent both rubbing inside and outside using 70% ethyl alcohol solution. Seeds of groundnut were surface sterilized by dipping 1 minute into 3% H_2O_2 solution. Then seeds were dipped into respective inoculant strains suspension for 30 minutes and then used to sow into the soil in pot and covered by soil. Soil was mixed with seedling solution of half strength @ 200 ml seedling solution per pot.

Layout of the experiment

The experiments were laid out in a randomized complete block design with three replications. The total number of pot was 15. The treatment combination of the experiment was assigned at random into 15 pots of each at 3 replications (Table 1).

Application of chemical fertilizers and vermicompost

The required amounts of P, K, Zn and B fertilizers (Triple Super Phosphate, Muriate of Potash, Zinc Sulphate and Borax respectively) were applied at the time of soil preparation (Table 2).

Table 1. Treatments combination

Treatments	Description
T_1	T_1:I_0+VC_0 (no Inoculant+ noVermicompost)
T_2	T_2:$N_{60}P_{60}K_{75}S_{60}$ (60 mg pot^{-1} Nitrogen, Phosphorous, Sulphur and 75 mg pot^{-1} Potassium)
T_3	I_1+$P_{60}K_{75}S_{60}$ (Rhizobial Inoculant of Groundnut+ $P_{60}K_{75}S_{60}$)
T_4	VC_{10}+ $P_{60}K_{75}S_{60}$ (10 g pot^{-1}Vermicompost+$P_{60}K_{75}S_{60}$)
T_5	I_1+VC_{10}+ $P_{60}K_{75}S_{60}$

Table 2. Nutrient contents in vermicompost

Items	Percent
Organic carbon	15.2%
N	1.42%
P	1.45
K	1.52%
S	0.35%

Seed sowing

Binachinabadam-4 was used as test crop. Three seeds were sown in each whole and after germination five healthy plants were maintained in each pot. Half strength sterile seedling solution was applied in pot as per requirement aseptically. Sowing date was 30 January 2024.

Cultural and management practices

Various intercultural operations such as thinning of plants, weeding and spraying of insecticides were accomplished whenever required to keep the plants healthy and the field weed free. Special care was taken to protect the crop from birds especially after sowing and germination stages. The field was irrigated when necessary.

Harvesting

The crop was harvested at maturity on. The harvested crop of each individual pot was bundled separately. Yields were recorded pot wise separately and the yields were expressed in g pot^{-1}.

Collection of data

Data of groundnut growth and nodulation indicators was recorded at 62 Days After Sowing (DAS). Yield & yield contributing characters were documented on 6

June 2024. Plant height, No. of nodule plant^{-1}, No. of effective nodule plant^{-1}, wt. of effective nodule plant^{-1}, Number of branches plant^{-1}, Fresh wt. plant^{-1}, No. of fruits plant^{-1}, Wt. of fruits plant^{-1}, Yield (g pot^{-1}) were recorded.

Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the differences among pairs of treatment means was estimated by the Least Significant Difference (LSD) test at 5% and 1% level of probability and DMRT was calculated (Gomez and Gomez, 1984).

RESULTS

Effect of rhizobial inoculation and vermicompost on growth and nodulation of groundnut

Significant variations ($p < 0.05$) were observed among the treatments for all growth and nodulation parameters of groundnut at 62 days after sowing (DAS) (Table 3). According to Duncan's Multiple Range Test (DMRT), the maximum root length (11.50 cm), shoot length (17.00 cm), and plant height (28.50 cm) were recorded in T4 (VC10 + P60K75S60), which was statistically at par with T3 (I1 + P60K75S60) and T5 (I1 + VC10 + P60K75S60). In contrast, the uninoculated control (T1 [I0 + VC0]) exhibited the lowest values for these parameters.

Table 3. Effect of rhizobial strain on the growth and nodulation of groundnut at 62 DAS

Treatments	Root length (cm)	Shoot length (cm)	Plant height (cm)	No. of nodule plant^{-1}	No. of effective nodule plant^{-1}	Wt. of effective nodule plant^{-1} (g)	No. of branch plant^{-1}	Fresh wt. plant^{-1} (g)
T_1: $I_0 + VC_0$	8.17c	12.00a	20.17b	0.00b	0.00c	0.00c	3.00b	10.18b
T_2: $N_{60}P_{60}K_{75}S_{60}$	9.33bc	14.83a	24.17ab	7.33b	0.00c	0.00c	4.00ab	18.50ab
T_3: $I_1 + P_{60}K_{75}S_{60}$	11.17a	14.67a	25.83ab	81.60a	69.0b	0.330b	4.00ab	21.16a
T_4:$VC_{10}+P_{60}K_{75}S_{60}$	11.50a	17.00a	28.50a	21.67b	9.00c	0.08c	3.67b	18.38ab
T_5:$I_1+VC_{10}+P_{60}K_{75}S_{60}$	10.83ab	14.33a	25.17ab	81.67a	96.67a	0.60a	4.33a	20.14a
CV	6.85	5.61	7.21	6.34	7.53	7.97	8.99	6.37

*Subscripts of N, P, K, S& VC represent g pot^{-1}.

Table 4. Effect of rhizobial strain on yield contributing characters and yield & of groundnut

Treatments	Root length (cm)	Shoot length (cm)	Plant height (cm)	No. of fruits Plant^{-1}	Wt. of fruits plant^{-1} (g)	Yield (g pot^{-1})	% Yield increase over control
T_1: $I_0 + VC_0$	14.17b	12.17b	26.34c	5.00b	3.78e	9.07e	
T_2: $N_{60}P_{60}K_{75}S_{60}$	14.50b	17.00a	31.50a	8.33ab	5.51d	13.22d	45.76
T_3: $I_1 + P_{60}K_{75}S_{60}$	15.33a	18.00a	33.33a	9.83a	6.79b	16.30b	79.71
T_4:$VC_{10}+ P_{60}K_{75}S_{60}$	15.00b	17.89a	32.89a	9.00ab	6.13c	14.71c	62.18
T_5:$I_1+VC_{10}+ P_{60}K_{75}S_{60}$	14.67b	16.53a	31.20b	10.833a	7.25a	17.4a	91.84
CV(%)	6.58	7.54	7.01	6.97	5.10	6.19	

*Subscripts of N, P, K, S& VC represent g pot^{-1}.

Nodulation was strongly influenced by rhizobial inoculation and vermicompost application ($p < 0.05$). The highest number of nodules per plant (81.67), number of effective nodules per plant (96.67), and nodule weight per plant (0.60 g) were obtained in T5 (I1 + VC10 + P60K75S60), which differed significantly from all other treatments according to DMRT. The uninoculated control (T1) produced no nodules, while chemical fertilizer alone (T2 [N60P60K75S60]) resulted in very few, non-effective nodules.

Similarly, the number of branches per plant and fresh plant weight were also significantly higher ($p < 0.05$) in T5, followed by T3, indicating a synergistic effect of rhizobial inoculation and vermicompost on vegetative growth and nodulation efficiency in groundnut.

Effect of rhizobial inoculation and vermicompost on yield and yield-contributing characters

Significant differences ($p < 0.05$) were also recorded for yield and yield-contributing characters among the treatments (Table 4). The combined application of rhizobial inoculant and vermicompost (T5: I1 + VC10 + P60K75S60) produced the highest number of fruits per plant (10.83), fruit weight per plant (7.25 g), and yield per pot (17.4 g), showing a 91.84% increase in yield over the control. These values were statistically superior to all other treatments as per DMRT.

Treatment T3 (I1 + P60K75S60) ranked second, recording a yield of 16.30 g pot^{-1} with a 79.71% increase over control, followed by T4 (VC10 + P60K75S60), which showed a 62.18% increase. The lowest yield was obtained from the uninoculated control (T1 [I0 + VC0]), while chemical fertilizer alone (T2 [N60P60K75S60]) produced moderate improvement.

Overall, the integration of rhizobial inoculation and vermicompost with balanced NPKS fertilization (T5) significantly enhanced plant growth, nodulation, and yield performance of groundnut, confirming the positive interaction between biofertilizers and organic amendments under the tested conditions ($p < 0.05$, DMRT).

DISCUSSION

The present study demonstrated that rhizobial inoculation and vermicompost application significantly enhanced growth, nodulation, and yield parameters of groundnut (*Arachis hypogaea* L.). The combined treatment (I1 + VC10 + P60K75S60) produced the highest values for plant height, nodulation, and yield, confirming the synergistic effect of biofertilizer and organic amendment integration.

Effect on growth and nodulation

The significant improvement in root and shoot growth following rhizobial inoculation could be attributed to enhanced nitrogen fixation and improved nutrient availability. Rhizobia form symbiotic associations with legumes, fixing atmospheric nitrogen and supplying it to plants, thereby promoting vigorous vegetative growth (Herridge *et al.*, 2008; Tairo and Ndakidemi, 2013). Moreover, vermicompost provides essential macro- and micronutrients in readily available forms, improves soil structure, and enhances microbial activity, all of which contribute to better root proliferation and shoot elongation (Ramasamy and Suresh, 2011; Hatti *et al.*, 2010).

The findings align with Argaw and Mnalku (2017), who reported that the combined use of *Rhizobium* inoculant and vermicompost significantly increased nodulation and biomass in faba bean. Similarly, Debela *et al.* (2021) observed a marked increase in effective nodules and nodule mass in soybean when inoculated with *Rhizobium* and supplemented with NPS fertilizer and vermicompost. The present results also agree with Mmbaga *et al.* (2014), who found that co-application of rhizobial inoculants and phosphorus enhanced nodule efficiency and root development in legumes.

Effect on yield and yield attributes

Yield improvements due to rhizobial inoculation and vermicompost incorporation can be attributed to enhanced nitrogen fixation, improved soil fertility, and better plant vigor. The synergistic interaction between *Rhizobium* and organic manure ensures sustained nutrient release and greater efficiency in nutrient uptake (Singh and Sharma, 2003; Rai *et al.*, 2014). Bekele *et al.* (2019) similarly reported that integrated application of nitrogen, phosphorus, and vermicompost significantly improved groundnut yield in eastern Ethiopia. Chuong *et al.* (2021) also confirmed that *Rhizobium* inoculation combined with organic amendments, such as cow manure, increased both yield and quality of peanut in degraded soils.

The significant increase in yield (up to 91.84% over control) under combined treatment (I1 + VC10 + P60K75S60) supports the concept of integrated nutrient management. Vermicompost not only enhances soil physicochemical properties but also increases microbial enzymatic activity and soil mesofauna, which collectively improve nutrient cycling and plant productivity (Prasanthi *et al.*, 2019). Rekha *et al.* (2013) and Ramasamy and Suresh (2011) also observed similar improvements in black gram and sunflower, respectively, where vermicompost promoted plant growth and yield performance.

Comparative insights with previous studies

The observed enhancement in yield components—such as number and weight of fruits per plant—suggests that rhizobial inoculation improves the internal nitrogen pool necessary for pod development, while vermicompost ensures balanced nutrient supply and moisture retention (Akram *et al.*, 2018). These findings are consistent with studies on other legumes, where the combination of biological nitrogen fixation and organic matter addition improved pod filling and total seed weight (Argaw and Mnalku, 2017; Debela *et al.*, 2021).

The role of vermicompost in improving soil organic carbon and nutrient-holding capacity has been well-documented (Buri *et al.*, 2010; Singh and Sharma, 2003). Vermicompost introduces beneficial microorganisms and humic substances that enhance root activity and nutrient absorption, translating into higher yields (Rai *et al.*, 2014; Bekele *et al.*, 2019).

Nutritional and environmental significance

Groundnut is a nutritionally valuable and climate-resilient crop rich in oil, protein, and micronutrients (Akhtar *et al.*, 2014; Arya *et al.*, 2016). The integration of *Rhizobium* and organic fertilizers not only improves yield but also reduces dependence on chemical fertilizers, thus minimizing environmental pollution and enhancing sustainability (Schultze-Kraft *et al.*, 2018). Sustainable production of groundnut through such bio-integrated systems supports both soil health and nutritional security, particularly under climate change scenarios (Akram *et al.*, 2018).

Overall, the combined application of *Rhizobium* inoculant and vermicompost with balanced NPKS fertilization significantly improved plant growth, nodulation efficiency, and yield performance of groundnut. These findings corroborate earlier conclusions by Argaw and Mnalku (2017), Debela *et al.* (2021), and Bekele *et al.* (2019), emphasizing that integrated bio-organic nutrient management enhances legume productivity in a sustainable and eco-friendly manner.

The present study, therefore, supports the hypothesis that synergistic use of biological inoculants and organic amendments is an effective strategy for improving the productivity of *Arachis hypogaea* while maintaining soil fertility and reducing the need for chemical fertilizers.

CONCLUSION

The present study demonstrated that combined application of *Rhizobium* inoculant and vermicompost, along with balanced NPKS fertilization, significantly improved the growth, nodulation, and yield performance of groundnut (*Arachis hypogaea* L.). Among all treatments, I_1 + VC_{10} + $P_{60}K_{75}S_{60}$ produced the highest values for plant height, number and weight of nodules, and yield, showing a 91.84% yield increase over the uninoculated control. These findings clearly indicate that integrating biological inoculants with organic manures enhances nitrogen fixation efficiency and soil fertility while reducing dependence on synthetic fertilizers.

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