~~Bio-consortia: a potential ecofriendly weapon to enhance the productivity of the green gram~~

or

Bio-consortia: a potential ecofriendly bio-based product to enhance the productivity of the green gram

Abstract

The present investigations on the studies to see the effect of seed biopriming with bacterial consortia in green gram were conducted in a field experiment employing randomized block design with nine treatments and three replications during kharif season 2022-2023 at the Post Graduate Institute, research farm of the Department of Plant Pathology and Agricultural Microbiology, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra. The result revealed that, among the treatment, T4 recorded the highest average plant height (65.66 cm) and average number of leaves (22.79 plant-1), average number of branches (5.23), average number of pods (30.93), average grain yield (9.18 q ha-1), average stalk yield (24.25 q ha-1) and 1000 seed weight i.e. test weight (33.78 g).

Keywords: *Vigna radiata*, potential bacteria, *Rhizobium*, PSB, KMB, growth and yield—write PSB and KMB full forms in parenthesis.

INTRODUCTION

Pulses are important not only due to their values as human food, but also because of high protein content for livestock. Grain, legumes (pulses) are important dietary sources of protein and are also recognised as the poor man's meat and rich man's vegetable. The year 2016, was declared as an "International Year of Pulses" (IYP) by the Food and Agriculture Organization of the United Nations which offers an opportunity to focus global attention on this important group of crops, the role they play in human and animal nutrition, their current and potential productivity and their contribution to sustainable agriculture. Pulses like green gram (mung), chickpea (chana), pea, pigeon pea, lentils, black gram, rajma etc. are some of the widely grown and consumed pulses in India. India is the largest producer as well as the consumer of pulses in the world accounting for about 29 per cent of world area and 19 per cent of the world production [1]. It is grown in about 4.5 million hectares with the total production of 2.5 million tonnes with a productivity of 549 kg/ha and contributing 10 per cent to the total pulse production. Green gram (*Vigna radiata* L Wilczek), commonly known as mung bean, golden gram, mung or moong is an ancient and well-known leguminous crop of Asia. According to Vavilov classification of canters of origin, green gram originated in the Central and Asiatic canter. As the exact progenitor of green gram is not known, the species *Vigna radiata var sublobata* acts as the

closest relative, which occurs in wild form in India and Indonesia and has been considered as the progenitor of green gram. Seeds of mungbean consists of approximately 25.0 to 28.0 per cent protein, 1.0 to 1.5 per cent oil, 3.5 to 4.5 per cent fiber, 4.5 to 5.5 percent ash and 62.0 to 65.0 per cent carbohydrates on a dry weight basis [2,3].

To meet the increasing demands of dietary protein on account of increasing population of our country, the productivity of grains and legumes in general and green gram in particular needs have to be enhanced in order to bridge the deficits. In the 21st century, many established strategies have been adopted to enhance the crop productivity which include use of chemical fertilizers, manures and pesticides. However, these strategies frequently have a negative impact on the environment include nitrate leakage into the groundwater, phosphorus and nitrogen losses from surface runoff and eutrophication of aquatic ecosystems. The growing need to conserve the environment has prompted significant attempts to reduce the usage of chemical fertilizers and pesticides [4]. These traditional techniques are being integrated with more eco-friendly methods by using beneficial microorganisms [5,6,7,8,9].

Legume plant have a unique ability in establishing symbiotic relationship with nitrogen fixing bacteria of the family Leguminoceae. Rhizobia have ability to develop nodules on their host plants inside of which they fix nitrogen [10]. Phosphorus is one of the major essential nutrients for plant growth. In soil phosphorus is immobilized and become less soluble through chemical precipitation or absorption. Only a little amount of 'P' is available for uptake by plants. The foremost mechanism of mineral phosphate solubilization by microorganism is the production of organic acids and acid phosphatases which mineralize and mobilize phosphorus in the soil. Potassium, the third major essential nutrient for plant growth, plays a major role for enzyme activation, protein synthesis and photosynthesis. Certain microorganisms in the soil have ability to solubilize unavailable forms of potash bearing minerals such as micas, elite and orthoclase, by releasing organic acids that either directly dissolves rock phosphate or chelating silicon ions to bring the potash into solution [11, 12]. It is well known that, phosphate solubilizing bacteria (PSB) and *Rhizobium* have synergistic effect on legume crops [13]. It has been attempted to develop consortia with one strain of *Rhizobium,* PSB and PGPR [14], whereas potash mobilizing bacteria increased 'K' availability in soils and increased mineral uptake by plants [15].

Biofertilizers maintain the soil environment rich in all kinds of micro and macro nutrients *viz*., Nitrogen fixation, Phosphate solubilization, Potash mobilization and release of plant growth regulating (PGPR) substances [10]. Shete *et al*. 2019 [16] formulated MS III culture medium to support the growth of nitrogen fixing, phosphate solubilizing and potash mobilizing bacteria in a consortium. Application of PGPR to seed through seed bio-priming enhances plant performance under stress environments and consequently enhances plant yield both directly and indirectly [17]. Many studies have been documented the beneficial effects of certain rhizobial strains in improving growth of legumes as well as non-legumes. Inoculation of *Rhizobium* in consortium with free-living rhizospheric bacteria has also given excellent results in enhancing crop growth and productivity [18, 19]. These PGPRs can be used effectively to meet the nutrient - deficient conditions and their use can be favourable to reduce the use of chemical fertilizers and support of environment friendly crop

productivity [20]. As defined by Mc Donald, seed priming is soaking the seeds in any solution containing our required priming agent followed by re-drying the seeds which initiates germination process apart from radical emergence. The seed bio-priming is recently adopted method of seed priming. Bio-priming is potentially able to promote quick and even germination as well as better plant growth [21]. In case of efficacy and survival of biological agents, priming has been shown to be beneficial and exported to improve the plant growth and yield [22, 23]. Seed biopriming with plant growth promoting rhizobacteria (PGPR) results in improved seedling establishment and germination [24].

Seed bio-priming is an eco-friendly procedure and is also a substitute to chemical pesticides. Even though there are different types of priming approaches being adopted in the crops, seed bio-priming with microbial consortia could be a holistic approach in achieving the benefits of their application by obtaining high yield in low input conditions. Visualizing the benefits of consortium of microbial inoculants over single microbial inoculants, the present study was conducted with studies on seed biopriming with Bacterial consortia in green gram.

2. Material and Methods

2.1 Field experiment on Studies on seed biopriming with Bacterial consortiaa in green gram

A field experiment was conducted during *kharif* 2022-2023 to study the effect of seed biopriming with Bacterial consortia in green gram. The methodology followed for conducting the field experiment is described as under. Design: Randomised Block Design, Replications: Three, Plot size: Gross: 2.40 × 2.0 m (8 Rows 30 cm apart), Net: 1.80 × 1.60 m (8 Rows), Spacing: 30 × 10 cm, Variety: Phule Chetak, Treatments: Nine, Date of Sowing: 20th June., 2022, Location: PG Research Farm of Dept. of Plant Pathology and Agril. Microbiology, MPKV, Rahuri. The details of the treatments as follows.

T_1: Only seed biopriming (No soil application of RDF of N, P_2O_5 and K_2O ha^{-1}.

T_2: Seed biopriming with *Rhizobium,* PSB and KMB + 50 % RDF of N, P_2O_5 and K_2O ha^{-1}

T_3: Seed biopriming with *Rhizobium,* PSB and KMB +75 % RDF of N, P_2O_5 and K_2O ha^{-1}

T_4: Seed biopriming with *Rhizobium,* PSB and KMB + 100 % RDF of N, P_2O_5 and K_2O ha^{-1}

T_5: Seed biopriming with MPKV's reference strain of *Rhizobium*, PSB and KMB+ 50 % RDF of N, P_2O_5 and K_2O ha^{-1}.

T_6: Seed biopriming with MPKV's reference strain of *Rhizobium*, PSB and KMB + 75 % RDF of N, P_2O_5 and K_2O ha^{-1}.

T_7: Seed biopriming with MPKV's reference strain of *Rhizobium*, PSB and KMB + 100% RDF of N, P_2O_5 and K_2O ha^{-1}.

T_8: Only seed biopriming with MPKV's reference strain of *Rhizobium*, PSB and KMB (No soil application of RDF of N, P_2O_5 and K_2O).

T_9: Absolute control

Note: FYM was applied @2.5 MT ha^{-1} to all plots 15 days prior to sowing on area basis (3 kg plot ^{1}).

The soil in each plot was mixed with urea, single superphosphate and murate of potash to supply N, P_2O_5 and K_2O calculated on area basis as per the treatments taking into account the

recommended dose of green gram as 25:50:25 kg N, P_2O_5 and K_2O ha^{-1} recommended by the Mahatma Phule Krishi Vidyapeeth, Rahuri.

2.1.1 Seed inoculation

Seed biopriming with bacterial consortia was carried out by soaking the seed of green gram variety *Phule Chetak* (obtained from Oil Seed Research Station, Jalgaon) 8 hrs in spore/cell suspension prepared of by mixing liquid cultures of *Rhizobium, Bacillus* and *P. fluorescens* @ 25 ml each lit^{-1} water kg^{-1} seed. In case of T_9 i.e., absolute control, the seed was not bio primed with liquid cultures of *Rhizobium,* PSB and KMB before sowing while no any application of RDF of N, P_2O_5 and K_2O ha^{-1} was given.

2.1.2 Sowing

Sowing was done 20th June, 2022 by dibbling bio primed two seeds at each hill at recommended spacing 30 cm × 10 cm.

2.1.3 Irrigation and aftercare

The experimental area was lightly irrigated prior to sowing to set the soil in the plots so as to ensure good seed germination after sowing. Dibbling was carried out on 20/06/2022 after the soil attained *wafsa* (please write technical term either optimum moisture or other word which readers can understand) condition. The plots were lightly irrigated after sowing. Thereafter, the plots were irrigated at 25-30 DAS and at 45-50 DAS with equal quantity of water for each plot. The interval, however, varied depending on the moisture level of the soil. After 20 days of dibbling, only one vigorous seedling was maintained at each hill by thinning. The weeds were removed by hand weeding.

2.1.4 Intercultural operations

After 20 days, only one vigorous seedling was maintained at each hill by thinning**.** Two hand weeding and one hoeing were given during the growing period of green gram for control of weeds and aeration in the soil.

2.1.5 Plant protection

For preventing green gram from attack of pod borers, Phosalone 0.07 % SL was sprayed @ 625 ml per 10 litre water three times at an interval of 15 days starting from 15 days after sowing and the crop was kept pest - disease free till the harvest.

2.1.6 Harvesting

Manual harvesting was carried out at physiological maturity of crop with the help of labour. Threshing was carried out as per treatment and seeds were separated by winnowing. The clean seeds were weighed separately and final yield, was recorded in kg $plot^{-1}$.

2.2 Biometrical Observations

2.2.1 Sampling technique

Five plants from each net plot were randomly selected and labelled for taking biometric observations at different growth stages. The same five plants were harvested separately for post-harvest studies. The schedules of biometric observations on various parameters recorded during the present investigation.

2.2.2 Plant sampling

Five representative plants from each plot were randomly selected, uprooted, labelled and were stored in paper bag for taking biometric observations.

2.2.3 Germination

The germination counts i.e. number of hills germinated out of total number of hills was recorded at 20 days after sowing and before thinning. The number of hills germinated out of total number of hills was expressed as germination percentage and then after single plant/hill was maintained as mentioned earlier.

2.2.4 Shoot length at 20 DAS

The shoot length of 5 randomly selected plants in each plot was measured with a scale at 20 DAS and the average of 5 plants was calculated and expressed as shoot length at 20 DAS.

2.2.5 Root length at 20 DAS

The 5 randomly selected plants as above in each plot were uprooted at 20 DAS and the root length was measured with a scale and the average of 5 plants was calculated and expressed as root length at 20 DAS.

2.2.6 Plant height at flowering stage

The plant height of 5 randomly selected plants in each plot was measured with a scale at flowering stage of green gram crop and the average of 5 plants were calculated and expressed as plant height at flowering stage.

2.2.7 Number of branches plant^{-1}

Total numbers of branches plant^{-1} were counted at each various growth stages of green gram crop and average value was recorded.

2.2.8 Number of Leaves plant^{-1}

Total number of leaves per branches were counted at flowering stage of green gram crop and average value was recorded.

2.2.9 Number of pods plant^{-1}

Number of pods from each plant were counted and average value was recorded as no. of pods plant^{-1}.

2.2.10 Harvesting

The green gram pods from the plants in the net plot area were harvested when 85 per cent of the pods were fully matured.

2.2.11 Grain yield

The green gram pods after harvesting were dried for 2-3 days in sunlight and the colour changed from green to brownish black. The produce was cleaned, stored in gunny bags and kept off the floor and away from the wall in order to avoid pest attack. The grain yield per plot was recorded which was later converted to grain yield per hectare.

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield (kg plot}^{-1}\text{)}}{\text{Net plot area (m}^2\text{)}} \times 10{,}000$$

2.2.12 Test weight (1000 seed weight)

The test weight i.e. weight of 1000 seeds (g) was recorded after threshing, cleaning and drying of the produce for 2-3 days to reduce the seed moisture content to 8-10 per cent. For this, 1000 seeds from each treatment were randomly selected and the weight was recorded on electronic balance.

3. Result and discussion

3.1 Germination, shoot length and root length

Seed germination, average shoot and average root length were significantly influenced by different seed biopriming treatments with *Rhizobium,* PSB and KMB applied along with different fertilizer doses. The treatment, T_4 of seed biopriming with *Rhizobium*, PSB & KMB with 100 % RDF i.e. (25:50:25 kg N, P_2O_5, K_2O ha^{-1}) recorded the maximum germination of 97.48 per cent and was at par with T_3 of seed biopriming with *Rhizobium*, PSB &KMB with 75 % RDF. The treatment T_9, i.e. Absolute control, on the other hand, recorded the least germination (80.89 %). As regards the shoot length (Table 1), all treatments were significantly superior to the treatment T_9, (i.e. Absolute control) which recorded the lowest average shoot length (20.98 cm). The treatment, T_4 i.e. Seed biopriming with *Rhizobium,* PSB and KMB with 100% RDF) recorded more average shoot length upto 28.82 cm.

The next treatments in the decreasing order of average shoot length were T_3 (Seed biopriming with *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O (27.59 cm), followed by T_2 (Seed biopriming with *Rhizobium,* PSB and KMB with 50 % RDF of N, P_2O_5 and K_2O (26.18 cm). T_7 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with 100% N, P_2O_5 and K_2O ha^{-1} (25.01 cm), T_6 (Seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with 75 % N, P_2O_5 and K_2O ha^{-1} (24.16 cm). T_5 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB with 50 % RDF of N, P_2O_5 and K_2O ha^{-1} (23.81 cm). T_1 only seed biopriming with *Rhizobium*, PSB and KMB with no soil application of RDF of N, P_2O_5 and K_2O ha^{-1} (23.53 cm) and T_8 i.e. Only seed biopriming with MPKV's reference strain of *Rhizobium,* PSB and KMB with no soil application of RDF of N, P_2O_5 and K_2O ha^{-1} (23.16 cm). The data on average root length presented in Table 1 showed significant differences. The treatment, T_4 (Seed biopriming with *Rhizobium,* PSB and KMB with 100% RDF) recorded the highest average root length of 14.06 cm. However, it was at par with T_3 (13.70 cm). The absolute control treatment, i.e. T_9 on the other hand, recorded the least average root length (8.11 cm).

Mahmood *et al.* 2016 [25] stated that seed priming with living bacterial inoculum is termed as biopriming that involves the application of plant growth promoting rhizobacteria to seeds. It increases speed and uniformity of germination; also ensures rapid, uniform and high establishment of crops; and hence improves harvest quality and yield. Seed biopriming allows the bacteria to adhere the seeds and also acclimatization of bacteria in the prevalent conditions. They concluded that biopriming is a promising technique for application of helpful microbes to the seeds. The improvement in seed germination, seedling growth and a good field stand may be attributed to the growth promoting substances produced by the biofertilizers in addition to the enhanced nutrient availability. Vishwas *et al*. 2017 [26] while evaluating seed bio-priming with *Rhizobium* + *Pseudomonas* @ 10 % for 12 hrs recorded significantly higher germination (87 %), speed of germination (77.11), shoot length (20.33 cm), root length (16.14 cm), seedling length (24.91 cm), seedling dry weight (150.4 mg), seedling

fresh weight (1200.3 mg), seedling vigour index-I (2225.37) and seedling vigour index II (11766.67) as compared to control and thus was followed by *Rhizobium* alone @ 10 % for 12hrs. The results obtained in the present investigation are also in agreement with earlier findings.

3.2 Average plant height and average number of leaves

As regards the average plant height (Table 1), all treatments were significantly superior to the treatment T_9, i.e. Absolute control which recorded the least average plant height (45.10cm). The treatment, T_4 (Seed biopriming with *Rhizobium,* PSB and KMB with 100% RDF) recorded the highest average plant height of 65.66 cm. The treatments following in the decreasing order of plant height were T_3 i.e. Seed biopriming with *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O (63.15 cm), T_2 i.e. Seed biopriming with *Rhizobium*, PSB and KMB with 50 % N, P_2O_5 and K_2O ha^{-1} (59.99 cm), T_7 i.e. Seed biopriming with MPKV's reference strain of *Rhizobium,* PSB and KMB with 100% N, P_2O_5 and K_2O ha^{-1} (55.24 cm) and T_6 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB ha^{-1} with 75 % N, P_2O_5 and K_2O ha^{-1} (51.92 cm), T_5 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with 50 % RDF of N, P_2O_5 and K_2O ha^{-1} (50.99 cm), T_1 i.e. Only seed biopriming with *Rhizobium,* PSB and KMB with no soil application of RDF (50.86 cm). T_8 i.e. Only seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with no soil application of RDF (49.58 cm).

A similar trend was observed in case of the average number of leaves (Table 1). The treatments, T_4 (Seed biopriming with *Rhizobium*, PSB and KMB with 100% RDF) recorded the highest average number of leaves (22.79) followed by T_3 i.e. Seed biopriming with *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O recorded the second highest average number of leaves (21.15 per plant). However, T_4 was at par with T_3. The next treatments in the decreasing order of number of leaves were T_2 i.e. Seed biopriming with *Rhizobium*, PSB and KMB with 50 % N, P_2O_5 and K_2O ha^{-1} (19.73 $plant^{-1}$), T_7 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with 100 % N, P_2O_5 and K_2O ha^{-1} (18.60 $plant^{-1}$) and T_6 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O ha^{-1} (18.49 $plant^{-1}$). T_5 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with 50 % RDF of N, P_2O_5 and K_2O ha^{-1} (18.20 $plant^{-1}$). T_1 only seed biopriming with *Rhizobium*, PSB and KMB with no RDF recorded (17.53) aaverage number of leaves. T_8 i.e. Only seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with no RDF recorded (15.65) average number of leaves. The absolute control treatment i.e. T_9 recorded only 13.76 leaves $plant^{-1}$. The improvement in plant growth in terms of plant height and number of leaves/plants have been reported by [27] and studied the effect of different fertilizer and bio-fertilizer levels on growth and yield of summer green gram and reported the dual inoculation seed inoculation of *Rhizobium* + PSB observed significantly the highest mean plant height (32.21 cm) followed by the alone seed inoculation of *Rhizobium* (30.57 cm) and alone seed inoculation of PSB (27.99 cm). The results obtained in present investigations are in agreement with these finding.

3.3 Average number of branches and average number of pods

The observations on average number of branches are presented in Table 3. All treatments were found significantly superior to the treatment T_9, i.e. Absolute control in which the least average

number of branches (3.05 plant^{-1}) were noticed. The treatment, T_4 (Seed biopriming with *Rhizobium*, PSB and KMB with 100% RDF) recorded highest average number of 5.23 per plant. The next treatments in the reducing order of average number of branches were T_3 i.e. Seed biopriming with *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O (5.03 plant^{-1}). T_2 i.e. Seed biopriming with *Rhizobium*, PSB with 50 % N, P_2O_5 and K_2O ha^{-1} (4.67 plant^{-1}), T_7 i.e. Seed biopriming with MPKV's reference strain of *Rhizobium,* PSB and KMB with 100 % N, P_2O_5 and K_2O (4.33 plant^{-1}) and T_6 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O ha^{-1} (3.98 plant^{-1}, T_5 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB with 50 % RDF of N, P_2O_5 and K_2O ha^{-1} (3.90 plant^{-1}), T_1 i.e. Only seed biopriming with *Rhizobium*, PSB and KMB with no RDF (3.57 plant^{-1}). T_8 i.e. Only seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with no RDF (3.33 plant^{-1}).

Table 1. Effect of seed biopriming with bacterial consortia on germination shoot length, Root length at 20 days after sowing and number of leaves, plant height, number of branches and number of pods in green gram crop

Tr. No.	Treatment details	Germination (%)	Average Shoot length (cm)	Average Root length (cm)	At Flowering stage		Average number of branches	Average number of pods
					Average number of leaves	Average plant height		
T_1	Only seed bio-priming (No soil application of RDF of NPK).	88.89 (70.52) *	23.53	9.61	17.53	50.86	3.57	17.53
T_2	Seed bio-priming with *Rhizobium*, PSB & KMB + 50 % RDF of NPK.	91.68 (73.23) *	26.18	12.58	19.73	59.99	4.67	25.80
T_3	Seed bio-priming with *Rhizobium,* PSB & KMB + 75 % RDF of NPK	93.11 (74.78) *	27.59	13.70	21.15	63.15	5.03	28.73
T_4	Seed bio-priming with *Rhizobium,* PSB & KMB + 100% RDF of NPK	97.48 (80.86) *	28.82	14.06	22.79	65.66	5.23	30.93
T_5	Seed bio-priming with MPKV's reference strain of *Rhizobium*, PSB & KMB + 50 % RDF of NPK	89.53 (71.12) *	23.81	10.73	18.20	50.99	3.90	18.20
T_6	Seed biopriming with MPKV's reference strain of *Rhizobium*, PSB & KMB + 75 % RDF of NPK	89.68 (71.26) *	24.16	11.08	18.49	51.92	3.98	21.13
T_7	Seed bio-priming with MPKV's reference strain of *Rhizobium,* PSB & KMB + 100% NPK	90.20 (71.75) *	25.01	12.21	18.60	55.24	4.33	23.40
T_8	Only seed biopriming with MPKV's reference strain of *Rhizobium*, PSB & KMB (No soil application of RDF of NPK).	85.93 (67.96) *	23.16	9.18	15.65	49.58	3.33	14.53
T_9	Absolute control	80.89 (64.07) *	20.98	8.11	13.76	45.10	3.05	13.73
	General mean	89.71	24.80	11.25	18.43	54.72	4.12	21.55
	S.Em. ±	2.58	0.73	0.44	0.65	1.59	0.13	1.00
	CD at 5%	7.74	2.20	1.26	1.97	4.78	0.39	3.00

* Figures in parentheses indicated arc sign transformed values.

A similar trend of results could be seen in case of the average number of pods shown in Table 1. The treatments, T_4 (Seed biopriming with *Rhizobium*, PSB and KMB with 100 % RDF) recorded the maximum average number of pods (30.93 plant^{-1}) followed by T_3 i.e. Seed biopriming with *Rhizobium,* PSB and KMB with 75 % N, P_2O_5 and K_2O which recorded the second highest average number of pods (28.73 plant^{-1}). The treatments following in the decreasing order of average number of pods were T_2 i.e. Seed biopriming with *Rhizobium,* PSB and KMB with 50 % N, P_2O_5 and K_2O ha^{-1} (25.80 plant^{-1}), T_7 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB + 100% N, P_2O_5 and K_2O (23.40 plant^{-1}) and T_6 i.e. Seed biopriming with MPKV's reference strains of *Rhizobium,* PSB and KMB seed with 75 % N, P_2O_5 and K_2O ha^{-1} (21.13 plant^{-1}). T_5 i.e. Seed biopriming with reference strains of *Rhizobium,* PSB and KMB with 50 % RDF of N, P_2O_5 and K_2O ha^{-1} (18.20 plant^{-1}). T_1 only seed biopriming with *Rhizobium,* PSB and KMB with no RDF recorded (17.53 plant^{-1}) average number of pods in T_8 i.e. Only seed biopriming with MPKV's reference strains of *Rhizobium*, PSB and KMB with no RDF recorded 14.53 pods plant^{-1}. The absolute control treatment i.e. T_9 recorded only 13.73 pods plant^{-1}.

Increment in the average growth and yield of green gram as influenced by bio-fertilizer and phosphorous application was reported by Singh *et al*., 2004 [28]. In their studies four bio-fertilizers and four phosphorous levels were evaluated in relation to their effect on the growth and yield of green gram. Bio-fertilizers along with increase in phosphorous level up to 60 kg P_2O_5 ha^{-1} had shown significant effect on yield of green gram, attributes to cumulative effect of growth attributes *viz*., plant height, number of branches plant^{-1}, number of trifoliate leaves, Leaf Area Index (LAI), dry matter accumulation plant^{-1}, CGR, RGR and NAR and yield attributes *viz*., pods plant^{-1}, pod length, seed pod plant^{-1}, thousand seed weight and seed yield plant^{-1}. Shete *et al*., 2021 [29] reported that in a field experiment which was conducted for three consecutive years in four different locations to evaluate the effect of consortium of *Rhizobium,* PSB and potash mobilizing bacteria on growth and yield of mungbean. Among various inoculation treatments, they noticed that seed inoculation with microbial consortium (*Rhizobium,* PSB and KMB0 along with 75 % recommended nitrogen and phosphorus was found to be the most effective in producing maximum number of nodules (73.41 plant^{-1}), number of pods (37.93 plant^{-1}), grain yield (9.16 q ha^{-1}) and thousand grain weight (38.0 g) and shown similar results with the treatment of consortium + 100 % recommended dose of nitrogen and phosphorus for all growth and yield attributing characters. Their results indicate saving of 25 percent chemical nitrogen and phosphorus fertilizer for mungbean. Present investigations are in accordance to these findings.

3.4 Yield

3.4.1 Yield attributes

The data pertaining to yield attributes *viz*., grain, straw yield and test weight are presented in Table 2. The results on yield attributes were significantly influenced by different treatments and have found significant for grain and straw yield of green gram.

3.4.2 Grain yield

The average grain yield of green gram significantly varied due to application of liquid bio-fertilizer. The data on effect of seed biopriming with bacterial consortia in grain yield of green gram are

presented in Table 2. It was observed from the results that the treatment T_4 recorded significantly higher average grain yield (9.18q ha^{-1}) over the rest of treatments and was followed by treatments T_3 (8.70 q ha^{-1}) and T_2 (8.21 q ha^{-1}). The treatments T_4 and T_3 were at par with each other. The lowest average grain yield was recorded in treatment T_9 (5.81q $ha^{-1)}$ i.e. Absolute control. Further, it was observed that the average grain yield of green gram was significantly decreased in T_2 (Seed biopriming with *Rhizobium*, PSB and KMB + 50 % RDF of NPK) by 8.21q ha^{-1}, in T_7 by 7.90 q ha^{-1}, in T_6 by 7.40 q ha^{-1}, in T_5 by 7.22q ha^{-1}, in T_1 by 6.63 q ha^{-1} and T_8 by 6.43 q ha^{-1} due to seed biopriming with bacterial consortia.

3.4.3 Straw yield

It was observed that, the data regarding effect of seed biopriming with Bacterial consortia with different treatments on average straw yield of green gram is presented in Table 2. Average straw yield is directly related with increase in vegetative growth of the plant. It was observed from the results that the treatment T_4 recorded significantly higher average stalk yield (24.25 q ha^{-1}) over the rest of treatments and it was followed by treatments T_3 (22.39 q ha^{-1}) and T_2 (22.08 q ha^{-1}). The treatments T_4 and T_3 were at par with each other. The lowest average grain yield was recorded by treatment T_9 (19.28 q ha^{-1}) i.e. absolute control. Further, it was observed that the stalk yield of green gram was significantly decreased over T_7 by 21.89 q ha^{-1}, in T_6 by 21.72 q ha^{-1}, in T_5 by 21.63 q ha^{-1}, in T_1 by 21.32 q ha^{-1} and in T_8 by 21.06 q ha^{-1} due to seed biopriming with bacterial consortia. Dhakal *et al*. 2016 [30] carried field experiment on green gram inoculation with individual *Bradyrhizobium* and PSB inoculum and they observed that inoculated seed gave significantly higher grain yield and straw yield over uninoculated treatment.

3.4.4 Test weight of seed

The data regarding thousand seed weight of green gram influenced by various bio-fertilizer treatments which is presented in Table 2. It was evident from the results that, the test weight of seed was significantly influenced due to seed biopriming with bacterial consortia. The higher test weight (g) was observed with the treatment T_4 (33.78 g) which significantly superior over rest of the treatments followed by T_3 (31.72 g) and T_2 (30.28 g). The lower test weight (g) was observed with treatment T_9 (18.38 g) i.e. Absolute control which was inferior over rest of the treatments. The treatments T_3 and T_4 were at par each other. Bahadur and Tiwari 2014 [31], observed that the test weight of the green gram which was significantly increased under liquid culture dose of biofertilizer. The current investigations are in parallel to their findings.

Table 2. Effect of seed biopriming with bacterial consortia on average grain yield, average stalk yield and thousand seed weight (test weight) in green gram

Tr. No.	Treatment details	Average grain yield (q ha^{-1})	Average straw yield (q ha^{-1})	Test weight (g)
T_1	Only seed bio-priming (No soil application of RDF of NPK).	6.63	21.32	22.62
T_2	Seed bio-priming with *Rhizobium*, PSB & KMB + 50 % RDF of NPK.	8.21	22.08	30.28
T_3	Seed bio-priming with *Rhizobium,* PSB & KMB + 75 % RDF of NPK	8.70	22.39	31.72
T_4	Seed bio-priming with *Rhizobium,* PSB & KMB + 100 % RDF of NPK	9.18	24.25	33.78

T_5	Seed bio-priming with MPKV's rreference (check spelling) strain of *Rhizobium*, PSB & KMB + 50 % RDF of NPK	7.22	21.63	24.54
T_6	Seed biopriming with MPKV's rreference strain of *Rhizobium*, PSB & KMB + 75 % RDF of NPK	7.40	21.72	25.29
T_7	Seed bio-priming with MPKV's rreference strain of *Rhizobium,* PSB & KMB + 100 % NPK	7.90	21.89	28.20
T_8	Only seed biopriming with MPKV's rreference strain of *Rhizobium*, PSB & KMB (No soil application of RDF of NPK).	6.43	21.06	20.10
T_9	Absolute control	5.81	19.28	18.38
	General mean	7.50	21.73	26.10
	S. Em. ±	0.24	0.65	1.11
	CD at 5%	0.73	1.94	3.33

Conclusion

It is concluded that, the treatment T4 showed the highest average values in various plant parameters, including plant height, number of leaves, branches, pods, grain yield, stalk yield, and 1000 seed weight. However, it was statistically comparable to Treatment T3, which exhibited slightly lower but still significant averages in all the mentioned parameters. T4 had an average plant height of 65.66 cm, 22.79 leaves per plant, 5.23 branches, and 30.93 pods. Additionally, T4 recorded the highest grain yield (9.18 q ha-1), stalk yield (24.25 q ha-1), and 1000 seed weight (33.78 g), with T3 closely following with values of 8.70 q ha-1, 22.39 q ha-1, and 31.72 g, respectively.

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