RESEARCH ARTICLE Agricultural Science Digest, Volume 46 Issue 2: 319-324 (April 2026)

Effects of Seed Treatment and Foliar Application by using Biological Control Agents and Liquid Organic Fertilizers on Development and Yield on Moong Bean (*Vigna radiata* L.)

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ABSTRACT

Background: A two-year field study was carried out during the *Kharif* seasons of 2023 and 2024 at the Institutional farm of ANDUAT Kumarganj in Ayodhya, Uttar Pradesh. The research aimed to assess the effects of seed biopriming and foliar application using biocontrol agents and liquid biofertilizers on the growth and yield of Moong bean.

Methods: Seed biopriming typically involves the application of beneficial microorganisms to enhance germination potential. The present investigation was carried out on two varieties of green gram *i.e.*, NDM-1 (Collect from ANDUAT, Kumarganj, Ayodhya, U.P) and Sikha (collect from IIPR, Kanpur, U.P) and seed biopriming with two different biocontrol agents (*Pseudomonas fluorescens* and *Trichoderma viridae*) used in different concentration and two different liquid biofertilizers (*Azospirillum* and *Phosphobacteria* @20% respectively) following randomised block design with three replication. The experiment comprised of sixteen biopriming along with hydropriming and control. Seed had been treated with control (T_0), seeds soaked in distil water/hydropriming (T_1); PF @ 25% (T_2); PF @ 50% (T_3); PF @ 75% (T_4); TV @ 25% (T_5); TV @ 50% (T_6); TV @75% (T_7); liquid ASP @ 20%(T_8); liquid PB @ 20% (T_9); T_2 + foliar spray of PF @ 2 g/l (T_{10}); T_3 + foliar spray of PF @ 2 g/l of water (T_{11}); T_4+ foliar spray of PF @ 2 g/l of water (T_{12}); T_5 + foliar spray of TV @ 2 g/l of water (T_{13}); T_6 + foliar spray of TV @ 2 g/l of water (T_{14}); T_7 + foliar spray of TV @ 2 g/l of water (T_{15}); T_8 + foliar spray of ASP @ 2 g/l of water (T_{16}); T_9 + foliar spray of PB @ 2 g/l of water (T_{17}).

Result: Seed bio primed with *pseudomonas fluorescens* @ 75% (T_4) was found very effective in both *Kharif* season (2023 and 2024), which enhance the plant height, no. of branches/plant, no. of pods/plant, seed yield and its attributes. The seed yield/plant for this treatment was 4.46 gm and 4.03 gm respectively followed by seed biopriming with *pseudomonas fluorescens* @50% + foliar application of *pseudomonas fluorescens* @ 2 g/l of water (T_{10}) on 30 and 45 DAS in both *kharif* season as compared to non-primed seed 1.73 gm and 1.99 gm respectively.

Key words: Biocontrol agents, Biopriming, Liquid biofertilizers, Moong bean, Seed yield.

INTRODUCTION

Vigna radiata, commonly known as green gram or mung bean (moong) in India, is a member of the legume family. India leads the world in green gram production, with cultivation occurring in nearly all states. During the 2021-22 periods, green gram was cultivated on approximately 40.38 lakh hectares, yielding a total production of 31.5 lakh tonnes. The crop's productivity stood at 783 kg/ha, accounting for 11% of India's total pulse production. In *Kharif* 2022-23, green gram production was 17.5 lakh tonnes, (1st advance estimates) in an area of 33.37 lakh hectares. According to Government of India, 1st advance estimates during 2022-23, green gram was grown in 0.08 lakh hectares with a production of 0.04 lakh tonnes and productivity was 493 kg/ha. Green gram is an excellent source of high-quality protein (25%) having high digestibility. It is consumed as whole grains as well as "Dal" in a variety of ways in our food. Green grammes are grown largely for their seeds, which occur in three colours: green, black and yellow. The seeds are consumed in a variety of forms, including whole beans, split beans (dal) and flour. Mature mung bean seeds are cooked or milled. Green gram also produces sprouts, which are often used in salads and stir-fries. Green gram is occasionally planted expressly for hay, green manure, or cover crops. Green manure enriches the soil with nitrogen during fallow seasons, minimising the demand for chemical fertilisers. The plant uses less water and has a shorter

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How to cite this article: Kumari, A., Vimal, S.C, Prasad, S., Yadav, S.K. and Kumar, A. (2026). Effects of Seed Treatment and Foliar Application by using Biological Control Agents and Liquid Organic Fertilizers on Development and Yield on Moong Bean (*Vigna radiata* L.). *Agricultural Science Digest.* **46(2):** 319-324. doi: 10.18805/ag.D-6366.

Submitted: 07-05-2025 **Accepted:** 04-07-2025 **Online:** 14-07-2025

development cycle, making it ideal for areas with scarce water or short growing seasons. This helps to promote biodiversity and sustainable farming techniques. As a short-duration crop, it may be used in a variety of cropping systems, including as an intercrop with many commercial crops. Seed priming is a novel and promising approach for enhancing seed germination, seedling emergence and plant plantations in order to attain self-sufficiency in grain, legume and oilseed production under stress conditions. Bio-priming is an ecological strategy that combines biological features like seed inoculation with beneficial organisms to protect the seed and manage infections, as well as physiological aspects like seed hydration.

MATERIALS AND METHODS

The experiment material consists of two variety NDM-1 and Sikha of mung bean in a randomised block design with 03 replication for consecuting 02 Seasons *(Kharif)* 2023 and 2024 for 2 years at Student institutional farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, U.P. Concept of seed biopriming of (Taylor and Harmon, 1990) was adopted and seed biopriming was done in green gram are as follow:

Various concentrations of biocontrol agents and liquid biofertilizers were suspended in one litre of sterilised distilled water.

- 1 kilogramme seed was suspended in the aforesaid solution and soaked for 6 hours.
- After soaking, the seeds were spread on blotter paper to dry.
- The seeds were sown immediately to verify their effectiveness in the field.
- The control group consisted of hydrated seeds without anytreatment.
- Treatment includes *Pseudomonas fluorescens*, *Trichoderma viridae,* liquid *Phosphobacteria* and liquid *Azospirillum*, seeds with hydration priming and absolute control.

The bio primed seeds were sown with a spacing 30 × 10 cm. A recommended package of actions, including plant protection measures, was provided for growing a healthy crop. The foliar spraying was carried out according to the treatment plan on 30 and 45 DAS, using a backpack sprayer in the early morning.

Observations taken

At maturity, except for days to 50% flowering and days to maturity, which were recorded on a plot basis, five plants were randomly selected and tagged in each replication and treatment to record growth metrics. The observations were based on eleven quantitative characteristics: Days to 50% flowering, days to maturity, plant height, number of branches/plant, number of pods/plant, number of seeds/pod, number of clusters/plant, seed yield/plant, biological yield, test weight and harvest index. The data were examined using analysis of variance, as described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Days to 50% flowering and days to maturity

The days to 50% flowering observed at those days when approx. 50% flowering occur in this plot same as days to maturity observed when approx. 50% pods become mature. Both showed a significant difference due to seed biopriming treatment. Minimum flowering period was observed in T_4 (35.50) followed by T_3 (35.83) and T_2 (36.17) as compared to control (T_0) *i.e.*, (42.17), same as minimum maturity period was observed in T_4 (55.50) followed by T_3 (55.83) and T_2 (56.17) as compared to control (62.17) (Table 1). Kumar *et al.* (2016) determined the number of days to 50% flowering, days to maturity, plant height (cm), number of effective tillers per plant, length of spike (cm), number of spikelet's per spike, number of grain per spike, 1000 grain yield per plant (g), length of seed (mm), breath of seed (mm), seed germination (%), root length (cm), shoot length (cm) and vigour index. The 1000-seed weight, seed germination, shoot length, vigour index and grain yield per plant were all deemed significant at 5% probability.

Plant height (cm)

The differences in plant height among the treatments were highly significant. After maturity plant height was recorded the tallest plant was produced by seeds bio primed with PF @75 % (46.71 cm) followed by seeds bio primed with PF 50% + foliar spray of PF @ 2 g/l of water on 30 and 45 DAS (44.02 cm). Whereas non-primed seeds produced shorter plant with a height of 38.40 cm (Table 1). Hanaa and Safaa (2019) found that the highest plant height (92.36 cm), chlorophyll content (51.04) SPAD, spike length (14.25 cm), number of spikes/m^2 (365.3), 1000-grain weight (36.50g) and grain yield (6.61 t/ha^{-1}) were all generated by IAA at a concentration of 100 ppm.

No. of branches/plant

Regarding number of branches/plant, there was a significant difference due to treatments. Maximum number of branches/plant was observed in seeds bio primed with PF @75% (6.05) followed by seed bio primed with liquid Azospirrilum @20% (5.82). whereas non-primed seeds produced lower number of branches (3.12) (Table 2). Tamalla *et al.* (2014) examined the impact of *Trichoderma virens* and *Piriformospora indica* seed biopriming on the morphological, physiological and growth characteristics of mung beans (*Vigna radiata* L.).

Number of pods/plant

The treatment effect was significant on number of pods/plant. Highest number of pods per plant was recorded in seeds primed with PF@75% (18.18) followed by seeds bio primed with TV @50% (15.96). Whereas lowest number of pods per plant was recorded in non-primed seeds (7.57) (Table 2). Sarvjeet *et al.* (2018) standardize the biofertilizer doses with the selection of rhizobium strain for exploitation of its natural symbiosis with chickpea for effective nodulation,

Table 1: Effect of variety and treatment on following parameters.

Treatments	Days to 50% flowering			Days to maturity			Plant height (cm)		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
Variety									
V_1	36.93	38.93	37.93	56.93	58.93	57.93	44.72	43.94	44.33
V_2	37.93	39.93	38.93	57.93	59.93	58.93	41.15	41.94	41.55
S.Em. ±	0.156	0.157	0.155	0.155	0.157	0.154	0.33	0.322	0.236
CD at 5%	0.441	0.443	0.437	0.439	0.445	0.436	0.933	0.91	0.668
Treatment									
T_0	41.17	43.17	42.17	61.17	63.17	62.17	38.7	38.1	38.4
T_1	36.17	38.17	37.17	56.17	58.17	57.17	42.28	44.37	43.33
T_2	35.17	37.17	36.17	55.17	57.17	56.17	42.95	44.23	43.59
T_3	34.83	36.83	35.83	54.83	56.83	55.83	41.5	44.1	42.8
T_4	34.5	36.5	35.5	54.5	56.5	55.5	45.9	47.53	46.71
T_5	37.5	39.5	38.5	57.5	59.5	58.5	41.47	43.83	42.65
T_6	35.83	37.83	36.83	55.83	57.83	56.83	43.13	42.13	42.63
T_7	37.83	39.83	38.83	57.83	59.83	58.83	43.07	42.17	42.62
T_8	38.17	40.17	39.17	58.17	60.17	59.17	42.73	40.5	41.62
T_9	35.5	37.5	36.5	55.5	57.5	56.5	44.27	43.87	44.07
T_{10}	36.83	38.83	37.83	56.83	58.83	57.83	42.93	44.82	43.88
T_{11}	36.5	38.5	37.5	56.5	58.5	57.5	44.57	43.47	44.02
T_{12}	38.5	40.5	39.5	58.5	60.5	59.5	44.9	42.87	43.88
T_{13}	37.17	39.17	38.17	57.17	59.17	58.17	41.93	42.57	42.25
T_{14}	39.17	41.17	40.17	59.17	61.17	60.17	41.77	42.37	42.07
T_{15}	38.83	40.83	39.83	58.83	60.83	59.83	44.33	41.73	43.03
T_{16}	39.5	41.5	40.5	59.5	61.5	60.5	44.87	42.6	43.73
T_{17}	40.5	42.5	41.5	60.5	62.5	61.5	41.53	41.67	41.6
S.Em. ±	0.468	0.47	0.464	0.466	0.472	0.463	0.99	0.965	0.709
CD at 5%	1.324	1.328	1.312	1.317	1.336	1.309	2.8	2.729	2.005

maximum grain yield in chickpea. Maximum no. of pod per plant (75.38) and seed yield (Kg/ha) (2170.08) was recorded in inoculation with biofertilizer (Rhizobium).

Number of seeds/pod

The number of seeds/pod was significantly influenced by treatments. The highest number of seeds per pod was observed in seeds bio primed with PF @ 75% (7.73) followed by seed bio primed with PF @25% + foliar spray of PF 2 g/l of water (7.35). Whereas lowest number of seeds/pod was observed in non-primed seeds (5.30) (Table 2). Kumari *et al*. (2022) Interactive Effect of potential biocontrol agents and organic amendments on lentil wilt pathogen incited by *Fusarium oxysporum* f. sp. lentils and its management. *In vitro* bio efficacy of different antagonists and organic amendments on mycelial growth of *Fusarium oxysporum* f. sp. lentils by using seven *Trichoderma* spp. This combination enhances percent germination (96.67), phenological and biomass parameters like plant height (47.23 cm), pods/plant (60.42), seeds/plant and yield of seed/plant (4.45 g), fresh and dry weight of shoot and root (33.98, 2.89 and 6.97, 0.79 g) and reduces the disease incidence (14.88%).

Number of clusters/plant

Significant difference was noticed among treatments for number of clusters/plant. Seeds bio primed with PF @75% recorded a greater number of cluster/plant (4.32), followed by seeds bio primed with ASP @ 20% (4.08). Whereas lowest recorded in non-primed seed (1.82) (Table 2).

Seed yield/plant (gm)

Seed yield/plant showed a significant difference due to treatments. Highest seed yield/plant was recorded in seeds bio primed with PF @ 75% (4.24 gm) followed by seeds bio primed with PF @25% + foliar spray of PF 2 g/l of water (3.67). Whereas non-primed seeds recorded lower number of seed yield/plant (1.86 gm) (Table 3). Similarly, Raja *et al*. (2018) conducted to produce potential seedlings and sustained seed yield of black gram under rice fallow cultivation, Results of the both experiments revealed the superiority of 40% liquid Pseudomonas soaking for 3 hrs. + Polymer @ 3 g kg^{-1} over other treatments. Among the sowing methods, seeds sown at 7 days before paddy harvest (S_1) were recorded significantly maximum seed yield per plant (14.1 g), per plot (1.57 kg) and per hectare (523 kg).

Table 2: Effect of variety and treatment on following parameters.

Treatments	No. of branches/plant			No. of pods/plant			No. of seeds/pod			No. of cluster/plant		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
Variety												
V_1	5.51	5.31	5.41	15.71	15.13	15.42	7.73	6.67	7.20	3.82	3.71	3.77
V_2	4.71	4.87	4.79	13.71	14.11	13.91	6.74	5.82	6.28	3.29	3.44	3.37
S.Em. ±	0.075	0.073	0.048	0.161	0.122	0.087	0.078	0.074	0.064	0.059	0.056	0.044
CD at 5%	0.212	0.205	0.135	0.456	0.345	0.247	0.22	0.209	0.181	0.167	0.16	0.124
Treatment												
T_0	2.70	3.53	3.12	6.53	8.60	7.57	5.83	4.77	5.30	1.50	2.13	1.82
T_1	3.63	5.20	4.42	11.53	14.42	12.98	6.7	5.77	6.23	2.40	3.57	2.98
T_2	4.43	4.90	4.67	13.07	13.43	13.25	7.67	6.47	7.07	3.10	3.27	3.18
T_3	5.07	5.03	5.05	14.8	13.73	14.27	6.97	6.20	6.58	3.43	3.27	3.35
T_4	6.27	5.83	6.05	18.70	17.67	18.18	8.23	7.23	7.73	4.37	4.27	4.32
T_5	5.40	4.80	5.10	15.27	14.87	15.07	7.13	6.10	6.62	3.60	3.40	3.50
T_6	5.70	5.50	5.60	16.50	15.42	15.96	7.30	6.77	7.03	3.87	3.90	3.88
T_7	5.30	5.33	5.32	14.80	15.03	14.92	6.50	5.70	6.10	3.63	3.67	3.65
T_8	6.17	5.47	5.82	14.43	16.53	15.48	7.00	5.97	6.48	4.17	4.00	4.08
T_9	5.40	5.07	5.23	15.77	15.13	15.45	7.60	6.43	7.02	4.00	3.57	3.78
T_{10}	6.03	4.97	5.5	16.67	14.4	15.53	8.10	6.60	7.35	4.03	3.70	3.87
T_{11}	5.23	5.27	5.25	16.07	15.33	15.7	7.80	6.67	7.23	3.93	3.93	3.93
T_{12}	4.53	5.17	4.85	16.17	14.87	15.52	7.43	6.47	6.95	3.70	3.67	3.68
T_{13}	5.07	5.33	5.2	15.33	15.7	15.52	6.60	5.77	6.18	3.80	3.67	3.73
T_{14}	5.17	5.20	5.18	12.6	14.57	13.58	7.83	6.70	7.27	3.52	3.60	3.56
T_{15}	5.42	5.20	5.31	16.75	14.97	15.86	6.97	5.90	6.43	3.52	3.87	3.69
T_{16}	5.17	5.13	5.15	14.17	14.07	14.12	7.13	6.30	6.72	3.73	3.73	3.73
T_{17}	5.23	4.77	5.00	15.63	14.47	15.05	7.50	6.60	7.05	3.73	3.17	3.45
S.Em. ±	0.225	0.218	0.143	0.484	0.366	0.262	0.234	0.222	0.192	0.178	0.169	0.131
CD at 5%	0.635	0.615	0.404	1.367	1.035	0.74	0.661	0.627	0.543	0.502	0.479	0.371

Table 3: Effect of variety and treatment on following parameters.

Treatments	Seed yield/plant (gm)			Biological yield (gm)			Harvest index (%)			Test weight (gm)		
	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled	Year 1	Year 2	Pooled
Variety												
V_1	3.86	3.28	3.57	16.52	13.69	15.1	23.3	23.93	23.61	3.68	3.51	3.6
V_2	3.16	3.06	3.11	15.37	12.5	13.93	20.51	24.51	22.51	3.44	3.31	3.38
S.Em. ±	0.041	0.028	0.026	0.074	0.069	0.058	0.277	0.239	0.2	0.035	0.033	0.034
CD at 5%	0.117	0.08	0.074	0.21	0.195	0.165	0.784	0.684	0.565	0.1	0.094	0.096
Treatment												
T_0	1.73	1.99	1.86	13.96	12.47	13.22	12.43	15.92	14.18	3.12	2.92	3.02
T_1	2.98	3.12	3.05	16.17	12.59	14.38	18.51	24.88	21.69	3.77	3.61	3.69
T_2	3.29	3.05	3.17	15.92	13.69	14.81	20.6	22.34	21.47	3.51	3.42	3.47
T_3	3.51	3.06	3.29	16.26	12.72	14.49	21.52	24.22	22.87	3.67	3.53	3.6
T_4	4.46	4.03	4.24	17.08	14.37	15.73	26.08	28.06	27.07	3.86	3.77	3.82
T_5	3.52	3.09	3.3	16.16	12.79	14.48	21.75	24.2	22.97	3.46	3.29	3.38
T_6	3.45	3.28	3.37	16.54	13.01	14.78	20.86	25.24	23.05	3.45	3.29	3.37
T_7	3.34	2.9	3.12	15.58	12.32	13.95	21.46	23.63	22.55	3.71	3.53	3.62
T_8	3.91	3.28	3.59	16.04	14.11	15.08	24.35	23.31	23.83	3.44	3.29	3.37
T_9	3.84	3.36	3.6	16.41	13.48	14.94	23.41	24.93	24.17	3.67	3.48	3.58
T_{10}	4.01	3.33	3.67	16.68	12.95	14.82	24.01	25.72	24.87	3.42	3.29	3.36
T_{11}	3.99	3.23	3.61	16.11	12.97	14.54	24.67	24.86	24.76	3.7	3.52	3.61
T_{12}	3.64	3.31	3.48	15.41	13.43	14.42	23.63	24.7	24.16	3.61	3.44	3.52
T_{13}	3.44	3.23	3.33	16.08	12.62	14.35	21.39	25.74	23.57	3.49	3.34	3.42
T_{14}	3.5	3.19	3.35	15.73	12.86	14.3	22.26	24.83	23.55	3.53	3.42	3.48
T_{15}	3.72	3.22	3.47	15.58	12.94	14.26	23.83	24.87	24.35	3.58	3.41	3.5
T_{16}	3.31	3.14	3.23	15.49	12.95	14.22	21.35	24.36	22.85	3.54	3.32	3.43
T_{17}	3.49	3.26	3.37	15.72	13.49	14.6	22.16	24.16	23.16	3.62	3.45	3.54
S.Em. ±	0.124	0.085	0.078	0.223	0.207	0.175	0.832	0.716	0.6	0.106	0.1	0.102
CD at 5%	0.35	0.239	0.221	0.631	0.584	0.494	2.353	2.024	1.695	0.3	0.283	0.287

Test weight (gm)

Regarding test weight (100 seed weight), significant difference was noticed due to treatments. Seeds bio primed with PF@75% showed maximum weight (3.82 gm) followed by seeds bio primed with TV@75% (3.62) whereas minimum weight observed in non-primed seeds (3.02) (Table 3). Safeer *et al.* (2017) experiment was reported that application of thiourea significantly improved yield contributing traits like number of productive tillers, number of grains per spike, 1000-grain weight and grain yield by 10.32%, 13.1%, 23% and 17%, respectively as compared to control.

Biological yield (gm)

Biological yield was significantly influenced by treatments. Maximum biological yield showed by seeds bio primed with PF @ 75% (15.73), followed by seeds bio primed with ASP @20% (15.08) whereas minimum biological yield recorded in non-primed seeds (13.22) (Table 3). Negi *et al.* (2021) studied the effect of seed biopriming with different bioagents including plant growth promoting rhizobacteria (PGPR-1), rhizobial biofertilizer (Rhizobium strain B1) and biological control agent (*Trichoderma viride*) was observed on plant growth, seed yield and incidence of diseases in french bean.

Harvest index (%)

Significant difference was observed among treatments for harvest index. Harvest index percentage was highest observed in seeds bio primed with PF @75% (27.07), followed by seeds bio primed with PF @25% + foliar spray of PF 2 g/l of water (24.87). Whereas lowest percentage showed by non-primed seeds (14.18) (Table 3). Similarly, Khangarot *et al.* (2022) studied the effect of PROM and microbial inoculants on the growth and yield of mungbean. The results showed that combined application of PROM+PSB+VAM+PF reported the maximum values of most of the growth and yield attributing characters *i.e.* plant height, number of branches/plant, dry matter accumulation, total and effective number of root nodules per plant, fresh and dry weight of nodules per plant, crop growth rate, chlorophyll content, number of pods/plant, number of seeds/pod, test weight, seed, straw and biological yield of mungbean as compared to other combinations and control.

CONCLUSION

Two-year field experiment clearly suggests that usefulness of seed biopriming in moong bean by *Pseudomonas fluorescens*, *Trichoderma viridae, Azospirilum* and *Phosphobacter* for growth and productivity of moong bean. This will improve plant health and give healthy produce. The productivity of moong bean could be increased due to seeds bio primed with *Pseudomonas fluorescens* @75% through improved growth and yield attributing parameters when compared to nonprime seeds.

ACKNOWLEDGEMENT

The authors thank the authorities of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, U.P. India for providing all the facilities to conduct this investigation.

Conflict of interest

All authors declare that they have no conflict of interest.

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