



Nitrogen Indices, Nodulation and Yield of Mung Bean (*Vigna radiate* L.) as Influenced by Integrated Nutrient Supply

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Authors' contributions

This work was carried out in collaboration among all authors. Author ST conceived the idea, wrote the protocol, performed the statistical analysis and designed the study. Author SI wrote the first draft of the manuscript, formatted the draft and choosed the journal for submission. Author ZB managed the analyses of the microbial study. Author MN searched and managed the literature to cite in the manuscript. Author BH provided the recent data pertaining to the manuscript. Author AR revised the manuscript with suggestions by reviewers. All authors read, reviewed and approved the final manuscript.

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ABSTRACT

The present study was conducted to find out the impact of inorganic nutrients (Nitrogen @ 20 kg ha⁻¹ and Phosphorus 40 kg ha⁻¹) blended with and without biofertilizers (Rhizobium and PSB) on growth and yield of mung bean. Significant increments in seed yield of 31.07% followed by 23.34% were recorded from the plots exposed to 20 kgN/ha + 40 kgP₂O₅/ha along with dual inoculation by Rizobium and PSB (T₉) and 20 kgN/ha + 40 kgP₂O₅/ha + Rizobium (T₇). Highest seed yield (13.23 q/ha) realized under T₉ supported by increased final aboveground dry matter (29.33% & 26.21%), pod percentage (26.33% & 17.45%) and test weight (17.50% & 11.13%) compared to chemical fertilizers (T₄ & T₅ respectively). Highest number of nodules (68.17) & nitrogen use efficiency (18.32

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kg/kg) were recorded at flowering (50 DAS) stage of the crop under treatment-9. Functional relation between nodulation, NUE, AAR, pods plant⁻¹ and yield were positive and linear ($R^2=0.987, 0.9987, 0.9501, 0.9115$, respectively). To ascertain the higher productivity in mung bean it is recommended that the application of phosphorus @ 40 kg ha⁻¹ with starter dosage of N @ 20 kg ha⁻¹ along with dual inoculation by *Rizobium* and PSB should be applied for higher seed yield under temperate agro-ecological conditions.

Keywords: *Rhizobium*; PSB; phosphorus; nitrogen indices; yield; mung bean.

1. INTRODUCTION

Mung bean an annual, herbaceous, self-pollinated pulse crop that is raised for grain, foodstuff, vegetable, green manure and feed stock [1]. Global area under mung bean is about 7.3 million ha having an output production of about 5.3 million tons with India and Myanmar each producing 30%, China 16%, and Indonesia 5% of the total production [2]. As a legume, the crop fixes most of its own nitrogen requirement [3,4] and contributes significantly to improving the sustainability of farming systems [5]. Mung bean also provides an important source of dietary protein for millions of people living in South and South East Asia, many of whom are also vegetarians [6]. Seeds of mung bean contain approximately 25-28% protein, 1.0-1.5% oil, 3.5-4.5% fiber, 4.5-5.5% ash and 62-65% carbohydrates on dry weight basis [7]. Its input requirement per unit area is low, and its drought tolerance permits it to face up to adverse environmental conditions, permitting its successful growth in rainfed areas [8]. Most of the Indian soils particularly the light textured ones are deficient in nitrogen which is one of the basic plant nutrients [9]. Phosphorus (P) is also an important nutrient and its deficiency is an important factor for decreasing crop growth. Only 25% to 30% of the applied P is available to crops and remaining P is converted into insoluble P [10]. Besides, P fertilization may be a crucial input for nodule development in legumes [11]. Nitrogen and phosphorus are both essential elements and playing structural, biochemical and physiological roles in crop growth [12]. N₂-fixing and Phosphate solubilizing microorganism could also be vital for plant nutrition by increasing N and P availability and uptake by the plants [13]. Phosphate solubilizing microorganism (PSB) living in each terrestrial and water system play a significant role in phosphorus nutrition to plants [14,15], that improves and maintain the fertility of farmlands [16]. Keeping in view the importance of mung bean as a pulse crop and its management in relation to chemical and biological fertilizers, this study has been carried

out to evaluate the impact of NP levels with and without biofertilizers on growth, yield and yield components of mung bean under temperate agro-ecosystem.

2. MATERIALS AND METHODS

A field experiment was conducted at Agronomy Research Farm (34.35°N; 74.40°E), Faculty of Agriculture, Wadura, Sopore- Jammu & Kashmir during Kharif 2016 and 2017 on sandy loam soil and medium in fertility (organic carbon 0.72%; 215 kg N, 20 kg P₂O₅ and 256 kg K₂O ha⁻¹) Table 1. The area receives an average rainfall of 615 mm year⁻¹ (Fig. 1). Ten treatment (Table 2) were used for their diverse impact on plant height, dry weight, nodulation potential, acetylene reduction rate (ARR), pod number, grains per pod, test weight and yield of mung bean. A basal dose of 30 kg N ha⁻¹ (urea); 60 kg P₂O₅ ha⁻¹ (DAP) and 40 kg K₂O ha⁻¹ (Murriet of potash) was applied uniformly. Crop (cultivar *Shalimar Mung bean-1*) was sown with a row to row spacing of 30 cm using 25 kg seed ha⁻¹ inoculated with *Rizobium* (*Bradyrhizobium japonicum*) and phosphate solubilizing bacteria (PSB) cultures. Observation on growth characters were measured at 25, 50 and 75 days after sowing whereas yield attributes were recorded at the time of physiological maturity. All the plants within a 6.5 m² area from each plot were hand-harvested at maturity to measure the yield. NHI (nitrogen harvest index) as the ratio of N uptake with grain to total N uptake was calculated as described by Delogu et al. [17]; NUE (nitrogen utilization efficiency), as the ratio of grain yield to total N uptake [18]; AE (agronomic efficiency), as the ratio of (grain yield at Nx– grain yield at N₀) to applied N at Nx was determined as described by Yadav [19]; RF (apparent recovery fraction), as the ratio of (total N uptake at Nx– total N uptake at N₀) to applied N at Nx; ARR was determined by the method Kjeldahl method of Bremner [20]. Data was analysed for analysis of variance (ANOVA) using theSPSS-software. Correlation coefficient was also calculated between yield and yield contributing parameters.

Table 1. Physico-chemical properties of experimental soil before the start of experiment

Soil properties	Values
pH in H ₂ O	7.06
EC (mS cm ⁻¹)	0.07
Organic carbon (%)	1.36
Total nitrogen (%)	0.18
NH ₄ -N (mg kg ⁻¹)	22.23
NO ₃ -N (mg kg ⁻¹)	26.71
Available P (mg kg ⁻¹)	11.44
Zn (mg kg ⁻¹)	0.14
B (mg kg ⁻¹)	0.83
K (cmol(+)kg ⁻¹)	1.19
Ca (cmol(+)kg ⁻¹)	21.72
Mg (cmol(+)kg ⁻¹)	13.17
Na (cmol(+)kg ⁻¹)	0.15
CEC (cmol(+)kg ⁻¹)	34.51
Clay (g kg ⁻¹)	34.0
Silt (g kg ⁻¹)	42.0
Sand (g kg ⁻¹)	18.0
Textural class (Clay Sandy loam Sandy clay loam Silty clay loam)	Silty clay
Number of indigenous rhizobia g ⁻¹ soil	1.1 × 10 ⁴

Table 2. Labels for different treatment combination of experiment

Labels	Treatments
T ₁	No fertilizer/biofertilizer [Absolute control]
T ₂	RDF [Recommended dose of fertilizers]
T ₃	20 kg N/ha applied as basal with inoculation [source Urea]
T ₄	20 kg N/ha applied as basal without inoculation [source Urea]
T ₅	40 kg P ₂ O ₅ /ha applied as basal with inoculation [source DAP]
T ₆	40 kg P ₂ O ₅ /ha] applied as basal without inoculation [source DAP]
T ₇	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rhizobium]
T ₈	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [PSB]
T ₉	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rhizobium + PSB]
T ₁₀	20 kg N/ha + 40 kg P ₂ O ₅ /ha without any inoculation

3. RESULTS AND DISCUSSION

3.1 Plant Height

Maximum increase in plant height (36.68%) over control was recorded from co-inoculation of *Rhizobium* and PSB+ NP (T₉) at 50 DAS and it was statistically similar with *Rhizobium* inoculation along with both fertilizers (T₇) (Table 3). *Rhizobium* inoculation along with both fertilizers (T₇) increased plant height by 33.19% over control (T₁) at 50 DAS. The increase in plant height could be attributed to the genetic characters enabling crop to more uptake of nutrients particularly nitrogen by the crop. These results are in line with the previous findings of Khalid et al. [21]; Biswas et al. [22]; Hilali et al. [23], who reported increased plant height of

various crop plants by microbial inoculation due to more availability of nitrogen. The highest plant height (41.33 cm) with dual inoculation and fertilization (T₉) at 50 DAS, was also highly correlated with plant nitrogen content and nodule number per plant. The results are in line with Nadira et al. [24] who observed that P @ 40 kg ha⁻¹ with *Rhizobium* produced the tallest plant of mung bean (55.4 cm) at 75 DAS. Similar results were also reported by Tiwari et al. [25] indicating that the increased growth parameters in mung bean may be attributed to increased cell division due to sufficient supply of nitrogen and phosphorus by PGR's and biofertilizers. Prasad et al. [26] also reported maximum plant height (60.27 cm), number of was recorded with *Rhizobium* + 60 kg P₂ O₅/ha.

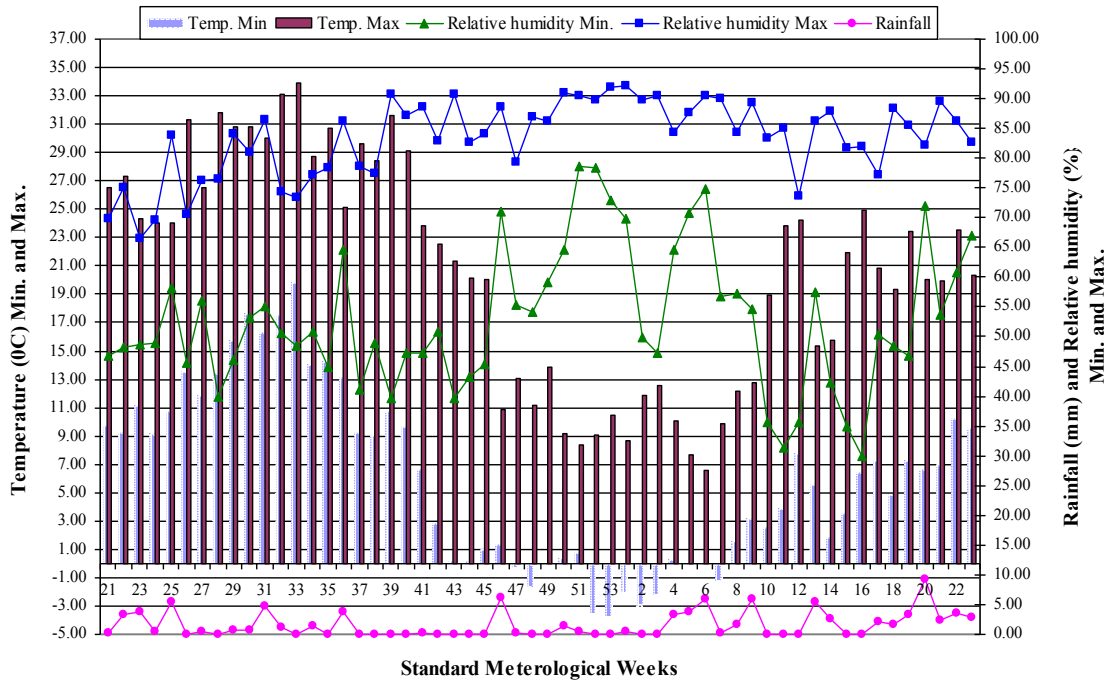


Fig. 1. Mean weekly meteorological parameters during growth period of 2016 and 2017

Table 3. Growth attributes

	Treatments	Plant height (cm)		Shoot dry weight (g) per plant	
		25 Days	50 days	25 days	50 days
T ₁	Absolute control [No fertilizer/biofertilizer]	5.20	26.17	0.075	4.27
T ₂	Recommended dose of fertilizers [NPK=30:60:30]	7.20	32.60	0.097	4.73
T ₃	20 kg N/ha applied as basal with dual inoculation [source Urea]	7.30	36.17	0.098	4.85
T ₄	20 kg N/ha applied as basal without inoculation [source Urea]	6.50	29.26	0.101	4.53
T ₅	40 kg P ₂ O ₅ /ha applied as basal with dual inoculation [source DAP]	7.80	34.55	0.095	4.79
T ₆	40 kg P ₂ O ₅ /ha applied as basal without inoculation [source DAP]	6.33	33.00	0.097	4.73
T ₇	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rizobium]	7.97	39.17	0.100	5.33
T ₈	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [PSB]	7.13	38.43	0.101	5.63
T ₉	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rizobium + PSB]	8.83	41.33	0.095	6.41
T ₁₀	20 kg N/ha + 40 kg P ₂ O ₅ /ha without any inoculation	7.33	37.0	0.095	5.09
	SE(m)±	0.48	1.17	0.03	0.39
	CD (P=0.05)	1.20	3.13	0.11	1.10

3.2 Shoot Dry Matter

Dry matter yield of mung bean was affected by varying input combinations of biofertilizers, nitrogen and phosphorus. The maximum shoot dry weight (6.41 g) per plant was found in 20 kg N ha⁻¹ + 40 kg P₂O₅ ha⁻¹ with dual inoculation of *Rhizobium* and PSB treatment which was higher from other treatments but statistically similar with that of 20 kg N ha⁻¹ + 40 kg P ha⁻¹ with *Rhizobium* (5.33 g) however, minimum shoot dry weight (4.27 g) was recorded in control (T₁) treatment (Table 3). On an average, 33.38% increase in dry matter yield was recorded under treatment-9 relative to control (T₁) at 50 DAS. The increase in symbiotic growth and more availability of N and P nutrients through chemical and biofertilizers could be attributed to higher dry matter after flowering. The results are in conformity with Asaduzzaman et al. [27] who reported that the maximum above ground dry matter (23.36 g) with nitrogen fertilization in mung bean at harvest (85 DAS). The results are also in line with findings of Nadira et al. [24]; Khan et al. [28] who reported that maximum shoot dry weight (7.05 g) per plant in mung bean was found at 40 kg P ha⁻¹ with *Rhizobium* treatment.

3.3 Nitrogen Content

Unlike dry matter yield, highest nitrogen content (71.24 mg plant⁻¹ & 0.29 g seed plant⁻¹) in the was recorded for plant and seed respectively, indicating a clear benefit from integration of bio inoculants and fertilizers. Dual strain inoculation with fertilization increased nitrogen content per plant and seed which was significantly higher by 35.7% and 32.14% than with control (Table 5). Nitrogen content in plant was closely correlated with ARR per plant, while as ARR per plant was marginally correlated with 1000-seed weight at maturity (Table 5).

3.4 Acetylene Reduction Rate (ARR)

The higher ARR (29.51) was recorded in dual inoculation+ both fertilizers (T₉) followed by *Rhizobium* inoculation+ with dual fertilizer (T₇) but both were statistically insignificant (Table 5). Strong correlation was observed between nodulation % per plant with acetylene reduction rate per plant ($R^2 = 0.9501$) and negatively with seed nitrogen content. Nitrogen content in plant was closely correlated with ARR per plant. Marginal correlation was observed among ARR per plant (at 30d), seed weight ($P = 0.052$), and

with seed nitrogen ($P = 0.047$) at maturity. Buttery et al. 1997 also observed similar results and reported that within the 17 mungbean cultivars, plant weight was highly correlated with plant nitrogen, acetylene reduction rate per plant, and both nodule weight and number per plant. ARR per plant seems to be a good indicator of nitrogen fixing potential of young mung bean plants, but final seed yield a less useful indicator.

3.5 Nodules per Plant

Nodule number is one of the important indicators for measuring nitrogen fixation by rhizobium, the effect of dual strain inoculation on number of nodules per plant presumably reflects differences in host-microbe interaction and the application of nitrogen fertilization. Nodule number was recorded at two different stages of crop growth (25 DAS & 50 DAS) with highest 14.83 and 68.17 achieved in seed inoculation with *Rhizobium* along with NP and the lowest 3.31 and 44.11 in non-inoculation with non-fertilization respectively (Fig. 2). However, treatment-9 showed increased number of nodules by 35.29% over control at 50 DAS (Fig. 2). Un-inoculated treatments (RDF, NPK=30:60:30; 20 kg N/ha applied as basal without inoculation) showed marginal effect on nodules per plant with decreased number by 43.51% over T₉ at 50 DAS. This could be attributed by better symbiosis between mung bean and rhizobium (nitrogen fixing bacteria) and increase in P availability through solubilization by PSB in rhizosphere. Nodulation per plant was significantly correlated ($R^2=0.91$) with different plant attributes, however seed weight was marginally correlated with nodule number per plant (Figs. 4, 5). The results are in line with findings of Stancheva et al. [29] and Ogutcu et al. [30] who reported significant impact of microbial inoculation on nodulation and yield of legume crops. Yadav et al. [31]; Bansal [32] also reported that the number of nodules and nodule dry weight at flowering stage were increased significantly by seed inoculation of mungbean with PGPR combination of *Rhizobium* + *Azotobacter*+ *Pseudomonas* over control.

3.6 Yield and Yield Attributes

Biofertilizers inoculation along with N and P application were able to improve the yield attributes compared with control. Yield attributes including numbers of pods/plant, grains/pods and seed weight was significantly increased by all the treatments compared with control.

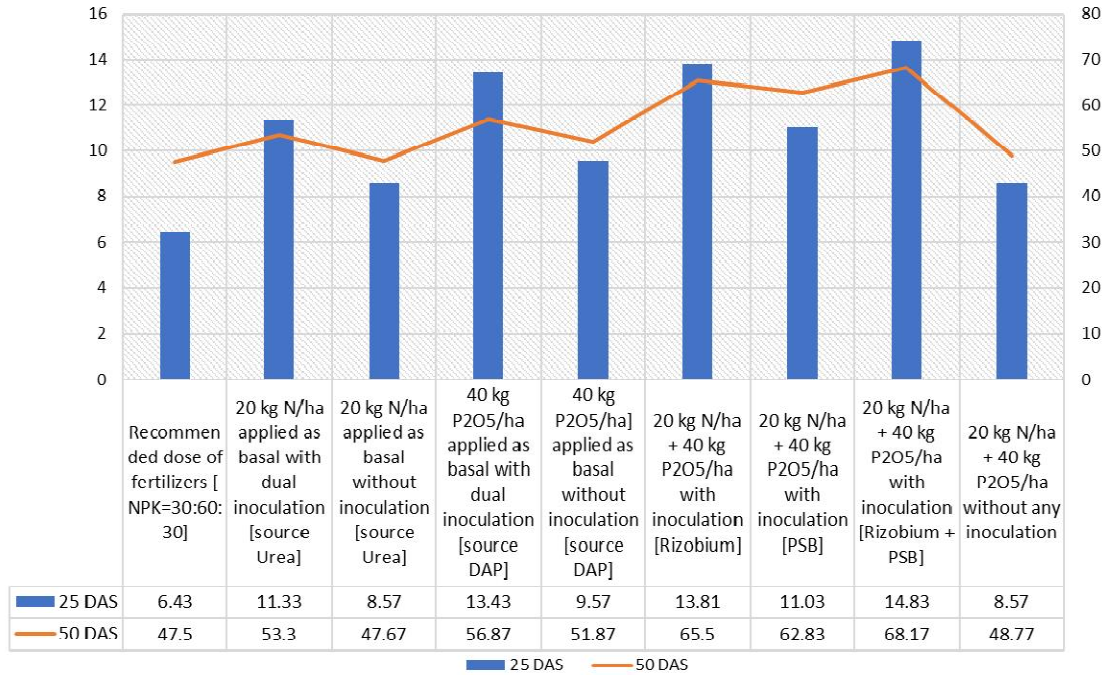


Fig. 2. Nodulation per plant as influenced by combination of bio and chemical fertilizers at two different dates after sowing

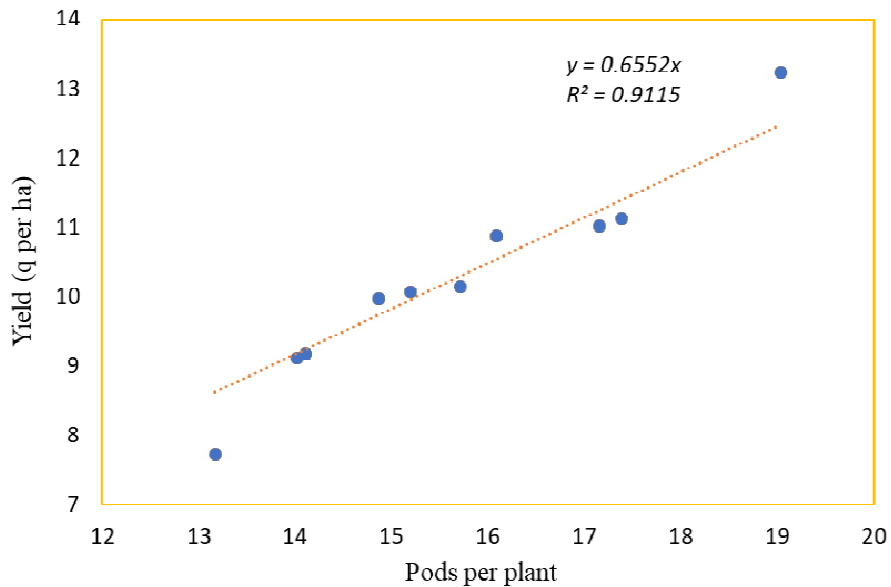


Fig. 3. Relationship between pods/plant and yield of mung bean

3.7 Pods per Plant

Dual strain inoculation with nitrogen and phosphorus application produced the highest number (19.03) of pods per plant which as

statistically at par with application of nitrogen and phosphorus + Rhizobium inoculation (Treatment-7) and nitrogen and phosphorus + PSB inoculation (Treatment-8). The lowest number (13.17) of pods per plant were noted in non-

inoculated, non-fertilized plots (absolute control) which was significantly correlated with the final seed yield (Fig. 3). This could be attributed due to the contribution of biologically fixed N on increasing the filled pod number against few hollow pods under control treatment which was a remarkable observation. The results are in the

line with Patel et al. [33] who studied the effect of PSB inoculum and under application of graded P and S levels on green gram and reported maximum increase (18) in pods per plant. Bhabai, et al. [34] also reported that the maximum pods plant⁻¹ were recorded at P₃ (60 P kg ha⁻¹) mixed with biofertilizer in mung bean.

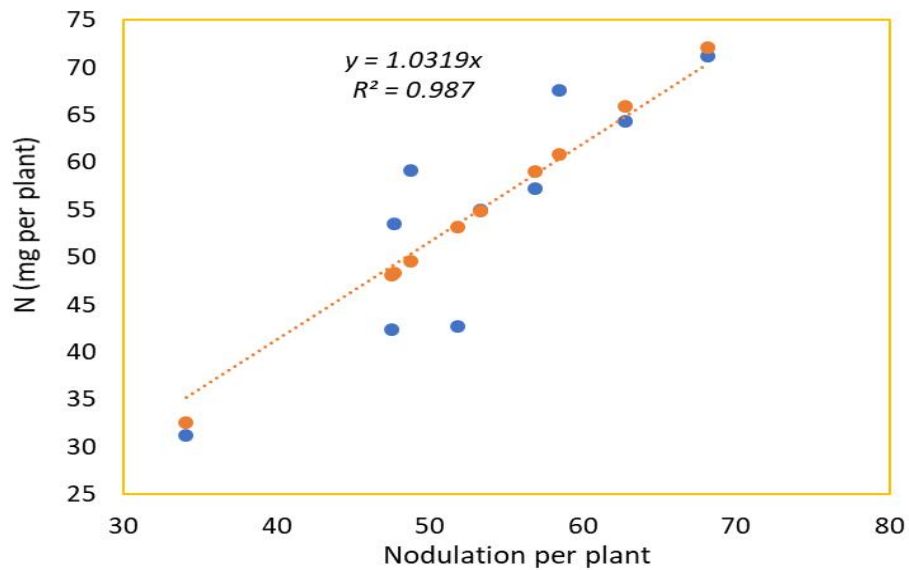


Fig. 4. Relationship between nodulation per plant at flowering/plant and N (mg per/plant) of mung bean

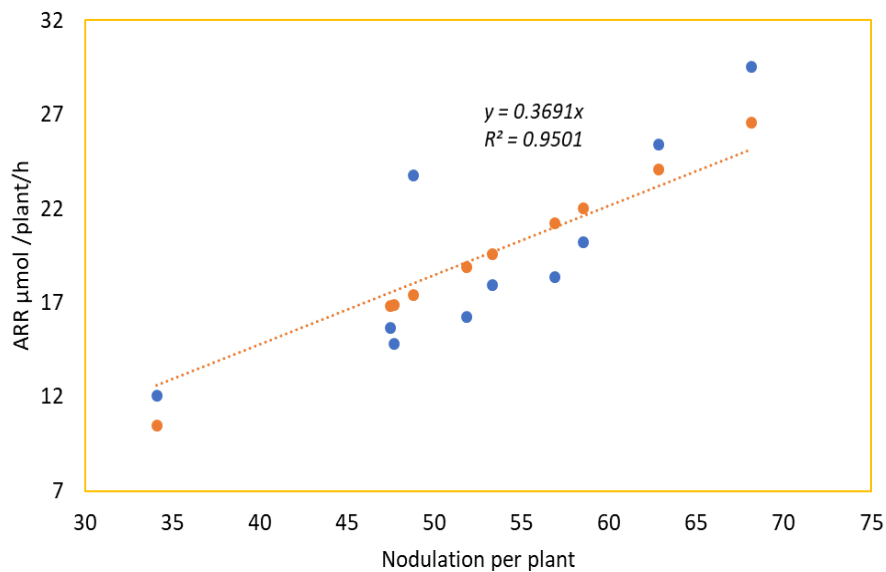


Fig. 5. Relationship between nodulation per plant and ARR μmol /plant/h of mung bean

Table 4. Yield attributes and yield

	Treatment	No. of pods/plant	Grains/pod	1000-Seed weight (g)	Seed yield q ha⁻¹
T ₁	Absolute control [No fertilizer/biofertilizer]	13.17	5.03	32.80	7.72
T ₂	Recommended dose of fertilizers [NPK=30:60:30]	14.11	6.47	35.16	9.17
T ₃	20 kg N/ha applied as basal with dual inoculation [source Urea]	14.87	6.80	37.54	9.97
T ₄	20 kg N/ha applied as basal without inoculation [source Urea]	14.02	6.57	36.62	9.12
T ₅	40 kg P ₂ O ₅ /ha applied as basal with dual inoculation [source DAP]	16.09	7.97	40.09	10.87
T ₆	40 kg P ₂ O ₅ /ha applied as basal without inoculation [source DAP]	15.71	7.60	39.45	10.14
T ₇	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rhizobium]	17.39	8.60	42.60	11.12
T ₈	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [PSB]	17.15	8.23	42.11	11.02
T ₉	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rhizobium + PSB]	19.03	9.55	44.39	13.23
T ₁₀	20 kg N/ha + 40 kg P ₂ O ₅ /ha without any inoculation	15.20	7.53	39.27	10.07
	SE(m)±	0.78	0.43	0.72	0.84
	CD (P=0.05)	2.03	1.16	1.71	2.17

3.8 Seeds per Pod

The treatment of dual bacterial inoculation with application of 20 kg N ha⁻¹+ 40 kg P ha⁻¹ (T₉) out yielded rest of the treatments. The highest number of seeds per pod (9.55) were recorded under treatment-9, which was statistically similar with treatment-7 (8.60) and treatment-8 (8.23). Co-inoculation of *Rhizobium* +PSB+ fertilizers showed 47.32% increase in number of seeds per pod followed by treatment-7 *Rhizobium* inoculation (41.51%) over control. 1000-seed weight significantly increased by all treatments compared with the control but increase under treatments viz; T₂, T₃ and T₄ was marginal. The application of nitrogen + phosphorus with dual inoculation also produced maximum 1000- seed weight (44.39 g) resulting ultimately maximum grain yield during both the years (Table 4). Similar results were also revealed by Naidra et al. [24] who reported that significantly higher 1000 seed weight (34.43 g) was obtained with P @ 40 kg ha⁻¹ with *Rhizobium* and the lowest (30.01 g) with the control. Ali et al. [35] also reported maximal 1000-grain weight, grain yield and protein contents in mung bean from the inoculated plots supplied with phosphorus @ 50 kg ha⁻¹. Pir et al. [36] conducted an experiment on green gram

and revealed that green gram crop with 5 t FYM ha⁻¹ conjugated with 40 kg P₂O₅ ha⁻¹ + seed inoculation with PSB gave highest values of pods per plant, nodule count and test weight. The results of Sanaullah et al. [37] also showed that there was a linear effect of increasing P levels on weight of seeds plant⁻¹ and there was consecutive improvement in weight of seeds, which is positively correlated with the seed yield of mung bean [38].

3.9 Seed Yield

There was an uneven increasing trend in seed yield of mung bean with different combinations of bio and chemical fertilizer. Seed yield varied between 7.72 q h⁻¹ and 13.23 q h⁻¹ (Table 4) however, mean seed yield under *Rhizobium*+ phosphorus solubilizing bacteria + 20% nitrogen +40% phosphorus was maximum (13.23 qtls) followed by *Rhizobium*+ 20% nitrogen +40% phosphorus (11.12 qtls) and lowest (7.72 qtls) recorded in absolute control. Dual strain inoculation along with fertilizer application in mung bean led significant increase in grain yield by 30.70% and 41.60% compared with maximum fertilizer (RDF) and absolute control respectively (Table 4). Yield in the simple fertilizer treatments (T₄; T₆; T₁₀) did not differ significantly from the

RDF (T_2). The highest seed yield produced by treatment -9 might be due to maximum production of crop characters and influenced the plant to have good production of dry matter in early stage and that eventually raised and partitioned to the reproductive units. The results are in line with Nadira et al. [24] who reported that 40 kg P ha⁻¹ with *Rhizobium* inoculants produced the highest seed yield (2.12 t ha⁻¹) in mung bean, which was 54.74% higher than the control. Inoculation of *Rhizobium* along with application of Phosphorus and Molybdenum in mungbean significantly increased the growth of plants, number of nodules, dry matter production as well as grain yield compared to uninoculated [35]. Seed yield was found closely correlated ($R^2 = 0.9987$) with nitrogen use efficiency (NUE) was) at maturity.

3.10 Nitrogen Efficiency Indices

Nitrogen content in plant and seed are indicators of nitrogen fixation potential. Data regarding nitrogen contents and its uptake in straw and seed (Table 6) revealed that co-inoculation (T_9) increased N concentration by 36.15% & 32.14% in straw and seed respectively over control, while as with T_7 of *Rhizobium* inoculation enhanced N contents by 32.21% over control. The effect of all other inoculation treatments remained non-significant against each other but were significant

over control (T_1). The highest nitrogen rate (T_2) significantly reduced the nitrogen harvest index and nitrogen use efficiency of mung bean. On an average, NUE under treatment-9 was significantly higher by 26.72% than NUE in control (Table 6). The Nitrogen harvest index varied between 29.31- 41.47% and highest (81.12) was recorded in T_9 which was statistically at par with *Rhizobium* inoculation with N and P at 20 and 40 kg/ha (T_7). Irrespective of biofertilizer inoculation NHI and NUE for mung beans were affected by nitrogen input. This could be attributed due to the large distribution of N between straw and seed and marginally depends upon the dry matter portioning between the two. Agronomic efficiency of applied nitrogen with due inoculation was almost three times higher than control. The apparent recovery fraction was not affected by experimental treatments.

3.11 Correlation and Regression Analysis

The relationship of seed yield was positive and linear with pods/plant ($R^2 = 0.9115$) and nitrogen use efficiency ($R^2 = 0.9987$). Number of nodules/plants had positive correlation with nitrogen content in plant ($R^2 = 0.987$) (Figs. 3, 4 and 5). The regression equation was established for the corresponding tests of the effects of N, P with and without dual inoculation on yield and yield components.

Table 5. Treatment effect on means for plant Nitrogen content, seed nitrogen content, acetylene reduction rate

Labels	Treatments	N (mg Plant ⁻¹)	N-Seed (g plant ⁻¹)	ARR $\mu\text{mol plant}^{-1}\text{h}^{-1}$
T ₁	Absolute control [No fertilizer/biofertilizer]	45.84	0.19	12.03
T ₂	Recommended dose of fertilizers [NPK=30:60:30]	47.37	0.21	15.67
T ₃	20 kg N/ha applied as basal with dual inoculation [source Urea]	55.04	0.25	17.91
T ₄	20 kg N/ha applied as basal without inoculation [source Urea]	53.55	0.23	14.82
T ₅	40 kg P ₂ O ₅ /ha applied as basal with dual inoculation [source DAP]	57.22	0.26	18.35
T ₆	40 kg P ₂ O ₅ /ha applied as basal without inoculation [source DAP]	48.71	0.23	16.23
T ₇	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rizobium]	67.63	0.25	25.19
T ₈	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [PSB]	64.31	0.21	20.42
T ₉	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rizobium + PSB]	71.24	0.29	29.51
T ₁₀	20 kg N/ha + 40 kg P ₂ O ₅ /ha without any inoculation	59.16	0.18	23.73
	SE(m)±	1.18	0.07	1.22
	CD (P=0.05)	3.24	0.20	3.32

Table 6. Effect of biofertilizer strains and fertilizers on nutrient use efficiency (NUE), agronomic efficiency (AE), nitrogen harvest index (NHI) and recovery efficiency (RE) in mung bean

Labels	Treatments	NUE kg/kg	AE Kg/Kg	NHI (%)	RF (%)
T ₁	Absolute control [No fertilizer/biofertilizer]	13.98	7.89	57.34	41.75
T ₂	Recommended dose of fertilizers [NPK=30:60:30]	16.10	8.72	64.52	55.22
T ₃	20 kg N/ha applied as basal with dual inoculation [source Urea]	14.78	11.10	67.72	62.43
T ₄	20 kg N/ha applied as basal without inoculation [source Urea]	15.30	10.09	74.13	54.62
T ₅	40 kg P ₂ O ₅ /ha applied as basal with dual inoculation [source DAP]	16.53	8.78	53.42	49.18
T ₆	40 kg P ₂ O ₅ /ha applied as basal without inoculation [source DAP]	14.33	8.87	54.98	56.12
T ₇	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rhizobium]	15.21	12.45	76.16	58.14
T ₈	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [PSB]	19.08	11.91	79.39	56.33
T ₉	20 kg N/ha + 40 kg P ₂ O ₅ /ha with inoculation [Rhizobium + PSB]	18.32	13.95	81.12	59.59
T ₁₀	20 kg N/ha + 40 kg P ₂ O ₅ /ha without any inoculation	16.03	9.46	65.10	51.20
	SE(m)±	0.65	0.75	1.25	1.35
	CD (P=0.05)	1.93	2.26	3.45	4.12

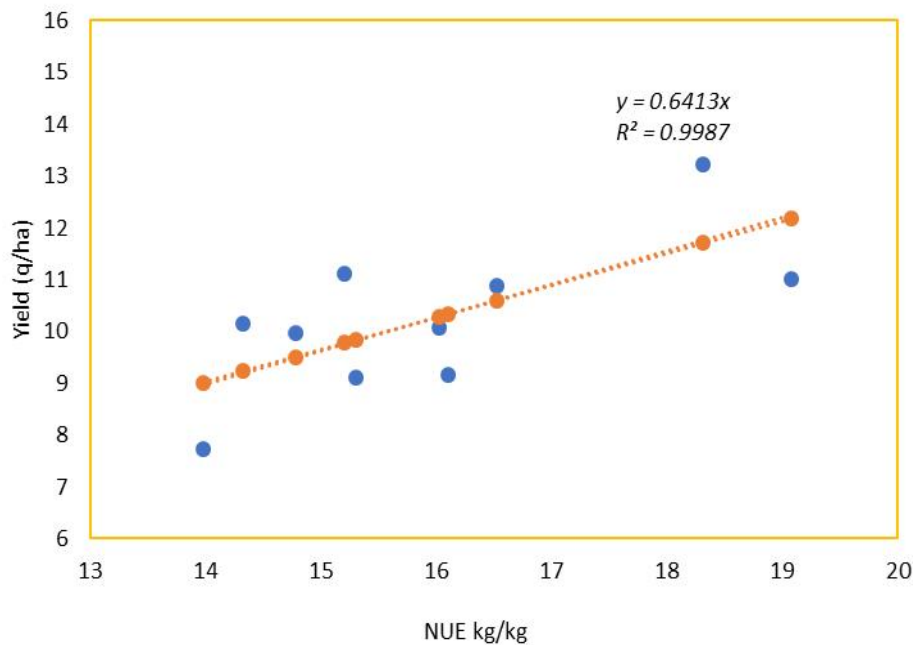


Fig. 6. Relation between nitrogen use efficiency (NUE) Kg/Kg and yield (q/ha) of mung bean

4. CONCLUSION

Co-inoculation with Rhizobium and phosphate solubilizing bacteria along with nitrogen and phosphorus were found more beneficial and

could be better option for getting reduction in chemical fertilization (up to 50% N) particularly in mung bean crop. The reasonable optimization of N and P with dual inoculation could improve yield components and yield in mung bean. For the

principle of reducing N and stabilization of P in mung bean crop should be inoculated with rhizobium and PSB to increase yield by 2.5% over control. Based on the present findings it is recommended that application of phosphorus @ 40 kg ha⁻¹ with starter dosage of N @ 20 kg ha⁻¹ should be applied in mung bean for higher seed yield under temperate agro-ecological conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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