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Effect of rhizobial inoculant in combination with vermicompost and molybdenum on soybean in pot condition

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ABSTRACT

A pot experiment was conducted to investigate the effect of rhizobial inoculants in combination with vermicompost and molybdenum on soybean in glass house at the Soil Science Division of BINA, Mymensingh. There were six treatments viz. T_1: I_0+VC_0 (no Inoculant + no Vermicompost), T_2: VC_{50} (50 g pot^{-1} VC), T_3: VC_{50}+I_1 (50 g pot^{-1}VC+Rhizobial Inoculant of Soybean), T_4: VC_{50}+I_1+Mo_2 (VC_{50}+I_1+2 mg Molybdenum pot^{-1}), T_5: I_1 and T_6: I_1+Mo_2. The experiment was conducted in a randomized complete block design with three replications during 2023. Plastic pot containing 10 kg soil was used. Nodulation data were recorded at vegetative stage. Yield attributing parameters were recorded after harvest of crop. Results showed significant increase in nodulation, plant height and yield with inoculated treatments over uninoculated control treatment. The highest no. of nodule plant^{-1}(38), and nodule fresh wt. plant^{-1} (0.82g) and no. of effective nodule plant^{-1} (26) were recorded in the treatment T_4. The treatment T_4 gave maximum grain yield (29.06 g pot^{-1}) followed by the treatment T_3 (22.66 g pot^{-1}). The treatments T_4 (VC_{50}+I_1+Mo_2) showed overall the best performance. There was no effective nodulation in the control (uninoculated) plot. The result indicated that rhizobial strain of soybean along with Mo and vermicompost increased soybean production.

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INTRODUCTION

Soybean (*Glycine max* L) is a major legume crop cultivated primarily for their edible beans (Ishaq *et al.*, 2022). In Bangladesh, soybean is one of the main crops used to produce oil. It is a superb source of fat, protein, vitamins, minerals, and some bodily components that are necessary for certain bodily functions, including as lecithin, polysaccharides, and isoflavones (Islam *et al.*, 2019). It has an excellent balance of 38 amino acids, 20% edible vegetable oil, and 40% high-quality protein (Fekadu *et al.*, 2009; Mahamood *et al.*, 2009). Vegetable soybean [*Glycine max* (L.) Merr.] has low cultivation costs, great nutritional value, a short growing season, and increased soil fertility. It offers people nutritious food that is also highly profitable. The need for vegetable soybeans has gradually grown in recent years due to increased awareness of the lack of nutrition and the desire for safer and healthier food options (Jiang *et al.*, 2018). Because of its high concentration of nutrients and appealing health profile, eating vegetable soybeans could help considerably lower the nutritional deficiencies that affect both adults and children (Mahoussi *et al.*, 2020). Legumes have made a significant contribution to both the promotion of ecosystems in agricultural production and sustainable intensive farming in Asian countries (Schultze-Kraft *et al.*, 2018). Studies on Biological Nitrogen Fixation in soybean using different methodologies revealed that soybean shows a strong demand for nitrogen up to 80kg N per 1000kg of soybean grain for optimal development and grain productivity (Hungria *et al.*, 2006; Salvagiotti *et al.*, 2008). N from the atmosphere can be fixed by soybeans ranging from 0–450kg N ha^{-1} (Giller, 2001; Unkovich and Pate, 2000). More than 60 to 70 percent of the soybean's N needs can be met by BNF in conditions that are conducive to N fixation (Herridge *et al.*, 2008), while the balance could be derived from the soil N stock.

Rhizobia inoculation has been regarded as a sustainable and cost-effective tool used to supplement the plants' nitrogen needs, and several studies have been reported that inoculation with rhizobia improves legume growth, nutrition, and production (Tena *et al.*, 2016; Koskey *et al.*, 2017; Nyaga *et al.*, 2020). Combination of strains or species acting in different microbial processes, results in combined benefits, resulting in higher yields. Available rhizobial inoculants in the market that have been tested and proven to increase yield include molybdenum, cobalt among others (Meena *et al.*, 2018).

The usage of chemical fertilizers has increased the risks to society and the environment on a global scale. Soil microorganisms and fertility have also been affected. Human health and agricultural productivity are negatively impacted by the use of these chemical fertilizers (Rai *et al.*, 2014). Earthworms and smaller microorganisms work together to create vermicompost, a natural substance. It has a low C: N proportion and is entirely balanced (Ramasamy *et al.*, 2011). Vermicompost is rich in vitamins, growth hormones, macro and micronutrients, and enzymes like cellulase, lipase, amylases, proteases, and chitinase etc. Even after the organic waste has been expelled from the worms, the enzymes still break it down (Barik *et al.*, 2011). Vermicompost has several positive impacts, including boosting plant secretion, improving soil structure over time, accelerating growth, increasing crop yields, and creating an environment that is fabourable to beneficial microorganisms (Olle, 2016)

An economic way of reducing the application of mineral N would be to choose soybean varieties with a high biological nitrogen fixation capacity and apply rhizobia inoculants (Kueneman *et al.*, 1984; Musiyiwa *et al.*, 2005; Bekere and Hailemariam, 2012; Thuita *et al.*, 2012; Ronner *et al.*, 2016). Two Isolated Bacteria with vermicompost and a half recommendation of mineral fertilizer improved some parameters of soybean growth, yield and gave significant effect in compare with separately addition of isolated bacteria, vermicompost and mineral fertilizer (Imran *et al.*, 2024). Symbiotic N fixation is a major source of fixed N in agriculture soils as well as each legume species requires specific *Rhizobium* strain for effective nodulation and N fixation (Shahid *et al.*, 2009).

Inoculation with *Rhizobium* improved soybean yield and yield components compared to non-inoculated seed (Ahmed, 2013). Adeyeye *et al.* (2017) found that inoculation of soybean seed with *Rhizobium* significantly improved the different parameters. Therefore, the present study was undertaken to investigate the effect of rhizobial inoculants in combination with vermicompost and Mo on soybean in pot condition.

MATERIALS AND METHODS

Experimental site

The research work relating to the study of the effect the effect of rhizobial inoculants in combination with vermicompost and Molybdenum on soybean in glass house at the Soil Science Division was carried out in BINA, Mymensingh during 2023.

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 soybean variety

Bangladesh Institute of Nuclear Agriculture (BINA) released Binasoybean-2, a soybean variety that is moderately resistant to the yellow mosaic virus (YMV). It has deep green leaves, a black hylum with a bright yellow seed coat color, a shorter plant height, and is suitable for both the Kharif and Rabi seasons. Maturity Period 95-100 days. It can be grown in a wide range of soil types from sandy to loam. Seed yield of 2.4-2.8 t/ha. Seeds contain 43.0% protein, 27.0% starch, and 18.0% oil. It is well suited for high and charland regions in the south and southwest parts of Bangladesh, and it may be cultivated in a variety of soil types, including sandy and loam soils.

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 10 kg soil was used in the pot. Soil was poured into pot-which was sterilized through washing by detergent both rubbing inside and outside using 70% ethyl alcohol solution. Seeds of soybean 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 experiment was laid out in a randomized complete block design with three replications. The total number of pot was 18. The treatment combination of the experiment was assigned at random into 18 pots of each at 3 replications (Table 1).

Table 1. Treatments combination

Treatments	Description
T_1	I_0+VC_0 (no inoculant + no vermicompost)
T_2	VC_{50} (50 g vermicompost pot^{-1})
T_3	VC_{50}+I_1 (50 g vermicompost pot^{-1}+ rhizobial inoculant of soybean)
T_4	VC_{50}+I_1+Mo_2 (50 g vermicompost pot^{-1}+ rhizobial inoculant of soybean+2 mg molybdenum pot^{-1})
T_5	I_1 (rhizobial inoculant of soybean)
T_6	I_1+Mo_2 (rhizobial inoculant of soybean+2 mg molybdenum pot^{-1})

Application of chemical fertilizers and vermicompost

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

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

Binasoybean-2 was used as test crop. Rhizobial inoculant was used. 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 28 August 2023.

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 soybean growth and nodulation indicators was recorded at 48 Days After Sowing (DAS). Yield and yield contributing characters were documented on 24 December 2023. Total plant height (cm), no. of nodule plant^{-1}, no. of effective nodule plant^{-1}, wt. of effective nodule plant^{-1}, Fresh wt. plant^{-1}, nodule fresh wt. plant^{-1}, dry wt. plant^{-1}, no. of fruits plant^{-1}, nodule dry wt. plant^{-1}, pod no. plant^{-1}, pod length (cm), effective seed pod^{-1}, effective seed 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 (Gomez and Gomez, 1984).

RESULTS

Growth, nodulation, yield and yield contributing characters were significantly influenced with the different treatments (Table 3 and 4).

Table 3. Effect of rhizobial inoculants in combination with vermicompost and Mo on the growth and nodulation of soybean at 48 DAS

Treatment	No. of nodule plant^{-1}	Effective nodule plant^{-1}	Root length plant^{-1} (cm)	Shoot length plant^{-1} (cm)	Total plant height (cm)	Fresh wt. plant^{-1} (g)	Nodule fresh wt. plant^{-1} (g)	dry wt. plant^{-1} (g)	Nodule dry wt. plant^{-1} (g)
T_1: I_0 + VC_0	5.72d	0.00d	7.00c	19.17d	26.17c	9.83d	0.016d	3.94b	0.00d
T_2:VC_{50}	9.50d	2.17d	9.67b	43.17bc	52.84b	13.42cd	0.06d	4.18b	0.20ab
T_3:VC_{50}+ I_1	29.00bc	22.50b	11.33b	48.13a	59.46a	20.33ab	0.59b	6.81a	0.24ab
T_4:VC_{50}+I_1+Mo_2	37.50a	26.00a	11.83a	47.47ab	59.30a	20.00a	0.82a	6.50a	0.27a
T_5: I_1	34.33b	17.17b	12.17b	39.50c	51.67b	16.07bc	0.56b	4.30b	0.19b
T_6:I_1+ Mo_2	21.00c	10.17c	11.50b	43.00bc	54.50b	16.02bc	0.36c	4.09b	0.12c
CV	5.44	6.26	7.27	7.87	8.11	6.75	5.85	7.22	7.09

Subscripts of Mo & VC represent g pot^{-1}

Results showed significant increase in nodulation, plant height and yield with inoculated treatments over control (uninoculated) plot. Several soybean growth indicators were recorded at 48 DAS. The treatment T_4 exhibited the maximum no. of nodule plant^{-1} (38), effective nodule plant^{-1} (26), and nodule fresh weight plant^{-1} (0.82g) while the treatment T_3 showed the highest plant height (59.46 cm) (Table 3).

The treatment T_4 exhibited over all the the highest pod no. plant^{-1} (46), effective seed plant^{-1} (57), and yield (29.06 g pot^{-1}). The treatment T_4 (i.e VC_{50}+I_1+Mo_2) outperformed the other five treatments (I_0+VC_0, VC_{50}+I_1, VC_{50}+ I_1+Mo_2, I_1andI_1+Mo_2). The substantial increase in yield observed in the *Rhizobium* inoculated seeds might be due to the nitrogen fixation potential of soybean. Effective nodulation was absent from the uninoculated control treatment. The result revealed that the treatment T_4 (50 g pot^{-1} Vermicompost + Rhizobial Inoculant of Soybean + 2 mg Molybdenum pot^{-1}) could be employed for further investigation in the field.

Table 4. Effect of rhizobial inoculants in combination with vermicompost and Mo on yield and yield contributing characters of soybean

Treatment	Pod no. plant^{-1}	Pod length (cm)	Effective seed pod^{-1}	Effective seed plant^{-1}	Yield (g pot^{-1})	% yield increased over control
T_1: I_0 + VC_0	24.55c	3.02c	1.67b	34.00b	17.34c	
T_2: VC_{50}	26.44c	3.16bc	2.00a	41.67a	21.25b	22.55
T_3: VC_{50}+ I_1	31.78c	3.22b	1.93ab	44.44a	22.66ab	30.68
T_4:VC_{50}+I_1+Mo_2	46.33a	3.39a	2.13a	56.99a	29.06a	67.59
T_5: I_1	41.22b	3.05c	1.87ab	40.22a	20.51b	18.28
T_6: I_1+Mo_2	32.89bc	3.41a	1.93ab	43.33a	22.10ab	27.45
CV	6.53	5.60	8.84	6.49	7.03	

DISCUSSION

The treatment T_4 exhibited overall good performance than other treatments. Supporting evidence was reported by Agha *et al.* (2004) who attributed the significant stimulation of nodules no. plant^{-1} and nodules dry weight by *Rhizobium* inoculation to the increase in nitrogenase activity. The substantial increase in yield observed in the *Rhizobium* inoculated seeds might be due to the nitrogen fixation potential of soybean. Similar results were reported by Patra *et al.* (2012). The increases in pod no. plant^{-1} as a result of *Rhizobium* inoculation, manure and micronutrients application might be due to their beneficial effect on nutrients availability considerably result in improved nodule development, energy transformation, metabolic processes and root growth. Ekaette (2017) found a great benefit of using micronutrients, *Rhizobium* inoculation, and organic fertilizers for improving soybean productivity. According to a study by Rabbani *et al.* (2005) on the impact of micronutrients and *Rhizobium* inoculation on pea nodulation, yield, and seed protein, inoculated plants contributed 80 kg N/ha, and their average dry matter yield was higher than that of the uninoculated control. According to other research, *Rhizobium* inoculation significantly increased protein content, pod yield, and seed yield (Tolkachev *et al.*, 1994). This result was in conformity with Kumar *et al.* (2005) and Roesty *et al.* (2006) who reported that the application of vermicompost, bio-fertilizer, and seed inoculated with bacteria, as well as biological nitrogen, root, and optimal absorption of water and nutrients, and the production of certain vitamins, will all increase the plant's growth both qualitatively and quantitatively, strengthening weight gain.

CONCLUSION

The growth and yield-contributing characteristics of Soybean were significantly influenced because of addition rhizobial inoculation, vermicompost and Mo. There is no nodulation in the control uninoculated treatment. Rhizobial inoculation along with micronutrient and vermicompost application enhanced soybean production. Therefore, rhizobial inoculant of soybean, 50 g pot^{-1} vermicompost and 2 mg molybdenum pot^{-1} application increased soybean production. So, rhizobial inoculation along with molybdenum and vermicompost can be a good approach for soil good health and higher soybean yield.

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