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Effect of liquid formulations of *Rhizobium* inoculation on growth and yield of mung bean

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Abstract
The mung bean (*Vigna radiata*) belongs to group of the legume family (Fabaceae). This family is a wide spread as it occupies the third largest family of flowering plants, with approximately 650 genera and nearly 20,000 species. The present study was to check the effect of liquid formulations of *Rhizobium* inoculation on Soil microbial population dynamics at periodic intervals in soil, nitrogen and phosphorus uptake by mung bean, growth and yield of mung bean as influenced by application of liquid *Rhizobium.* After considering all the parameters, inference could be drawn that *Rhizobium* application enhance the growth leading to increase in yield of mung bean. It was observed that T_3: S.T.L. liquid *Rhizobium* @ 25 ml/kg of seed each had higher arithmetic value for growth parameters including germination, plant height, number of branches, number of leaves, LAI, root nodules and yield parameters pods/ plant, 1000 seed weight ultimately yield/ ha. Other parameters including chemical and microbial parameters showed significant increase over the absolute control. Above investigation concluded that inoculation of liquid formulation of *Rhizobium* enhanced growth as well as yield of mung bean. Population of *Rhizobium* as influenced by inoculation of liquid formulations significantly was enhanced. Total N and P uptake by plant and grain sample was found to be significantly higher due microbial inoculations.

Keywords: Biofertilizers, influenced, legume, mung, *Rhizobium*

Introduction
The mung bean (*Vigna radiata*) belongs to group of the legume family (Fabaceae). This family is a wide spread as it occupies the third largest family of flowering plants, with approximately 650 genera and nearly 20,000 species. Mung bean has many local names "mung bean, mash, golden gram or green gram (Doyle, 1994) [22]. The crop has been cultivated since ancient times in India. The mung bean plant is not found in a wild state. It is said to be derived from *Phaseolus radiatus* L., which occurs wild throughout India and Burma, and which is occasionally cultivated.

Mung bean is an erect to sub-erect, self-pollinated, deep rooted, much branched and somewhat hairy annual herb ranging from 45-75 cm. Plants are generally branched and habit can vary from erect to sub-erect It may have tendency to twining sometimes. Stem is furrowed, squarish and hairy with green sometimes purple pigmentation.

Mung bean is important pulse crop in India. It is 70-80 days crop with minimum water requirement. Mung bean has been grown in south and Southeast Asia including India, Pakistan, Nepal, and Srilanka, China. It consists of about 23 to 24 % protein. Green gram is an excellent source of high-quality proteins having high digestibility. It is consumed as whole grains as well as "Dal" in a variety of ways in our food. Sprouted green gram is used in the preparation of curry or a savory dish (South India). It is supposed to be easily digestible and hence the patients prefer it. It contains high level of Lysine. Sprouted mung bean contains increased thiamine, ascorbic acid and niacin. When green gram is sprouted, seeds synthesized remarkable quantity of ascorbic acid (Vitamin C). Green gram is also used as green manure crop. It being a leguminous crop has capacity to fix the atmospheric nitrogen (30-40 kg N/ha). It also helps in preventing soil erosion. Being a short duration crop, it fits well in many intensive crop rotations. Green gram can be used as feed for cattle. After harvesting the pods, green plants are uprooted or cut from the ground level and chopped into small pieces and fed to the cattle. The husk of the seed can be soaked in water and used as cattle feed.

In North India, it is cultivated in both kharif and summer seasons and in South India, it is cultivated in *rabi* season. Chemical fertilizer requirement of mung bean for better yield is 20:40:00 kg NPK/ha. Due to increase in cost of chemical nitrogenous fertilizers, the marginal farmer cannot afford the fertilizers to the crop with the recommended doses.

Liquid biofertilizer technique is substitute to carrier based biofertilizers. It helps in preserving organism, to deliver them to their targets and improve their activities. Liquid biofertilizers are liquid formulations consisting desired microorganism and their nutrients but also special cell protectants or substances that encourage formation of resting spores or cyst for longer shelf life and tolerance to adverse condition. Unlike the lignite based biofertilizers, liquid biofertilizers have a longer shelf life.

Rhizobium is a group of Gram-negative aerobic rods, motile, when young have bipolar, subpolar or peritrichous flagella. Cells contain β – hydroxybutyrate (40-50% of cell dry weight). They are non-spore formers (Bergy, 1923) [9]. Symbiotic nitrogen fixation by *Rhizobium* in legumes contributes substantially to total biological nitrogen fixation. The roots of mung bean bear nodules that can fix atmospheric nitrogen via symbiotic association with bacterium *Rhizobium. Rhizobium* inoculation is well known agronomic practice to ensure inadequate nitrogen of legumes in lieu of N fertilizers. Although native *Rhizobium* is present in soil but not all of them are capable of forming nodules. Some strains are highly effective in this respect while others are partially or completely effective. It is reported that natural flora gradually loses their efficiency. Hence artificial inoculation with tested effective strains should be taken up as comparatively means, cheap insurance for obtaining optimum yield.

Materials and Methods

The present study entitled, "Effect of liquid formulation of *Rhizobium* inoculation on growth and yield of mung bean" was conducted at research farm, Department of Plant pathology and Agricultural Microbiology, college of Agriculture, Pune in *Kharif*, 2019. The materials that are used and methods followed during research are described as under.

Methods

Aseptic Precautions: Throughout the laboratory work period standard aseptic conditions necessary for bacteriological work/microbiological work were followed.

Sterilization: All the solutions, media were sterilized at 121.5^0 For 15 minutes in autoclave.

Methods of Soil Analysis: Methods used for soil analysis were given in Table No.1. And: Methods Used for Plant Analysis given in Table no 2.

Table 1: Methods used for soil analysis:

Parameter	Method	References
A) Chemical Properties		
Available N	Alkaline permagnate method	Subbiah and Asija (1956)
Available P	0.5M $NaHCO_3$ Olsen's method	Olsen *et al.* (1965)
B) Biological Properties		
Total *Rhizobium* count	Serial dilution and pour plate technique	Subbarao (1999)

Table 2: Methods Used for Plant Analysis:

Parameter	Method	References
Total Nitrogen	Microkjeldhal Method (Digestion-Distillation)	Bremer and mulvey (1982)
Total Phosphorous	Vandomolybdate yellow colour in nitric acid system	Jackson (1973)

Experimental Details

Experimental Site: Field experiment was carried out at research farm, Plant Pathology and Agriculture Microbiology, College of Agriculture, Pune.

Field Trial: Treatment details

a) Season : *Kharif*, 2019
b) Crop : Mung bean
c) Variety : *Vaibhav*
d) Spacing : 30 cm x 10 cm
e) Plot size : Gross : 2.40 m x 2.10 m
Net: 1.80 m x 1.90 m
f) Experimental design : Randomized Block Design
g) Treatments : 10
h) Replications : 3
i) Recommended fertilizers : 20:40:00 N:P: Kkg/ ha

Treatments

T_1: Seed treatment with liquid *Rhizobium* @ 25ml/kg of seed
T_2: Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each
T_3: T_4: Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each +75% RDF
T_5: Seed treatment of carrier based *Rhizobium* @ 25g/ kg of seed.
T_6: Seed treatment of carrier based *Rhizobium* 25g/kg of seed each
T_7: T_8: Seed treatment of carrier based *Rhizobium* 25g/kg of seed each+75% RDF
T_9: Recommended dose of fertilizers/ control
T_{10}: Absolute control

Note: (Recommended dose of fertilizers was common for T_1 to T_3 and T_5toT_7)

Agronomic Details

Sowing: Seeds were dibbled at distance of 30cm.

Irrigation: No external irrigation applied throughout crop growth period due to excessive rainfall.

Thinning: Unhealthy and off type plants are removed at 15 days after sowing.

Plant Protection: Protection measures such as Chlorpyriphos, cypermethrin, flubendamide were applied for respective pests.

Harvesting: Fully matured pods were harvested in three terms due to non-synchronous maturity.

Treatment Evaluation

Seed Germination: Number of seeds germinated per plot was recorded at 7 days after sowing. And germination percentage was calculated by formula.

$$Germination\ per\ cent = \frac{Total\ number\ of\ seeds\ germinated}{Total\ number\ of\ seeds\ sown} \times 100$$

Number of nodules per plant: Five plants were randomly selected from border and carefully uprooted without damaging their roots at flowering stage. Soil attached to roots was washed with water, nodules were calculated. The values were obtained. Effective nodules per plant were counted from same plants that were taken for total number of nodules. Healthy and pink colored nodules were counted as effective root nodules.

Number of leaves per plant: Five plants from each plot were randomly selected and tagged. Number of individual leaves was recorded at periodic intervals (30, 45 days after sowing and at harvest.)

Plant height: Plant height was measured in cm for five plants in each plot at periodic intervals and mean value obtained. The plant height was measured from base/ collar region to main shoot of plant.

Dry weight of leaves: Harvested plant was carefully uprooted at maturity stage. The roots were washed under tap water. The roots and shoots were dried separately in brown paper bags along with husk of pods at 70±2º C till constant dry weight is obtained.

Leaf area index: The leaf area index calculated by paper graph method. Total leaf cover of plot per plot is leaf area index; it was recorded at periodic intervals.

$$\text{Leaf area index} = \frac{\text{total leaf area of plot}}{\text{total ground area of plot}}$$

Pods per plant: Pods per plant were recorded at harvest for plants that were selected for other periodic observations.

1000 seed weight: Test weight for 1000 seeds for each plot was recorded after threshing and drying.

Yield per plot: Total grain weight per plot was recorded for each plot.

Benefit cost ratio: The benefit cost ratio was calculated by evaluating each treatment for cost of cultivation, gross returns and net returns.

Collection of Soil Samples for Microbial Analysis

Rhizobium count recorded at sowing, 30DAS, 60DAS using serial dilution and pour plate technique. The soil sample was collected from rhizosphere of crop. For *Rhizobium* Congo red yeast extract mannitol agar was used as growth media. After serial dilution and pour plating incubation at 28±2 ºC was done. Colonies were counted at 10 -5 dilution. Formula for *Rhizobium* population from one gram of soil is,

$$No.\ of\ Bacteria\ per\ Gram\ of\ soil = \frac{Average\ plate\ colony\ count \times dilution\ factor}{oven\ dry\ weight\ of\ one\ gram\ sample}$$

Collection and Preparation of Soil and Plant Samples for Chemical Analysis

Soil Sample: Initial soil sample was taken before sowing of seeds. Soil sample from each plot was collected at the time of harvest from rhizosphere. The soil samples were then dried in air and using wooden mortar-pestle crushed. The samples were sieved through 2mm sieve. Available N was determined by alkaline permanganate method as given by Subbiah and Asija, 1956. For available P, Olsen's method was used.

Plant samples: The mung bean plant samples were collected at the time of harvest of crop plot wise. Plant samples were wrapped in brown paper bags after air drying. The samples along with bags were oven dried at 60±2º C. The oven dried sample is then ground so that fine powder is obtained. This fine powder is used for chemical analysis. The sample powder is analyzed for N percent by Microjeldhal's method (Parkinson and Allen, 1975) [41] and for phosphorous spectrophotometric method is used.

Statistical Analysis: The data collected for various observations was analyzed using Randomized Block Design with 10 treatments and 3 replications. The standard statistical methods as provided by Panse and Sukhatme were (1985) followed for statistical significance. The data is mentioned in tabular form and illustrated by graphs and figures as and when necessary.

Results and Discussion

The investigation on aspect entitled, "Effect of liquid formulations of *Rhizobium* inoculation on growth and yield of mung bean." was carried out at research field of Plant Pathology and Agricultural Microbiology section, College of Agriculture, Pune during *kharif* season of 2019.The trial was laid out in randomized block design with ten treatments and replicated thrice. The variety used for trial was *Vaibhav*. The results obtained from the field trial and laboratory analysis were presented here in and discussed with earlier reports.

Effect on Seed Germination: The germination was recorded at 7 days after sowing. Germination per centage was recorded and mean of three replications calculated. The results as influenced by *Rhizobium* inoculation was presented in Table 3. The graphical representation of results was mentioned in Fig. 4.1. Inoculation of *Rhizobium* showed germination percentage in the range of 84.56 to 90.96.

All the imposed treatments showed significant impact on germination in comparison to T_{10}: absolute control (84.56 %). The treatment T_9: recommended dose of fertilizers (control) was statistically at par with T_5: S.T.C.B. *Rhizobium*@ 25 g/ kg of seed (87.06%) and T_1: S.T.L. *Rhizobium* @ 25ml/ kg of seed (87.11%). All the remaining treatments were statistically superior over T_9: Recommended dose of fertilizers (control). Treatment T_3: S.T.L. *Rhizobium* 25 g/ kg of seed (90.96%) had highest arithmetic value for germination, but it was statistically at par with T_7: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (90.35%), T_4: S.T.L. *Rhizobium* 25 g/ kg of seed each+75% RDF (89.50%). Treatments as T_2: S.T.L. *Rhizobium* @ 25 ml/ kg of seed (88.34%), T_2: S.T.L. *Rhizobium* @ 25 ml/ kg of seed (88.34%) and T_6: S.T.C.B. *Rhizobium* @ 25g/ kg of seed (87.88%) was statistically at the rate par with each other and was next best set of treatments.

Pawar *et al.* (2014) concluded that inoculation of *Rhizobium* found to significantly enhance germination per centage in pulses including green gram, moth bean, and Bengal gram. The findings of present investigation were in concurrence with this.

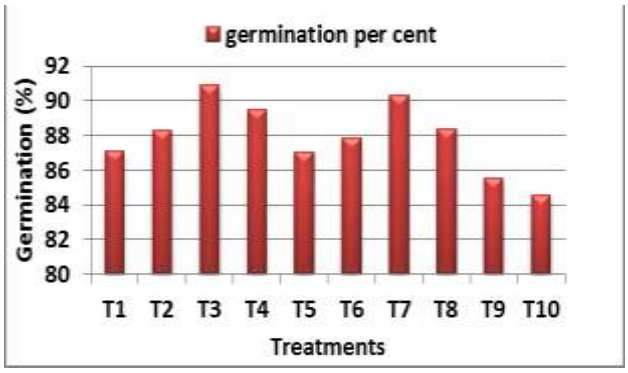

Fig 4.1: Effect of liquid formulations of *Rhizobium* inoculation on germination of mung bean.

Effect on Number of Leaves per Plant: The numbers of leaves were recorded at 30, 45 days after sowing and at harvest. The mean number of leaves per plant as affected by liquid formulation of *Rhizobium* inoculation were tabulated in Table 4 and graphically presented in Fig. 4.2.

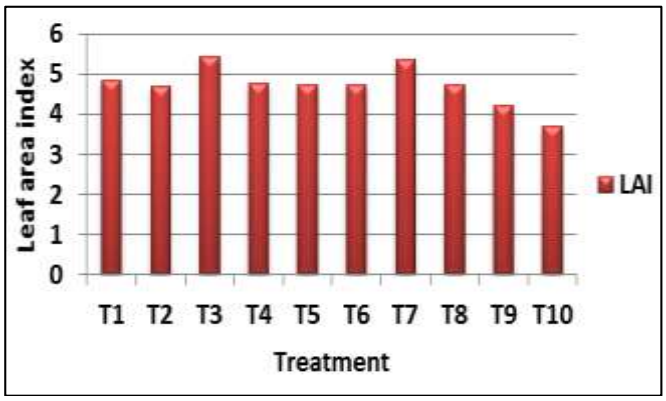

Fig 2: Effect of liquid formulations of *Rhizobium* inoculation on LAI of mung bean

Table 3: Effect of liquid formulation of *Rhizobium* inoculation on seed germination of mung bean.

Tr.	Treatment Details	Mean Germination Percent
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	87.11
T_2	S.T.L. *Rhizobium*@ 25 ml/ kg of seed	88.34
T_3	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each	90.96
T_4	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each+75% RDF	89.50
T_5	S.T.C.B. *Rhizobium* @ 25g/kg of seed	87.06
T_6	S.T.C.B. *Rhizobium* @ 25g/kg of seed	87.88
T_7	S.T.C.B. *Rhizobium*@ 25g/kg of seed each	90.35
T_8	S.T.C.B. *Rhizobium*@ 25g/kg of seed each+75% RDF	88.42
T_9	Recommended dose of fertilizers (control)	85.57
T_{10}	Absolute control	84.56
S.E. (m)±		0.56
C.D. (0.05)		1.66

Table 4: Effect of liquid formulation of *Rhizobium* inoculation on number of leaves of mung bean.

Tr.	Treatment Details	30DAS	45DAS	At harvest
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	13.73	15.87	16.47
T_2	S.T.L.PSB@ 25 ml/ kg of seed.	13.60	15.20	15.80
T_3	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each	14.00	16.07	16.47
T_4	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each+75% RDF	13.20	14.53	15.53
T_5	S.T.C.B. *Rhizobium* @ 25g/kg of seed.	13.40	15.07	15.60
T_6	S.T.C.B.PSB @ 25g/kg of seed	13.27	14.53	15.53
T_7	S.T.C.B. *Rhizobium*@ 25g/kg of seed each	13.67	15.47	16.40
T_8	S.T.C.B. *Rhizobium*@ 25g/kg of seed each+75% RDF	13.67	15.53	15.67
T_9	Recommended dose of fertilizers (control)	13.40	13.60	13.80
T_{10}	Absolute control	12.60	13.20	13.67
S.E.(m)±		0.35	0.55	0.54
C.D. (0.05)		NS	1.65	1.62

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7

30 Days after sowing: The treatments at this stage of growth did not showed significant difference. The highest number of leaves per plant was observed for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed (14.00) and least number of leaves in T_{10}: absolute control (12.60).

45 Days after sowing: Mean number of leaves ranged from 13.20 to 16.07 at this stage of crop growth. The treatment T_6: S.T.C.B *Rhizobium*. @ 25g/ kg of seed (14.53) and T_4: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each+75% RDF (14.53) were at par with T_{10}: absolute control. All the other treatments were statistically significant over T_{10}: absolute control. As compared to T_9: recommended dose of fertilizers/control (13.60), T_6: seed treatment with carrier-based *Rhizobium* @ 25 g/ kg of seed (14.53) and the T_4: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each+75% RDF (14.533) were statistically non-significant. All the other treatments were statistically significant over the T_9: recommended dose of fertilizers/ control (13.60). Highest arithmetic value was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (16.07).

At harvest: Number of leaves per plant at harvest ranged from 13.67 to 16.47. All the treatments as inoculated with *Rhizobium* showed significantly higher number of leaves compared to T_{10}: absolute control (13.67). Also, all the inoculated treatments were statistically significant over T_9: recommended dose of fertilizers/ control (13.80). The highest numerical value for number of leaves per plant was observed in T_1: S.T.L. *Rhizobium* @ 25 ml/ kg of seed (16.067) and T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each, but they were statistically at par with rest of the inoculated treatments.

Significant increase in number of leaves and other vegetative characters over control was recorded by Ravikumar *et al.* (2012), who inoculated *Vigna mungo* and *Vigna radiata* with *Rhizobium* under pot culture conditions. The findings were similar to results obtained for present study.

Leaf Area Index: The LAI as influenced by *Rhizobium* was measured at 45 days after sowing. The results as influenced by inoculation of *Rhizobium* was tabulated in Table no.5 and graphically represented in Fig. 4.3. The LAI ranged from 3.71 to 5.45.

All the imposed treatments showed statistically significance over LAI as compared to T_{10}: absolute control (3.71) as well as T_9: RDF / control (4.21). Highest arithmetic value was obtained for T_3: S.T.L. *Rhizobium* @ 25 g/ kg of seed each (5.45), but it was statistically at par with T_7: S.T.C.B. *Rhizobium* @ 25 ml/ kg of seeds each (5.37).

et al. (2013) observed higher green area index with inoculation of *Rhizobium* to *Pisum sativum* seeds. The findings concurred with present investigation. Dhakal *et al.* (2015) concluded that 75% RDF + 2.5 t/ ha vermicompost + *Rhizobium* + PSB and 100% RDF + *Rhizobium* + PSB combination significantly enhanced LAI in mung bean over control plot while carrying out research with graded levels of RDF along with different combinations of *Rhizobium*. The result for LAI for present investigation showed similar trends in LAI for *Rhizobium* inoculation.

T_3: S.T.L. *Rhizobium* @ 25 ml/kg of seed each
T_{10}: absolute control

Fig 3: Plate 4.5 Effect of liquid formulations oh *Rhizobium* inoculation on pods of mung bean.

Table 5: Effect of liquid formulation of *Rhizobium* inoculation on LAI of mung bean

Tr.	Treatment Details	LAI
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	4.86
T_2	S.T.L.PSB@ 25 ml/ kg of seed.	4.71
T_3	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each	5.45
T_4	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each+75% RDF	4.77
T_5	S.T.C.B. *Rhizobium* @ 25g/kg of seed.	4.75
T_6	S.T.C.B.PSB @ 25g/kg of seed	4.75
T_7	S.T.C.B. *Rhizobium*@ 25g/kg of seed each	5.37
T_8	S.T.C.B. *Rhizobium*@ 25g/kg of seed each+75% RDF	4.73
T_9	Recommended dose of fertilizers (control)	4.21
T_{10}	Absolute control	3.71
	S.E. (m)±.	0.15
	C.D. (0.05)	0.44

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7

Effect on Height of Plant: Plant height as influenced by *Rhizobium* recorded at 30 DAS, 45 DAS and at harvest. The mean plant height as affected by liquid formulation of *Rhizobium* inoculation was tabulated in Table no. 6 and graphically presented in Fig. 4.4.

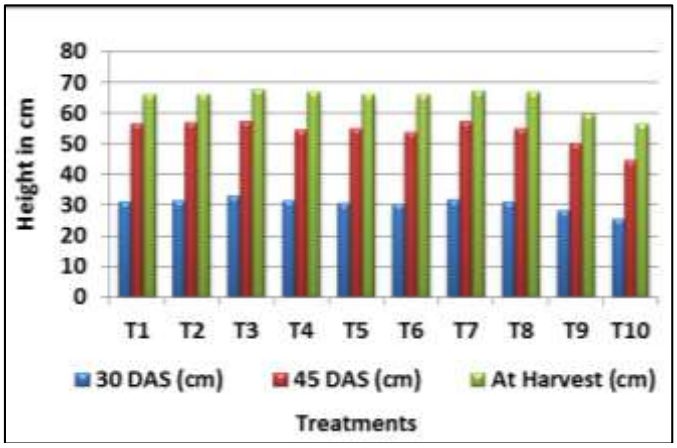

Fig 4.4: Effect of liquid formulations of *Rhizobium* inoculation on height of mung bean.

Table 6: Effect of liquid formulation of *Rhizobium* inoculation on height of mung bean

Tr.	Treatment Details	30 DAS (cm)	45 DAS (cm)	At Harvest (cm)
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	30.93	56.51	65.89
T_2	S.T.L.PSB@ 25 ml/ kg of seed.	31.34	56.67	65.98
T_3	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each	32.76	57.22	67.39
T_4	S.T.L. *Rhizobium* @ 25 ml/ kg of seed each+75% RDF	31.51	54.23	66.60
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed.	30.46	54.95	65.76
T_6	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	30.35	53.67	65.84
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	31.84	57.01	67.32
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each+75% RDF	30.95	54.99	66.61
T_9	Recommended dose of fertilizers (control)	28.11	49.85	59.59
T_{10}	Absolute control	25.45	44.66	56.59
	S.E.(m)±	0.63	0.88	0.62
	C.D. (0.05)	1.87	2.26	1.85

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5 to T_7

30 Days after sowing: The plant height as influenced by seed inoculation of biofertilizers ranged from 25.45 cm to 32.76 cm. All the imposed treatments showed statistically significant height over T_{10}: absolute control (25.45 cm). Similarly, all the inoculated treatments were statistically significant over T_9: recommended dose of fertilizers/ control (28.11 cm). Numerically highest value was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (32.76 cm), but it was statistically at par with rest of the inoculated treatments.

45 Days after sowing: Plant height at this stage of crop growth ranged from 44.66 cm to 57.22 cm. All the inoculated treatments were statistically significant over T_{10}: absolute control (44.60 cm).
All the treatments as inoculated with *Rhizobium* showed significantly higher plant height as compared to T_9: recommended dose of fertilizers/ control (49.85 cm).T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (57.22 cm) had highest numerical value, but it was at par with all other inoculated treatments.

At harvest: Plant height at harvest of crop as recorded and ranged from 56.59 cm to 67.39 cm. All the imposed treatments were statistically significant over T_{10}: absolute control (56.59 cm). All the inoculated treatments were statistically significant over T_9: recommended dose of fertilizers/ control (59.59 cm). Treatment T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (67.39 cm) had highest arithmetic value; however it was at par with all other seed treatments.
Singh *et al.* (2015) [43], in trial with graded level of P and biofertilizers (*Rhizobium* - with or without) found significant plant height was obtained for 40 kg/ ha P_2O_5 + PSB and 40kg/ ha + *Rhizobium* over control. The results therefore concur with present study. The results obtained concurred with Arafa *et al.* (2018) [3], who inoculated *Vigna unguiculata* L., *Pisum sativum* L., *Phaseolus vulgaris* L., *Trigonella foenum-graecum* L. with *Rhizobium* strains for two successive years. It was observed that plant height significantly increased over control plot.

Effect on Number of Branches/Plant: The mean number of branches per plant was recorded at 30, 45 days after sowing and at harvest. The results as influenced by inoculation of *Rhizobium* were tabulated in Table no.7 and graphically represented in Fig.4.5.

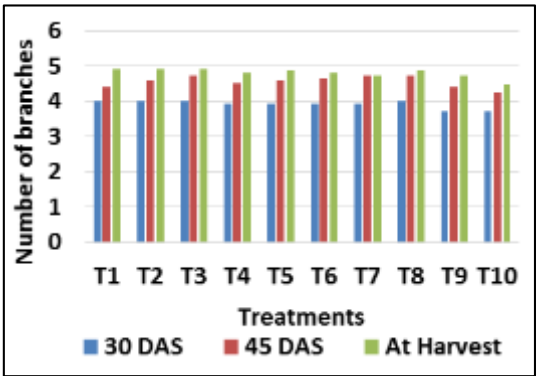

Fig 4.5: Effect of liquid formulations of *Rhizobium* inoculation on branches of mung bean.

Table 7: Effect of liquid formulation of *Rhizobium* inoculation on number of branches of mung bean

Tr.	Treatment Details	30 DAS	45 DAS	At Harvest
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	4.00	4.40	4.93
T_2	S.T.L. *Rhizobium* @25 ml/ kg of seed.	4.00	4.60	4.93
T_3	S.T.L. *Rhizobium* and PSB@ 25 ml/ kg of seed each	4.00	4.73	4.93
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	3.93	4.53	4.80
T_5	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed	3.93	4.60	4.87
T_6	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	3.93	4.67	4.80
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	3.93	4.73	4.73
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each + 75% RDF	4.00	4.73	4.87
T_9	Recommended dose of fertilizers (control)	3.73	4.40	4.73
T_{10}	Absolute control	3.73	4.27	4.47
S.E. (m)±		0.08	0.12	0.12
C.D. (0.05)		NS	NS	NS

30 Days after sowing: The number of branches as influenced by liquid biofertilizers ranged from 3.73 to 4.00. The results for number of branches did not show statistical significance in comparison with T_{10}: absolute control (3.73) and T_9: recommended dose of fertilizer/ control (3.73).

45 Days after sowing: Number of branches as influenced by inoculation of biofertilizers to seed ranged from 4.27 to 4.73. S.T.L. biofertilizers did not significantly influence number of branches/plant at 45 days after sowing over $T_{10:}$ absolute control (4.27) as well as T_9: recommended dose of fertilizers/ control (4.40). Highest arithmetic value was recorded for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (4.73), T_7: S.T.C.B. *Rhizobium* @ 25 g/ kg of seed each (4.73), T_8: S.T.C.B. *Rhizobium* @ 25 g/ kg of seed each + 75% RDF (4.73). The least number of branches were recorded in T_{10}: absolute control (4.26).

At harvest: Numbers of branches/ plant as influenced by liquid biofertilizers were not statistically significant as compared to T_{10}: absolute control (4.47). The imposed treatments were non-significant as compared to T_9: recommended dose of fertilizers/ control (4.73). The number of branches as influenced by seed inoculation ranged from 4.47 to 4.93. Numerically highest number of branches was recorded in T_2: S.T.L.PSB@ 25 ml/ kg of seed (4.93), $T_{3:}$ S.T.L.
Rhizobium @ 25 ml/ kg of seeds each (4.93), T_5: S.T.C.B. *Rhizobium* @ 25 g/ kg of seed (4.93). The least number of branches were recorded for T_{10}: absolute control (4.47).

Effect on Number of Nodules/Plant: The root nodules were counted at flowering stage of mung bean. The plants from border rows were uprooted carefully, soil adhered to the roots was washed off. The total number of root nodules from

uprooted plant was counted. Healthy and pink colored root nodules as effective root nodules were also enumerated from same plants. The results as influenced by inoculation of *Rhizobium* were tabulated in Table no.4.6 and graphically represented in Fig.4.6.

All the imposed treatments showed significant impact on number of effective root nodules/ plant in comparison over T_{10}: absolute control (25.17). All the imposed treatments also showed statistically significant influence on effective root nodules/ plant in comparison to T_9: recommended dose of fertilizers/ control (25.50). Arithmetically highest value was recorded for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (43.50). It was statistically at par with T_1: S.T.L. *Rhizobium* @ 25 ml/kg of seed (42.17), and other co-inoculation treatments.

Bahati (2012) [7] conducted a trial of *BradyRhizobium* inoculation on soybean nodulation. It was concluded by him that inoculation of *BradyRhizobium* significantly enhanced root nodules over control. Present study also showed similar results for nodulation.

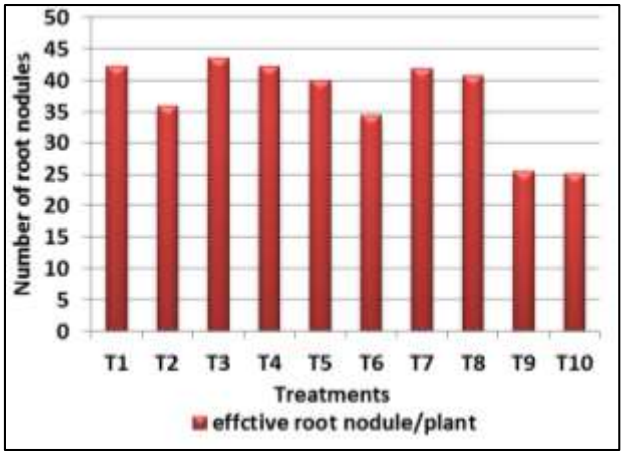

Fig 4.6: Effect of liquid formulations of *Rhizobium* inoculation on root nodules of mung bean.

Table 4.5: Effect of liquid formulation of *Rhizobium* inoculation on number of branches of mung bean.

Tr.	Treatment Details	30 DAS	45 DAS	At Harvest
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	4.00	4.40	4.93
T_2	S.T.L. *Rhizobium* @25 ml/ kg of seed.	4.00	4.60	4.93
T_3	S.T.L. *Rhizobium* and PSB@ 25 ml/ kg of seed each	4.00	4.73	4.93
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	3.93	4.53	4.80
T_5	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed	3.93	4.60	4.87
T_6	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	3.93	4.67	4.80
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	3.93	4.73	4.73
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each + 75% RDF	4.00	4.73	4.87
T_9	Recommended dose of fertilizers (control)	3.73	4.40	4.73
T_{10}	Absolute control	3.73	4.27	4.47
S.E. (m)±		0.08	0.12	0.12
C.D. (0.05)		NS	NS	NS

Effect on Dry Matter Weight of Plant: Dry matter weight was recorded treatment wise after harvest of the crop. The results as influenced by inoculation of *Rhizobium* for dry matter weight were tabulated in Table no. 4.7 and graphically represented in Fig. 4.7. All the treatments showed significantly higher dry matter weight in comparison with T_{10}: absolute control (26.67 g) as well as T_9: recommended dose of fertilizers/ control (26.80 g). The highest numerical value was recorded for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (34.57 g). It was statistically at par with all other inoculated treatments.

Ravikumar (2012) inoculated *Rhizobium* to *Vigna mungo* and *Vigna radiata* under pot culture conditions. He concluded that *Rhizobium* inoculation had higher dry weight as compared with respective controls, which was in congruence with present study Sulochana and Gadgi (2012) while working with Bengal gram, Green gram, and groundnut higher recorded significant enhancement in dry matter weight due to *Rhizobium* inoculation which was found concurrent to present study.

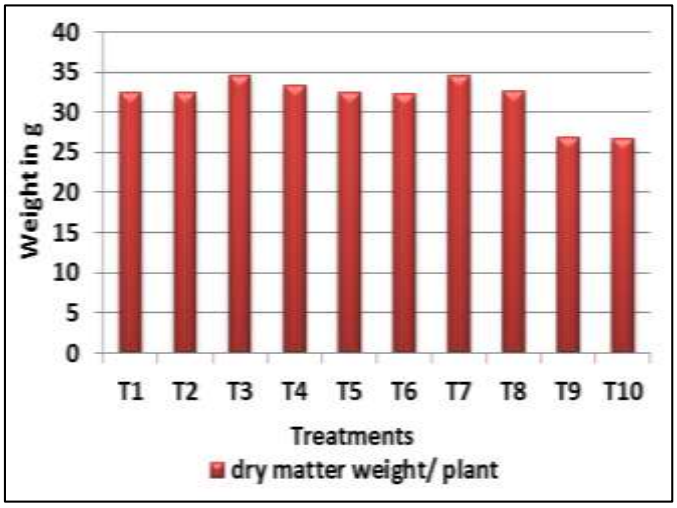

Fig 4.7: Effect of liquid formulations of *Rhizobium* inoculation on dry matter weight of mung bean.

Table 4.7: Effect of liquid formulation of *Rhizobium* inoculation on dry matter weight of mung bean.

Tr.	Treatment Details	Dry Matter Weight/plant (g)
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	32.50
T_2	S.T.L.PSB @ 25 ml/ kg of seed	32.40
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	34.57
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	33.33
T_5	S.T.C.B. *Rhizobium* @25 g/ kg of seed	32.53
T_6	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	32.33
T_7	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed each	34.50
T_8	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed each + 75% RDF	32.63

T_9	Recommended dose of fertilizers (control)	26.80
T_{10}	Absolute control	26.67
S.E. (m)±		0.55
C.D. (0.05)		1.63

Note: Recommended dose of fertilizers-common for T_1 to $T_3$and T_5toT_7)

Effect of Liquid *Rhizobium* Inoculation on Yield of Mung bean:

Effect on Number of Pods/ Plant: Number of pods from five randomly selected plants from each plot were harvested and counted for the data. The mean was obtained and further analyzed. The results as influenced by inoculation of *Rhizobium* were tabulated in Table no. 8. The graphical representation of the data was represented in Fig. 4.8.Number of pods as influenced by inoculation of biofertilizers ranged from 18.00 to 28.44. All the inoculated treatments were statistically significant over T_{10}: absolute control.

Similarly, all the inoculated treatments were statistically significant over T_9: recommended dose of fertilizers/ control (21.00). Numerically highest value was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (28.44). Among treatments of carrier-based biofertilizers highest number of pods numerically was yielded for T_7: S.T.C.B. *Rhizobium* @ 25 g/ kg of seeds each (28.30). Singh and Pareek (2003) conducted a trial with graded level of P_2O_5 and biofertilizers (*Rhizobium* -with or without) on mung bean. They observed that higher values were obtained for biofertilizers treatments. *Rhizobium* enhanced pods/plant as well as organic matter accumulation, branches/plant, nodules/plant, seed yield/ha. The results for present study concur with these findings. Bhuyan *et.al.* (2008) [11] inoculated five different varieties of mung bean with *BradyRhizobium*. It was concluded that inoculation significantly enhanced pods/ plant. These findings were similar to result of present study.

Elkoca *et al.* (2008) [27] reported higher number of pods with single, double, triple inoculation of *Rhizobium*, *Bacillus subtulis, B. megathrium* in chickpea. The present investigation showed similar trends.

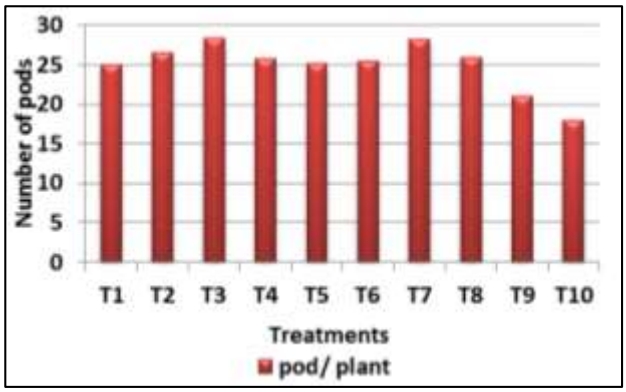

Fig 4.8: Effect of liquid formulations of *Rhizobium* inoculation on pods of mung bean.

Table 4.8: Effect of liquid formulation of *Rhizobium* inoculation on number of pods of mung bean.

Sr. No.	Treatment Details	Pods/Plant
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	25.00
T_2	S.T.L.PSB @ 25 ml/ kg of seed	26.56
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	28.44
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	25.73
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	25.15
T_6	S.T.C.B.PSB @ 25 g/ kg of seed	25.52
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	28.30
T_8	S.T.C.B. *Rhizobium*@ 25g/ kg of seed each + 75% RDF	26.00
T_9	Recommended dose of fertilizers/ control	21.00
T_{10}	Absolute control	18.00
S.E (m)±		1.18
C.D. (0.05)		3.55

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7

Effect on Yield/ha: The pods were harvested as per treatments in three harvests. The yield per plot was converted to per ha. Statistical analysis was carried out on per ha basis. The yield as influenced by *Rhizobium* inoculation ranged from 679.29 g to 912.01 g.

When converted to per ha basis, it ranged from 12.33 Quintal to 18.07 q/ ha. All the imposed treatments had significant influence over T_{10}: absolute control (12.33 q). Arithmetically and statistically highest value was recorded for T_3: S.T.L. *Rhizobium* @ 25 g/ kg of seeds each (18.07 q). Among carrier-based inoculations higher value was recorded for T_7: S.T.C.B. *Rhizobium* @ 25 ml/ kg of seeds each (17.16 q).

Oad *et al.* (2006) [37] reported that inoculation of *Rhizobium* enhanced yield up to dosage of 25 ml/ kg of seed of Soybean which was concurrent with present investigation. Chatha *et al.* (2017) [14] carried out trial with graded levels of fertilizers and biofertilizers (*Rhizobium*, PSB, and co-incubation) in mung bean. Significantly higher yield was obtained for co-inoculation of *Rhizobium* over control. Up to 19.14 % yield was enhanced.

The results obtained for present investigation showed similar trends. Yosemit *et al.* (2018) conducted a trial with chemical fertilizers and biofertilizers on two varieties of mung bean and concluded that inoculation of biofertilizers increased the yield of mung bean over the control plot. Results of present trial concur with this.

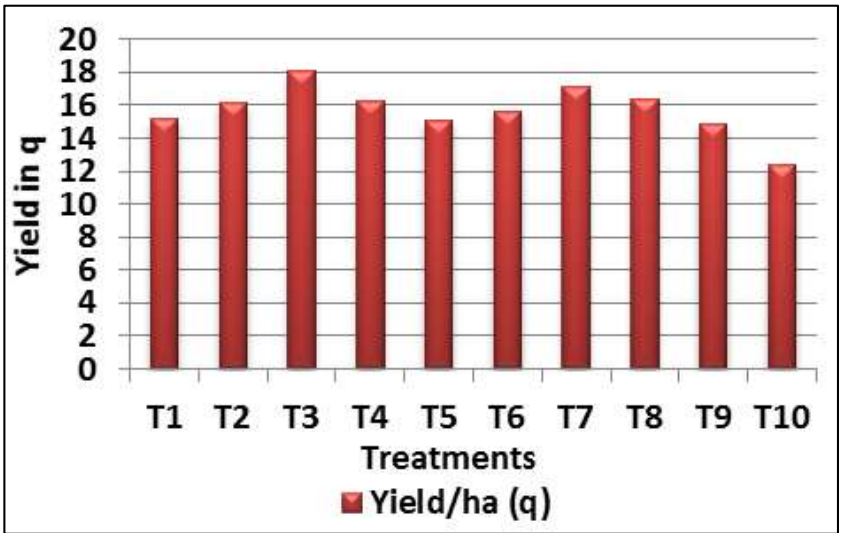

Fig 4.9: Effect of liquid formulations of *Rhizobium* inoculation on yield of mung bean.

Table 4.9: Effect of liquid formulation of *Rhizobium* inoculation on yield of mung bean.

Tr.	Treatment Details	Yield / Plot (g)	Yield/ ha (Q)
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	766.15	15.20
T_2	S.T.L.PSB @ 25 ml/ kg of seed	818.18	16.20
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	912.01	18.07
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	819.01	16.23
T_5	S.T.C.B. *Rhizobium* @ 25g/ kg of seed.	763.63	15.12
T_6	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	790.90	15.66
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	833.33	17.16
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each + 75% RDF	821.86	16.31
T_9	Recommended dose of fertilizers (control)	696.73	14.88
T_{10}	Absolute control	679.29	12.33
S.E (m)±			0.34
C.D. (0.05)			1.02

(Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7)

Effect on 1000 Seed Weight: The 1000 seed weight as influenced by inoculation of biofertilizers ranged from 33.73 g to 37.23 g. The results as imposed by inoculation of *Rhizobium* were tabulated in Table no.4.10 and graphically represented in Fig. 4.10. All the inoculated treatments were significant as compared over T_{10}: absolute control (33.73 g). As compared to T_9: recommended dose of fertilizers/control (33.93), all the imposed treatments were statistically significant. Arithmetically superior value was obtained for T_7: S.T.C.B. *Rhizobium* @ 25 g/ kg of seeds each (37.23 g) and T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed (37.23 g), but they were statistically at par with other inoculated treatments. Bhuvan *et al.* (2008) inoculated *BradyRhizobium* to mung bean seeds. The 1000 seed weight along other yield attributing characters significantly enhanced over the control. Similar results were obtained for present study.

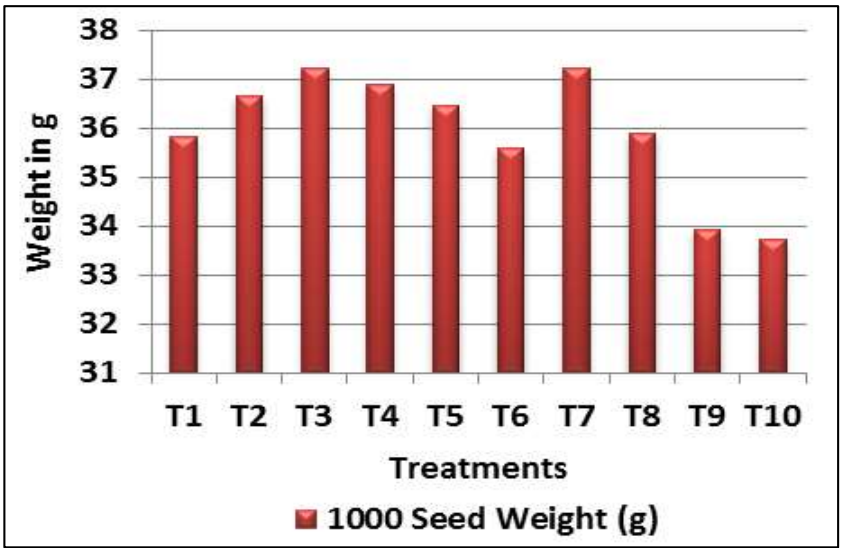

Fig 4.10: Effect of liquid formulations of *Rhizobium* inoculation on 1000 seed weight of mung bean

Table 4.10: Effect of liquid formulation of *Rhizobium* inoculation on 1000 seed weight of mung bean.

Tr.	Treatment Details	1000 Seed Weight (g)
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	35.83
T_2	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	36.67
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	37.23
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	36.90
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed	36.47
T_6	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed.	35.60
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	37.23
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each + 75% RDF	35.90
T_9	Recommended dose of fertilizers (control)	33.93
T_{10}	Absolute control	33.73
	S.E (m) ±	0.42
	C.D. (0.05)	1.36

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7

Effect of Liquid *Rhizobium* Inoculation on Microbial Population Dynamics of Mung bean:

Effect on *Rhizobium* Population: *Rhizobium* population was enumerated at 10^{-6} dilution by serial dilution technique. The *Rhizobium* population showed upward trend during initial period of crop growth and then declined towards harvest of the crop. The results as influenced by inoculation of *Rhizobium* were tabulated in Table no. 4.11 and graphically represented in Fig. 4.11

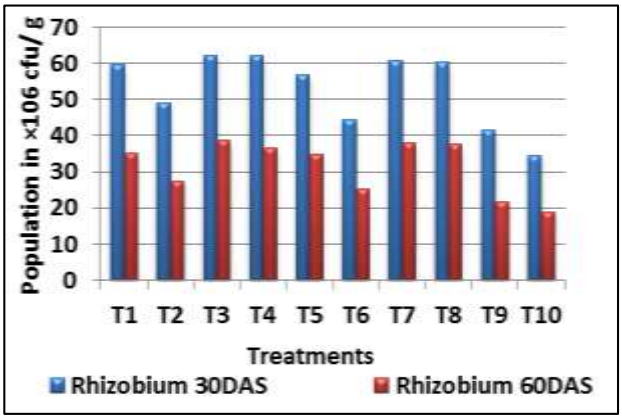

Fig4.11: Effect of liquid formulations of *Rhizobium* inoculation on

Table 4.11: Effect of liquid formulation of *Rhizobium* inoculation on *Rhizobium* population in mung bean

Tr.	Treatment Details	*Rhizobium* 30DAS×10^6 cfu/ g	*Rhizobium* 60DAS×10^6 cfu/ g
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	59.67	35.33
T_2	S.T.L.*Rhizobium* @ 25 ml/ kg of seed	49.10	27.53
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	62.33	38.78
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	62.10	36.55
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed.	57.00	34.96
T_6	S.T.C.B.*Rhizobium* @ 25g/ kg of seed	44.44	25.33
T_7	S.T.C.B. *Rhizobium*@ 25 ml/ kg of seed each	60.89	37.89
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each+ 75% RDF	60.33	37.55
T_9	Recommended dose of fertilizers (control)	41.67	21.67
T_{10}	Absolute control	34.55	19.00
	S.E. (m)±	2.66	1.70
	C.D. (0.05)	7.98	5.10

Note: 1. Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7

Population 30 days after sowing: *Rhizobium* population as influenced by inoculation of *Rhizobium* ranged from 34.55 × 10^6 cfu/ g to 62.33 × 10^6 cfu/ g. All the treatments as inoculated with *Rhizobium* alone or along with PSB showed significantly higher population of *Rhizobium* over T_{10}: absolute control (34.55× 10^6 cfu/ g) as well as T_9: recommended dose of fertilizers (41.67× 10^6 cfu/ g). Highest numerical value was recorded for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (62.33 × 10^6 cfu/g), but it was statistically at par with other *Rhizobium* inoculated treatments.

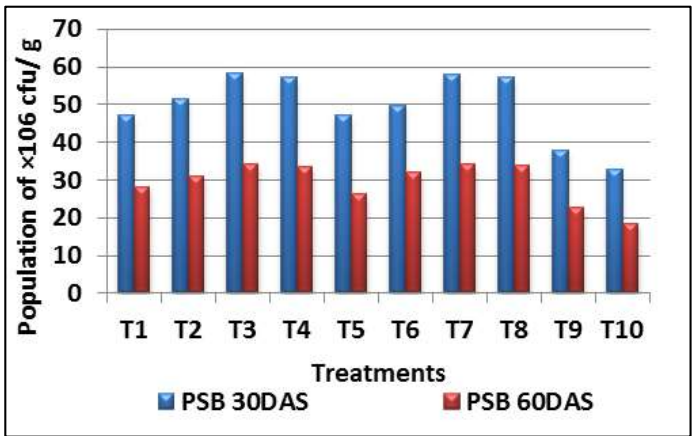

Fig 4.12: Effect of liquid formulations of *Rhizobium* inoculation on *RHIZOBIUM* population in mung bean

Table 4.12: Effect of liquid formulation of *Rhizobium* inoculation on population of *Rhizobium* in mung bean

Tr.	Treatment Details	PSB 30DAS×10^6 cfu/g	PSB 60DAS×10^6 cfu/g
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	47.33	28.33
T_2	S.T.L.PSB @25 ml/ kg of seed.	51.67	31.22
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	58.56	34.33
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	57.20	33.44
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed.	47.44	26.33
T_6	S.T.C.B.*Rhizobium* @ 25 g/ kg of seed.	49.89	32.00
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	58.00	34.22
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each+ 75% RDF	57.22	33.89
T_9	Recommended dose of fertilizers (control)	38.00	22.67
T_{10}	Absolute control	33.00	18.67
	S.E. (m)±	1.30	1.50
	C.D. (0.05)	3.88	4.49

Note: 1. Recommended dose of fertilizers will be common for T_1 to T_3 and T_5 to T_7)

***Rhizobium* population 60 days after sowing:** Population of *Rhizobium* declined at 60 days after sowing as compared to population at 30 days after sowing.

Rhizobium population as influenced by inoculation of *Rhizobium* ranged from 19 × 10^6 cfu/ g to 38.78 × 10^6 cfu/ g. All the treatments as inoculated with *Rhizobium* alone or along with PSB showed significantly higher population of *Rhizobium* over T_{10}: absolute control (19 × 10^6 cfu/ g) as well as T_9: recommended dose of fertilizers (21.67× 10^6 cfu/ g).

Highest numerical value was recorded for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seeds each (38.78 × 10^6 cfu/ g), but it is statistically at par with other *Rhizobium* inoculated treatments. Awasthy *et al.* (2017) [6] recorded PSB+ *Azospirillum* and humic acid and fish amino acid resulted in increased general as well as beneficial microbial population in soil rhizosphere.

Biofertilizers increase microbial fauna and improve soil health for better growth of plant.

The result obtained during this investigation was found to resemble present investigation of inoculation of *Rhizobium* to mung bean seeds as a seed treatment before sowing of the crop.

Effect of *Rhizobium* Inoculation on Chemical Properties of Soil: Initial Nitrogen in soil: 135.7 kg/ ha and Initial Phosphorous in soil: 9.27 kg/ ha Available Nitrogen and phosphorus were analyzed before sowing and after harvesting. Results obtained were tabulated in Table no. 4.13.

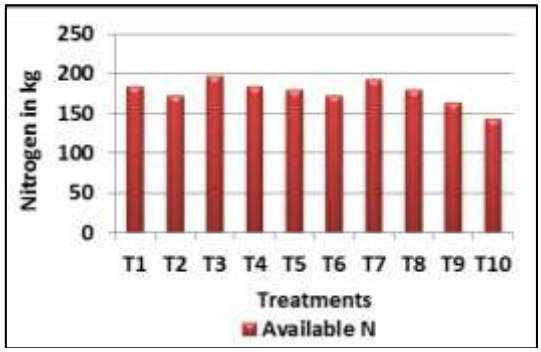

Fig 4.13.1: Effect of liquid formulations of *Rhizobium*inoculation on available N in soil of mung bean

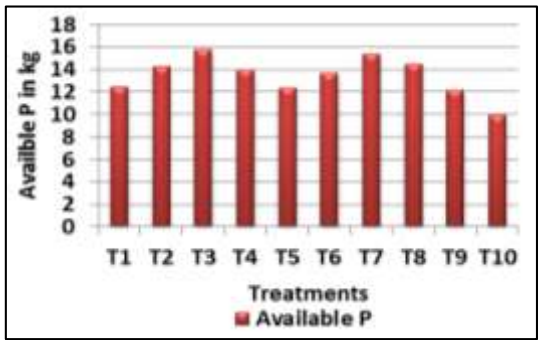

Fig 4.13.2: Effect of liquid formulations of *Rhizobium*inoculation on available P in soil of mung bean.

Table 4.13: Effect of liquid formulation of *Rhizobium*inoculation on available N and P in mung bean

Tr.	Treatment Details	Available Nitrogen (Kg/ha)	Available Phosphorous (Kg/ha)
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	183.99	12.46
T_2	S.T.L.*Rhizobium* @25 ml/ kg of seed	171.50	14.26
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	196.53	15.73
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	183.98	13.99
T_5	S.T.C.B. *Rhizobium*@ 25g/kg of seed.	179.80	12.36
T_6	S.T.C.B.*Rhizobium* @ 25g/kg of seed.	171.52	13.68
T_7	S.T.C.B. *Rhizobium*@25g/kg of seed each	192.36	15.42
T_8	S.T.C.B. *Rhizobium*@ 25g/kg of seed each + 75% RDF	179.87	14.51
T_9	Recommended dose of fertilizers (control)	162.62	12.11
T_{10}	Absolute control	142.25	9.91
	S.E (m)±	5.01	0.39
	C.D. (0.05)	15.01	1.16

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5toT_7

Available Nitrogen Content in Soil at Harvest: Available N content in soil showed significant impact with imposed treatments over T_{10}: absolute control (142.26 kg). Arithmetically highest value was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (196.53 kg), but it was statistically at par with other co-inoculated treatments.

Available Phosphorus Content in Soil: All the imposed treatments showed significant increase in available Phosphorus as compared to T_{10}: absolute control (9.27 kg/ ha). All the PSB inoculated treatments showed statistical significance over T_9: recommended dose of fertilizers/ control (12.11 kg/ ha).Highest numerical value was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (15.73 kg/ha), but it was statistically at par with T_7: seed treatment with carrier-based *Rhizobium* @ 25 ml/ kg of seed each (15.42 kg/ ha). Sundara *et al*. (2003) concluded that inoculation of B. megatherium var. phosphticum increased available P status in soil. The present findings showed similar trend. Singh and Rai (2004) concluded that inoculation of biofertilizers along with RDF enhanced soil available N, P, K in soil in soybean crop. Findings of present research concurred with it.

Effect of *Rhizobium* Inoculation on Nitrogen and Phosphorous Uptake by Mung bean: Crushed grains and dried plant sample was analyzed separately and nutrient uptake was calculated. The data for nutrient uptake by grain and plant sample was compiled and statistically analyzed. Result obtained were mentioned in Table no.4.14 and graphically represented in Fig. 4.14.

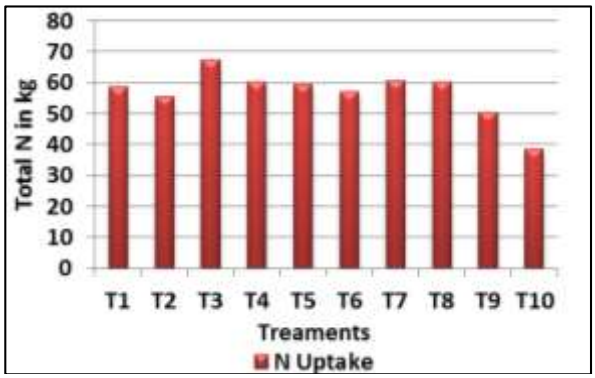

Fig 4.14.1: Effect of liquid formulations of *Rhizobium*inoculation on total N in soil of mung bean.

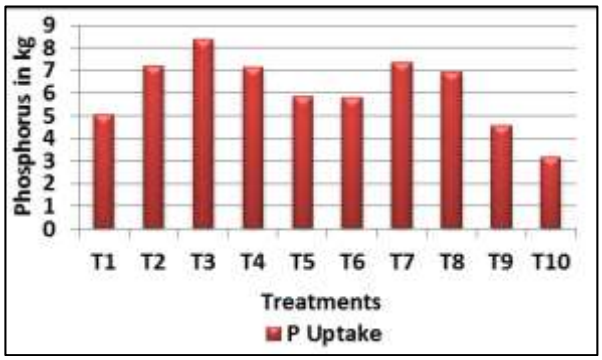

Fig 4.14.2: Effect of liquid formulations of *Rhizobium*inoculation on total P in soil of mung bean.

Table 4.14: Effect of liquid formulation of *Rhizobium*inoculation on N and P uptake in mung bean

Tr.	Treatment Details	N Uptake (Kg/ha)	P Uptake(Kg/ha)
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	58.72	5.07
T_2	S.T.L.PSB @25 ml/ kg of seed	55.55	7.22
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	67.16	8.36
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	60.14	7.14
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed.	59.24	5.87
T_6	S.T.C.B.PSB @ 25 g/ kg of seed.	57.16	5.83
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	60.71	7.37
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each+ 75% RDF	60.21	6.95
T_9	Recommended dose of fertilizers (control)	50.52	4.58
T_{10}	Absolute control	38.48	3.16
	S.E. (m)±	2.33	0.27
	C.D. (0.05)	6.97	0.80

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5 toT_7

Effect on N uptake: All the imposed treatments showed significantly higher uptake of N at harvest as compared to T_{10}: absolute control (38.48 kg/ ha).T_2: S.T.L. *Rhizobium* @ 25 ml/ kg of seed (55.55kg/ ha) was statistically at par with T_9: recommended dose of fertilizers/ control (50.72 kg/ ha). All other treatments were statistically significant over T_9:

recommended dose of fertilizers/ control. T_3: S.T.C.B. *Rhizobium* @ 25 ml/ kg of seed each (67.16 kg/ ha) had numerically high value, but was statistically at par with other *Rhizobium* inoculated treatments.

Effect on P uptake: The P uptake as influenced by *Rhizobium* inoculation ranged from 3.16 kg/ ha to 8.36 kg/ ha. All the imposed treatments showed significantly higher P uptake as compared to T_{10}: absolute control (3.16 kg/ ha). Similarly, all the *Rhizobium* inoculated treatments showed statistically significant P uptake as compared to T_9: recommended dose of fertilizers/ control (4.58 kg/ ha). The highest arithmetic value was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (8.36 kg/ ha). Among carrier-based treatments highest value was obtained for T_7: S.T.C.B. *Rhizobium* @ 25 ml/ kg of seed each (7.37 kg/ha). But it was at par with T_7: S.T.C.B. *Rhizobium* @ 25 g/ kg of seed each + 75% RDF (6.95 kg/ ha) and T_2:T_7: S.T.L. *Rhizobium* @25 ml/ kg of seed (7.22 kg/ ha).
Jat and Ahlawat (2008) inoculated chickpea with *Rhizobium.* They observed that inoculation of *Rhizobium* significantly enhanced N and P uptake by plant over control. The results of present study concur with these findings. Bahati *et al.* (2012) [7] concluded that *BradyRhizobium japonicum* enhanced N and P uptake in Soybean which was found to be in concurrence with present study. Gangaraddi and Brahmaprakash (2018) revealed that microbial inoculants in liquid formulation influenced more growth and nutrient uptake in mung bean when compared to other test formulations used in their study. These findings were in congruence with results of present study.

Benefit Cost Ratio: Cost benefit economics of treatments was calculated after harvest of the crop. The values were enumerated in Table no. 15.The cost of cultivation for mung bean as influenced by *Rhizobium* ranged from Rs. 69,086 to Rs. 79,890. Gross returns varied from Rs. 86,310 to Rs.1, 26,490. Highest gross returns were received for T_3: S.T.L. *Rhizobium* @ 25 g/ kg of seed each (Rs. 1, 26,490).
Net returns were highest for T_7: S.T.L. *Rhizobium* @ 25 g/ kg of seed each (Rs.53, 134) and lowest for T_{10}: absolute control (Rs. 21,815). All inoculated treatments had numerically higher value for net returns as compared over T_9: recommended dose of fertilizers/ control (Rs.30, 102).B: C ratio varied from 1.19 to 1.72. The highest B: C ratio was obtained for T_3: S.T.L. *Rhizobium* @ 25 ml/ kg of seed each (1.72) and least for T_{10}: absolute control (1.19). Meena *et al.* (2015) [35] conducted a field experiment to study effect of bio-inorganic nutrient combinations on yield, quality and economics of mung bean. Net highest returns were obtained with application 100% RDF+ *Rhizobium* + PSB rupees 52894.74. The result for net returns concurred with present findings.

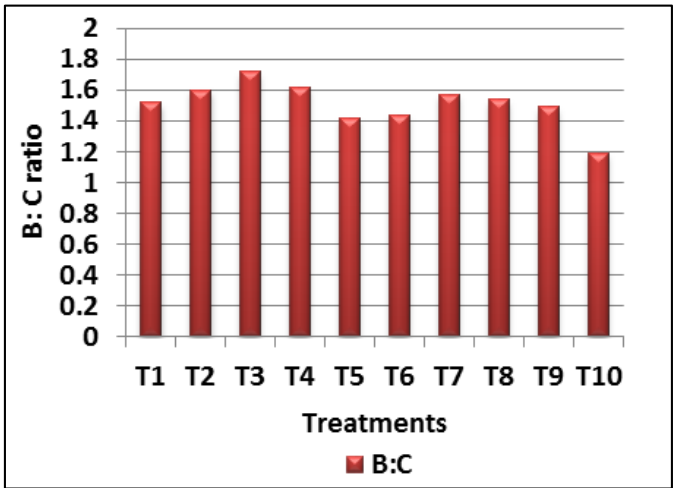

Fig 4.15: Effect of liquid formulations of *Rhizobium* inoculation on B:C ratio in soil of mung bean.

Table 4.15: Effect of liquid formulation of *Rhizobium* inoculation on economics of *Rhizobium* in mung bean

Tr.	Treatment Details	Cost of Cultivation	Gross Returns	Net Returns	B:C
T_1	S.T.L. *Rhizobium* @ 25 ml/ kg of seed	69,984	1,06,407	36,423	1.52
T_2	S.T.L.PSB @25 ml/ kg of seed	70,665	1,13,400	42,735	1.60
T_3	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each	73,356	1,26,490	53,134	1.72
T_4	S.T.L. *Rhizobium*@ 25 ml/ kg of seed each+ 75% RDF	69,086	1,11,610	42,524	1.62
T_5	S.T.C.B. *Rhizobium* @ 25 g/ kg of seed.	74,615	1,05,840	31,225	1.42
T_6	S.T.C.B.PSB @ 25 g/ kg of seed.	75,866	1,09,620	33,754	1.44
T_7	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each	79,890	1,15,500	35,610	1.57
T_8	S.T.C.B. *Rhizobium*@ 25 g/ kg of seed each+ 75% RDF	74,017	1,14,170	40,132	1.54
T_9	Recommended dose of fertilizers/ control	70,068	1,04,160	30,102	1.49
T_{10}	Absolute control	72,335	86,310	21,815	1.19

Note: Recommended dose of fertilizers-common for T_1 to T_3 and T_5 toT_7. Mung bean price- Rs. 70/ kg

5. Summary and Conclusion: The present investigation was carried out to study effect of liquid biofertilizers on growth and yield of mung bean. The study shows that growth, yield attributing characters and yield itself is increased by inoculation of *Rhizobium* inoculants. *Rhizobium* is capable of increasing soil physical, chemical and biological characteristics. *Rhizobium* fixes nitrogen enhancing nutrient availability to the crop. This is concurring to yield enhancement of crop. The study was carried out at an experimental field of Plant Pathology and Agricultural

Microbiology section, College of Agriculture, Pune in *Kharif*, 2019. The results of present study are summarized below.

The growth and yield parameters like germination percentage, number of leaves per plant, root nodules per plant, plant height, dry matter weight of plant, leaf area index, pods per plant, 1000 seed weight was recorded for inoculation of liquid *Rhizobium*. The yield per plot was recorded after harvest of the crop. Total *Rhizobia* count was evaluated initially, 30 and 60 days after sowing. The nitrogen and phosphorous content from grains and Stover was analyzed. The initial nitrogen and phosphorous content of soil along with available nitrogen and phosphorous content in soil was also evaluated.

The significant results were obtained for germination percentage. Seed treatment of carrier-based *Rhizobium* 25g/kg of seed each (90.96%), Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each (90.35%), Seed treatment of carrier-based *Rhizobium* 25g/kg of seed each+75% RDF (89.50%) was significantly higher as compared with un inoculated control (85.57%) and absolute control (84.56%).

The number of leaves was not significantly affected at 30 days after sowing but results was significant at 45 days after sowing and at harvest. The treatments with either inoculation with *Rhizobium* show significantly higher leaves per plant when compared with un-inoculated control. Number of leaves ranged from 13.200 to 16.067 at 45 DAS and 13.667 to 16.467 at harvest. Number of root nodules and effective number of root nodules with *Rhizobia* treatments significantly enhanced un-inoculated control and absolute control. Highest effective root nodules were recorded for Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each +75% RDF (43.500). The treatments T_1, T_3, T_5, T_7, T8are at par with it. The least number of effective root nodules were recorded for absolute control (25.167). Effect of liquid *Rhizobium* on plant height is also found to be significant at 30DAS, 45DAS and at harvest. The highest plant height was recorded for Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each (T_3), which is at par with T_7, T_8,T_4,T_2, T_1at all the stages of crop growth and superior to un -inoculated control and absolute control.

Dry matter weight ranged from 26.667 g to 34.567 g and significant result were obtained for Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each (34.567g). Treatments *viz.* T_7, $T_{2\ are}$ at par with it and superior over other treatments. The least dry matter weight was recorded for un-inoculated control. The number of branches was counted at 30, 45 days after sowing and harvest.

At every stage there is no significant increase in number of branches in mung bean. At harvest highest number of branches is seen in Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each (4.933) the least number of branches are observed in absolute control (4.467).

The leaf area index is found significant when calculated at flowering stage. The values for LAI ranged from 3.707 to 5.447. Seed treatment of carrier-based *Rhizobium* 25g/kg of seed each (5.447) had highest LAI, which is at par with T_3.The lowest LAI is recorded for absolute control (3.707).

Number of pods per plant significantly enhanced by inoculation of *Rhizobium.* Highest number of pods for Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seeds each (28.440), which is at par with Seed treatment of carrier-based *Rhizobium* 25g/kg of seed each (28.300). UN inoculated control (23.000) Absolute control is inferior to all other treatments (22.900). Grain yield also show similar trend wherein for Seed treatment with liquid *Rhizobium* @ 25 ml/kg of seed each (17.895Qtl/ha) and Seed treatment of carrier-based *Rhizobium* 25g/kg of seed each (17.827Qtl/ha) are superior to other inoculated treatments as well as controls. All the other inoculation treatments are at par and superior to UN inoculated control and absolute control. The yield per plot and effectively yield per ha increased from 11.71 % to 32.19% over absolute control and 9.90% to 29.44 % over un-inoculated control. Nitrogen and phosphorous content from seeds and Stover also significantly enhanced along with available nitrogen and phosphorous content from soil.

From the present findings it could be concluded that

1. Inoculation of liquid formulation of *Rhizobium* significantly enhanced soil microbial population of *Rhizobium* leading to nitrogen fixation.
2. Inoculation of liquid formulations of *Rhizobium* enhanced N and P uptake by mung bean plant as well as availability of N and P in soil.
3. Application of liquid formulations of *Rhizobium*shown positive influence on growth promoting characters like germination percentage, plant height, number of root nodules per plant, number of leaves per plant, dry matter weight. And yield attributing characters like number of pods per plant, 1000 seed weight and yield it.

Plate 4.3: Effect of liquid formulations oh *Rhizobium* inoculation on height of mung bean.T_3: S.T.L. *Rhizobium* @ 25 ml/kg of seed each T_{10}: absolute control

Plate 4.4: Effect of liquid formulations oh *Rhizobium* inoculation on root nodules of mung bean.T_3: S.T.L. *Rhizobium* @ 25 ml/kg of seed eachT_{10}: absolute control

Plate 4.5: Effect of liquid formulations oh *Rhizobium* inoculation f on pods of mung bean.T_3: S.T.L. *Rhizobium* @ 25 ml/kg of seed eachT_{10}: absolute control

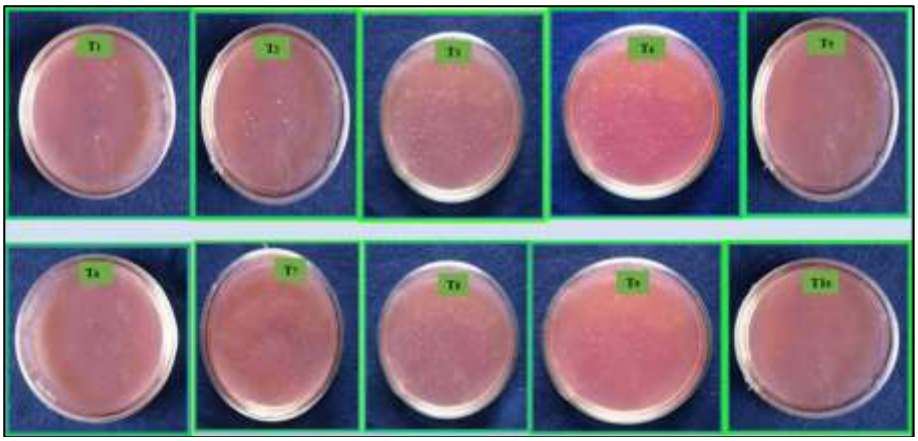

Plate 4.6: Effect of liquid formulations of *Rhizobium* inoculation on *Rhizobium* population at 30 days after sowing.

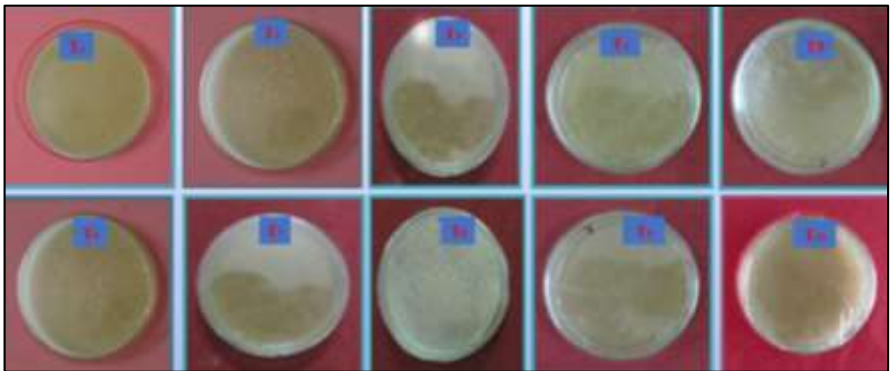

Plate 4.7: Effect of liquid formulations of *Rhizobium* inoculation on *Rhizobium* population at 30 days after sowing.

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