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Effect of Liquid Formulations of PSB Inoculation on Growth and Yield of Mung Bean

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A B S T R A C T

The present study entitled "Effect of liquid formulations of PSB on growth and yield of mung bean" was carried out at Department of Plant Pathology and Agricultural Microbiology, College of Agriculture, Pune. The mung bean variety used for experiment was '*Vaibhav'*. The objectives for present research were to study the effect of liquid formulations of PSB 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 PSB. There were ten treatments. These include seed treatment with liquid *PSB* @ 25ml/kg of seed, Seed treatment with liquid PSB@ 25ml/kg of seed, seed treatment with liquid PSB@ 25 ml/kg of seed each, seed treatment with liquid PSB@ 25 ml/kg of seed each +75% of recommended dose of fertilizers, seed treatment of carrier based *PSB* @ 25g / kg of seed, seed treatment of carrier based PSB @ 25g / kg of seed, seed treatment of carrier based PSB25g/kg of seed each, seed treatment of carrier based PSB25g/kg of seed each+75% recommended dose of fertilizers. The tenth treatment is absolute control. Each treatment is replicated three times in Randomized Block Design. The liquid formulations of PSB show positive effect on soil chemical, physical and microbial properties. There was ascendance in trend of population of PSB in soil which show descending trend as crop approaches maturity. Available nitrogen and phosphorus increased from initial stage of crop growth to harvest. After considering all the parameters, inference could be drawn that PSB application enhance the growth leading to increase in yield of mung bean. It was observed that T_3: S.T.L. liquid PSB @ 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. It was followed by T_7: S.T.C.B. PSB each for above parameters. Above investigation concluded that inoculation of liquid formulation of PSB enhanced growth as well as yield of mung bean. Population of PSB 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. Available N and P from soil at harvest also showed significant increase over absolute control. Ultimately higher net returns and B: C ratio was obtained for liquid bioinoculants.

Introduction

The mung bean (*Vigna radiata* L.) is one of the most important edible legume crops, grown on more than 6 million ha worldwide (about 8.5% of the global pulse area) and consumed by most households in Asia. Due to its characteristics of relatively drought-tolerant, low-input crop, and short growth cycle, the mung bean is widely cultivated in many Asian countries It has been known to be an excellent source of protein, dietary fiber, minerals, vitamins, and significant amounts of bioactive compounds, including polyphenols, polysaccharides, and peptides, therefore, becoming a popular functional food in promoting good health. India is the world largest homeland of vegetarian population and world leader in pulse production and import to provide protein supplements (Singh *et al.*, 2012).

Rapid population growth and low production especially of pulses have enhanced the problem of food security. Indian pulse production has been stuck in between 14 and 15 Mt since mid-nineties, resulting in poor consumption (33 g/capita/ day) during 2010 (Ali and Gupta, 2012). In the wake of these circumstances, it can be said that given due importance, mungbean can play a major role in the national economy of India due to their wider adaptability, easy digestibility, better palatability and higher market price (Patil *et al.*, 2003, Ramakrishna *et al.*, 2000 and Reddy, 2009)

Biofertilizers may also be defined as microbial inoculants which are artificially multiplied cultures of certain soil microorganisms that can improve soil fertility and crop productivity. Biofertilizers are low cost renewable sources of plant nutrients which supplement chemical fertilizers. Biofertilizers generate plant nutrients like nitrogen and phosphorous through their activities in the soil or rhizosphere and makes them available to the plants on the soil. Thus in this research the investigation has been carried in the isolation of phosphate solubilising bacteria from rhizosphere soil and then grown in selective media and finally used to check its effect on mung production by PSB bacteria in it.

Materials and 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 121.5^0C for 15 minutes in autoclave (American Society of Bacteriologist, 1957)

Methods of soil analysis: Methods used for soil analysis were given in table 1.

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

Field trial: Treatment details

Season	: *Kharif*, 2019
Crop	: Mung bean
Variety	: *Vaibhav*
Spacing	: 30 cm x 10 cm
Plot size	: Gross : 2.40 m x 2.10 m Net : 1.80 m x 1.90 m
Experimental design	: Randomized Block Design
Treatments	: 10
Replications	: 3
Recommended fertilizers	: 20:40:00 N:P: K kg/ ha

Treatments

T_1 : Seed treatment with liquid *PSB* @ 25ml/kg of seed; T_2 : Seed treatment with liquid PSB@ 25ml/kg of seed; T_3 : Seed treatment with liquid PSB@ 25 ml/kg of seed each; T_4 : Seed treatment with liquid PSB@ 25 ml/kg of seed each +75% RDF; T_5 :Seed treatment of carrier based *PSB* @ 25g/ kg of seed; T_6 : Seed treatment of carrier based PSB @ 25g/ kg of seed; T_7 :Seed treatment of carrier based PSB25g/kg of seed each; T_8 :Seed treatment of carrier based PSB25g/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

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

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. Numbers of individual leaves were 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: PSB count recorded at sowing, 30DAS, 60DAS using serial dilution and pour plate technique (Subba Rao, 1999). The soil sample was collected from rhizosphere of crop. PSB count was taken on Pikowaskaya's media at 10 -5 dilution. Used as growth media. After serial dilution and pour plating incubation at 28±2ºC was done. Colonies were counted at 10 -5 dilution.

Formula for PSB population from one gram of soil is

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

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 (Olsen *et al*, 1965).

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±2ºC. 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) 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 PSB 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 herein and discussed with earlier reports (Table 1 and 2).

Effect of liquid PSB inoculation on growth of mung bean

Effect on seed germination: The germination was recorded at 7 days after sowing. Germination percentage was recorded and mean of three replications calculated. The results as influenced by PSB inoculation were presented in Table 3. The graphical representation of results was mentioned in Fig. 1. Inoculation of PSB 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. *PSB* kg of seed (87.06%) and T_1: S.T.L. *PSB*@ 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. PSB25 g/ kg of seed each (90.96%) had highest arithmetic value for germination, but it was statistically at par with T_7: S.T.L. PSB@ 25 ml/ kg of seed each (90.35%), T_4: S.T.L. PSB25 g/ kg of seed each+75% RDF (89.50%). Treatments as T_2: S.T.L. PSB@ 25 ml/ kg of seed (88.34%), T_2: S.T.L. PSB@ 25 ml/ kg of seed (88.34%) and T_6: S.T.C.B. PSB @ 25g/ kg of seed (87.88%) was statistically at par with each other and was next best set of treatments.

The results concurred with Duarah *et al.*, (2011), who studied effect of PSB and consortia on rice and *Vigna ungiculata* seeds. The research findings concluded that germination index increased from 2.7 to 4.8 with inoculation of PSB and consortia over control without external application of N, P, and K.

Effect on number of leaves per plant: The number of leaves was recorded at 30, 45 days after sowing and at harvest. The mean number of leaves per plant as affected by liquid formulation of PSB inoculation were tabulated in Table 4 and graphically presented in Fig. 2.

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. *PSB*@ 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.PSB @ 25g/ kg of seed (14.53) and T_4: S.T.L. PSB@ 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 PSB @ 25 g/ kg of seed (14.53) and the T_4: S.T.L. PSB @ 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. PSB @ 25 ml/ kg of seed 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 PSB 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. *PSB* @ 25 ml/ kg of seed (16.067) and T_3: S.T.L. PSB@ 25 ml/ kg of seed each, but they were statistically at par with rest of the inoculated treatments. Singh *et al.*, (2008) carried out research with fertilizer sources and levels of P_2O_5 with or without PSB. Significant results were obtained for 40 kg/ ha P_2O_5 + PSB inoculation over control. This was in congruence with results of present investigation.

Leaf area index: The LAI as influenced by PSB was measured at 45 days after sowing. The results as influenced by inoculation of PSB were tabulated in Table 5 and graphically represented in Fig. 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. PSB @ 25 g/ kg of seed each (5.45), but it was statistically at par with T_7: S.T.C.B. PSB@ 25 ml/ kg of seed each (5.37). Dhakal *et al.,* (2015) concluded that 75% RDF + 2.5 t/ ha vermicompost + *PSB* + PSB and 100% RDF + *PSB* + 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 PSB. The result for LAI for present investigation showed similar trends in LAI for PSB inoculation.

Effect on height of plant: Plant height as influenced by PSB recorded at 30 DAS, 45 DAS and at harvest. The mean plant height as affected by liquid formulation of PSB inoculation was tabulated in Table 6 and graphically presented in Fig. 4.

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. PSB @ 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 PSB showed significantly higher plant height as compared to T_9: recommended dose of fertilizers/ control (49.85 cm). T_3: S.T.L. PSB @ 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. PSB @ 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), in trial with graded level of P and biofertilizers (PSB- 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.

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 PSB were tabulated in Table 7 and graphically represented in Fig. 5.

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. PSB @ 25 ml/ kg of

seed each (4.73), T_7: S.T.C.B. PSB @ 25 g/ kg of seed each (4.73), T_8: S.T.C.B. PSB @ 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. PSB@ 25 ml/ kg of seed each (4.93), T_5: S.T.C.B. *PSB* @ 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 PSB were tabulated in Table 8 and graphically represented in Fig. 5.

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. PSB @ 25 ml/ kg of seed each (43.50). It was statistically at par with T_1: S.T.L. *PSB* @ 25 ml/ kg of seed (42.17), and other co-inoculation treatments.

Bahati (2012) conducted a trial of *Bradyrizobium* inoculation on soybean nodulation. It was concluded by him that inoculation of *BradyPSB* significantly enhanced root nodules over control. Present study also showed similar results for nodulation. Patel and Ajay kumar (2014) concluded that combined inoculation of PSB significantly increased nodules in mung bean over control. The results were similar to present study.

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 PSB for dry matter weight were tabulated in Table 9 and graphically represented in Fig. 6.

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. PSB @ 25 ml/ kg of seed each (34.57 g). It was statistically at par with all other inoculated treatments. Rani *et. al.,* (2016) during investigation with inoculation of PSB to mung bean concluded that inoculation enhanced dry matter weight of plants significantly over control plot. Similar findings were observed in present study.

Effect of liquid PSB 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 PSB were

tabulated in Table 10. The graphical representation of the data was represented in Fig. 7. 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. PSB @ 25 ml/ kg of seed each (28.44). Among treatments of carrier-based biofertilizers highest number of pods numerically was yielded for T_7: S.T.C.B. PSB @ 25 g/ kg of seed each (28.30).

Hasan *et al.,* (2017) inoculated *Bacillus polimyxa* and *Pseudomonas striata* to mung bean. They found that pods / plant increased with inoculation of mentioned strains of phosphorous solubilizing bacteria over the control. Present study also concludes shows similar trends. Singh and Pareek (2003) conducted a trial with graded level of P_2O_5 and biofertilizers (PSB-with or without) on mung bean. They observed that higher values were obtained for biofertilizers treatments. PSB 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) 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) reported higher number of pods with single, double, triple inoculation of *Rhizobium*, *Bacillus subtilis*, *B. megathrium*in chickpea. The present investigation showed similar trends. Singh *et al.,* (2008) observed significant increase in number of pods in PSB inoculated plant over control in mung bean. The similar results were obtained for present study. Rani *et. al.* (2016) recorded that pods per plant with PSB inoculation significantly increased over control in mung bean. Present findings concurred for PSB inoculation to mung bean.

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 PSB 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 (12.33q). Arithmetically and statistically highest value was recorded for T_3: S.T.L. PSB @ 25 g/ kg of seed each (18.07 q). Among carrier-based inoculations higher value was recorded for T_7: S.T.C.B. PSB @ 25 ml/ kg of seed each (17.16 q). Patel and Ajay kumar (2014) found that co-inoculation of PSB in mung bean crop increased its yield over the control. The findings concur with present study.

Chatha *et al.,* (2017) 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 PSB over control. Up to 19.14 % yield was enhanced. The results obtained for present investigation showed similar trends. Yousefi *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. 8).

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 PSB

were tabulated in Table 11 and graphically represented in Fig. 9.

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. PSB @ 25 g/ kg of seed each (37.23 g) and T_3: S.T.L. *Rhizobium* + PSB @ 25 ml/ kg of seed (37.23 g), but they were statistically at par with other inoculated treatments. Hasan *et al.*, (2017) worked with two species of PSB *Pseudomonas striata* and *Bacillus polimyxa* on mung bean. Results revealed that inoculation of PSB increased 1000 seed weight (10.07-35.83%) over uninoculated control. Present study concurred with these findings.

Table.1 Methods used for soil analysis

Parameter	Method	References
A) Chemical Properties:		
Available N	Alkaline permanganate method	Subbiah and Asija(1956)
Available P	0.5M $NaHCO_3$ Olsen's method	Olsen *et al*. (1965)
B) Biological Properties		
Total PSB 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)

Table.3 Effect of liquid formulation of PSB inoculation on seed germination of mung bean

Tr.	Treatment Details	Mean Germination Percent
T_1	S.T.L. PSB @ 25 ml/ kg of seed	87.11
T_2	S.T.L. PSB@ 25 ml/ kg of seed	88.34
T_3	S.T.L. PSB@ 25 ml/ kg of seed each	90.96
T_4	S.T.L. PSB@ 25 ml/ kg of seed each+75% RDF	89.50
T_5	S.T.C.B. PSB @ 25g/kg of seed	87.06
T_6	S.T.C.B. PSB @ 25g/kg of seed	87.88
T_7	S.T.C.B. PSB @ 25g/kg of seed each	90.35
T_8	S.T.C.B. PSB @ 25g/kg of seed each+75% RDF	88.42
T_9	Recommended dose of fertilizers (control)	85.57
T_{10}	Absolute control	856
S.E. (m)±		**0.56**
C.D. (0.05)		**1.66**

Table.4 Effect of liquid formulation of PSB inoculation on number of leaves of mung bean

Tr.	Treatment Details	30DAS	45DAS	At harvest
T_1	S.T.L. PSB @ 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. PSB@ 25 ml/ kg of seed each	100	16.07	16.47
T_4	S.T.L. PSB@ 25 ml/ kg of seed each+75% RDF	13.20	153	15.53
T_5	S.T.C.B. PSB @ 25g/kg of seed.	13.40	15.07	15.60
T_6	S.T.C.B.PSB @ 25g/kg of seed	13.27	153	15.53
T_7	S.T.C.B. PSB @ 25g/kg of seed each	13.67	15.47	16.40
T_8	S.T.C.B. PSB @ 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)

Table.5 Effect of liquid formulation of PSB inoculation on LAI of mung bean

Tr.	Treatment Details	LAI
T_1	S.T.L. PSB @ 25 ml/ kg of seed	86
T_2	S.T.L.PSB@ 25 ml/ kg of seed.	71
T_3	S.T.L. PSB@ 25 ml/ kg of seed each	5.45
T_4	S.T.L. PSB@ 25 ml/ kg of seed each+75% RDF	77
T_5	S.T.C.B. PSB @ 25g/kg of seed.	75
T_6	S.T.C.B.PSB @ 25g/kg of seed	75
T_7	S.T.C.B. PSB @ 25g/kg of seed each	5.37
T_8	S.T.C.B. PSB @ 25g/kg of seed each+75% RDF	73
T_9	Recommended dose of fertilizers (control)	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)

Table.6 Effect of liquid formulation of PSB inoculation on height of mung bean

Tr.	Treatment Details	30 DAS (cm)	45 DAS (cm)	At Harvest (cm)
T_1	S.T.L. PSB @ 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. PSB@ 25 ml/ kg of seed each	32.76	57.22	67.39
T_4	S.T.L. PSB@ 25 ml/ kg of seed each+75% RDF	31.51	523	66.60
T_5	S.T.C.B. PSB @ 25 g/ kg of seed.	30.46	595	65.76
T_6	S.T.C.B. PSB @ 25 g/ kg of seed	30.35	53.67	65.84
T_7	S.T.C.B. PSB @ 25 g/ kg of seed each	31.84	57.01	67.32
T_8	S.T.C.B. PSB @ 25 g/ kg of seed each+75% RDF	30.95	599	66.61
T_9	Recommended dose of fertilizers (control)	28.11	49.85	59.59
T_{10}	Absolute control	25.45	466	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_5toT_7)

Table.7 Effect of liquid formulation of PSB inoculation on number of branches of mung bean

Tr.	Treatment Details	30 DAS	45 DAS	At Harvest
T_1	S.T.L. PSB @ 25 ml/ kg of seed	00	40	93
T_2	S.T.L. PSB @25 ml/ kg of seed.	00	60	93
T_3	S.T.L. PSB@ 25 ml/ kg of seed each	00	73	93
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	3.93	53	80
T_5	S.T.C.B. PSB@ 25 g/ kg of seed	3.93	60	87
T_6	S.T.C.B. PSB @ 25 g/ kg of seed	3.93	67	80
T_7	S.T.C.B. PSB @ 25 g/ kg of seed each	3.93	73	73
T_8	S.T.C.B. PSB @ 25 g/ kg of seed each + 75% RDF	00	73	87
T_9	Recommended dose of fertilizers (control)	3.73	40	73
T_{10}	Absolute control	3.73	27	47
S.E. (m)±		**0.08**	**0.12**	**0.12**
C.D. (0.05)		**NS**	**NS**	**NS**

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

Table.8 Effect of liquid formulation of PSB inoculation on dry matter weight of mung bean

Tr.	Treatment Details	Dry Matter Weight/plant (g)
T_1	S.T.L. PSB @ 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. PSB @ 25 ml/ kg of seed each	357
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	33.33
T_5	S.T.C.B. PSB @25 g/ kg of seed	32.53
T_6	S.T.C.B. PSB @ 25 g/ kg of seed	32.33
T_7	S.T.C.B. PSB @ 25 g/ kg of seed each	350
T_8	S.T.C.B. PSB @ 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)

Table.9 Effect of liquid formulation of PSB inoculation on number of pods of mung bean

Sr. No.	Treatment Details	Pods/Plant
T_1	S.T.L. PSB @ 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. PSB @ 25 ml/ kg of seed each	28.44
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	25.73
T_5	S.T.C.B. PSB @ 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. PSB @ 25 g/ kg of seed each	28.30
T_8	S.T.C.B. PSB @ 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)

Table.10 Effect of liquid formulation of PSB inoculation on yield of mung bean

Tr.	Treatment Details	Yield/Plot (g)	Yield/ha(Q)
T_1	S.T.L. PSB @ 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. PSB @ 25 ml/ kg of seed each	912.01	18.07
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	819.01	16.23
T_5	S.T.C.B. PSB @ 25g/ kg of seed.	763.63	15.12
T_6	S.T.C.B. PSB @ 25 g/ kg of seed	790.90	15.66
T_7	S.T.C.B. PSB @ 25 g/ kg of seed each	833.33	17.16
T_8	S.T.C.B. PSB @ 25 g/ kg of seed each + 75% RDF	821.86	16.31
T_9	Recommended dose of fertilizers (control)	696.73	188
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)

Table.11 Effect of liquid formulation of PSB inoculation on 1000 seed weight of mung bean

Tr.	Treatment Details	1000 Seed Weight (g)
T_1	S.T.L. PSB @ 25 ml/ kg of seed	35.83
T_2	S.T.L. PSB @ 25 ml/ kg of seed	36.67
T_3	S.T.L. PSB @ 25 ml/ kg of seed each	37.23
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	36.90
T_5	S.T.C.B. PSB @ 25 g/ kg of seed	36.47
T_6	S.T.C.B. PSB @ 25 g/ kg of seed.	35.60
T_7	S.T.C.B. PSB @ 25 g/ kg of seed each	37.23
T_8	S.T.C.B. PSB @ 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)

Table.13 Effect of liquid formulation of PSB 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. PSB @ 25 ml/ kg of seed	183.99	12.46
T_2	S.T.L. PSB @25 ml/ kg of seed	171.50	126
T_3	S.T.L. PSB @ 25 ml/ kg of seed each	196.53	15.73
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	183.98	13.99
T_5	S.T.C.B. PSB@ 25g/kg of seed.	179.80	12.36
T_6	S.T.C.B. PSB @ 25g/kg of seed.	171.52	13.68
T_7	S.T.C.B. PSB @25g/kg of seed each	192.36	15.42
T_8	S.T.C.B. PSB @ 25g/kg of seed each + 75% RDF	179.87	151
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)

Table.14 Effect of liquid formulation of PSB 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. PSB @ 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. PSB @ 25 ml/ kg of seed each	67.16	8.36
T_4	S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF	60.14	7.14
T_5	S.T.C.B. PSB @ 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. PSB @ 25 g/ kg of seed each	60.71	7.37
T_8	S.T.C.B. PSB @ 25 g/ kg of seed each+ 75% RDF	60.21	6.95
T_9	Recommended dose of fertilizers (control)	50.52	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)

Fig.1 Effect of liquid formulations of PSB inoculation on germination of mung bean

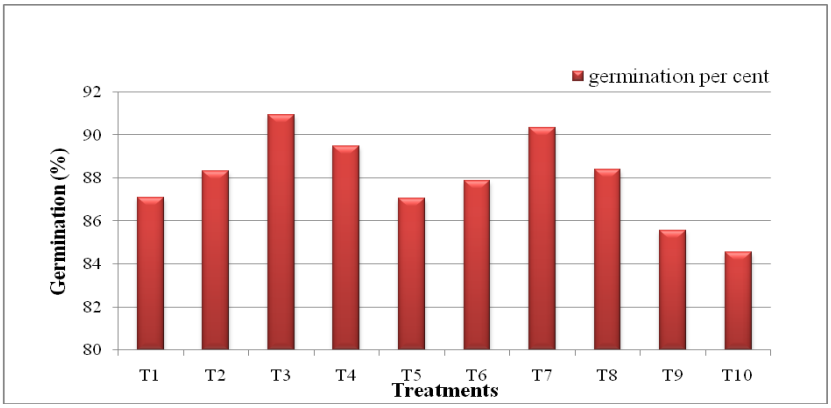


Fig.2 Effect of liquid formulations of PSB inoculation on number of leaves of mung bean

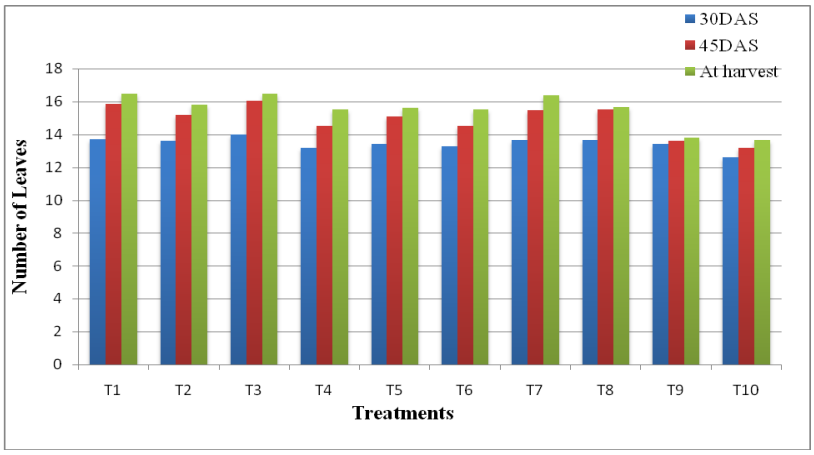


Fig.3 Effect of liquid formulations of PSB inoculation on LAI of mung bean

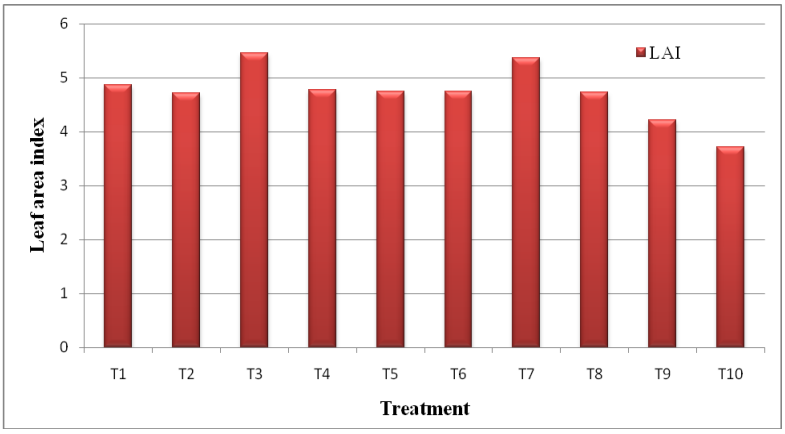


Fig.4 Effect of liquid formulations of PSB inoculation on height of mung bean

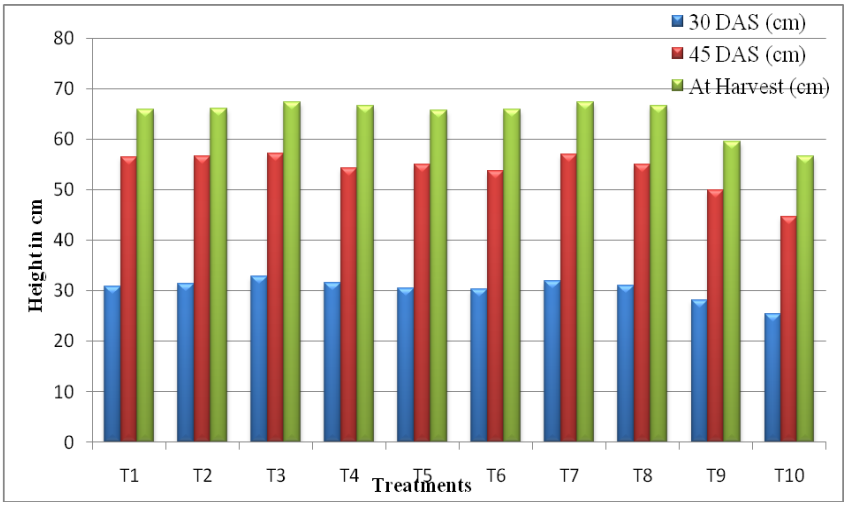


Fig.5 Effect of liquid formulations of PSB inoculation on root nodules of mung bean

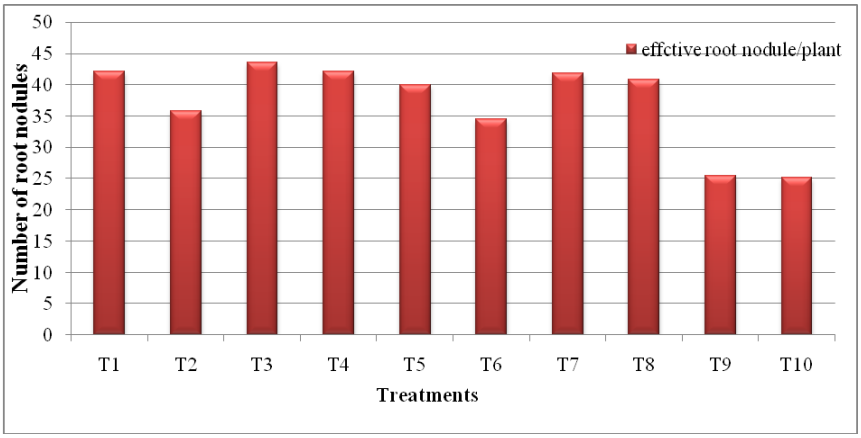


Fig.6 Effect of liquid formulations of PSB inoculation on dry matter weight of mung bean

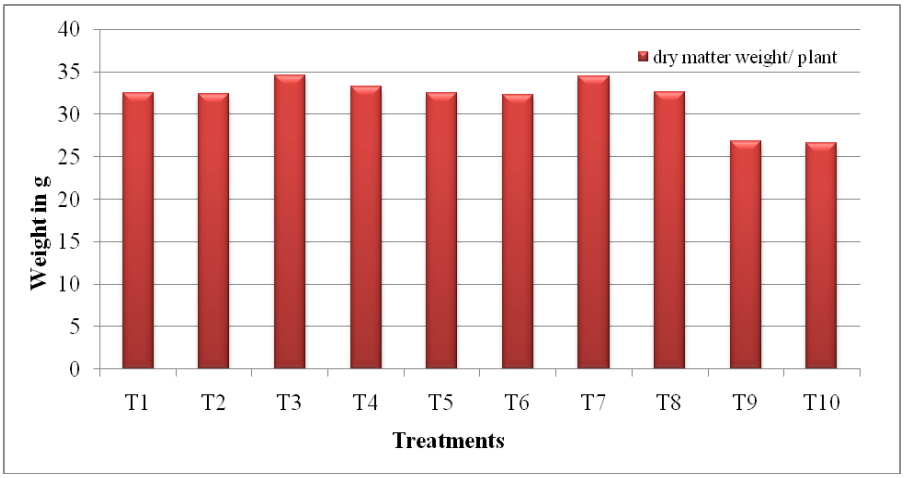


Fig.7 Effect of liquid formulations of PSB inoculation on pods of mung bean

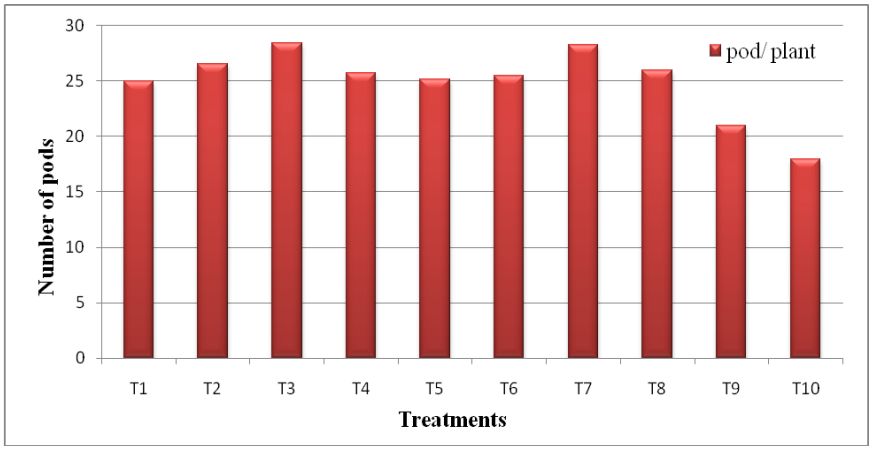


Fig.8 Effect of liquid formulations of PSB inoculation on yield of mung bean

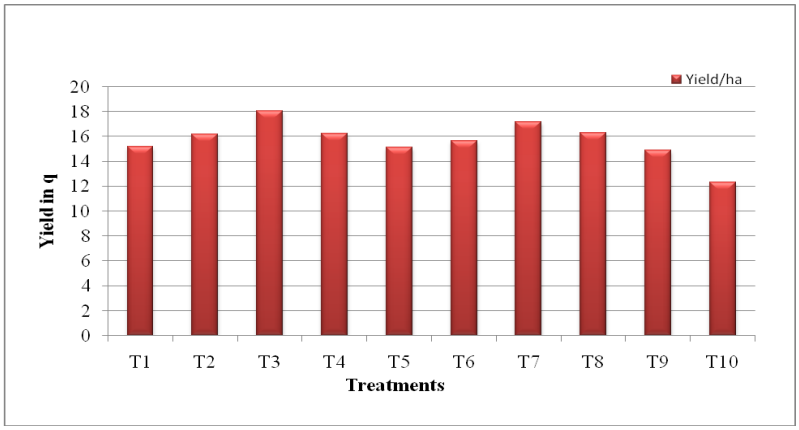


Fig.9 Effect of liquid formulations of PSB inoculation on 1000 seed weight of mung bean

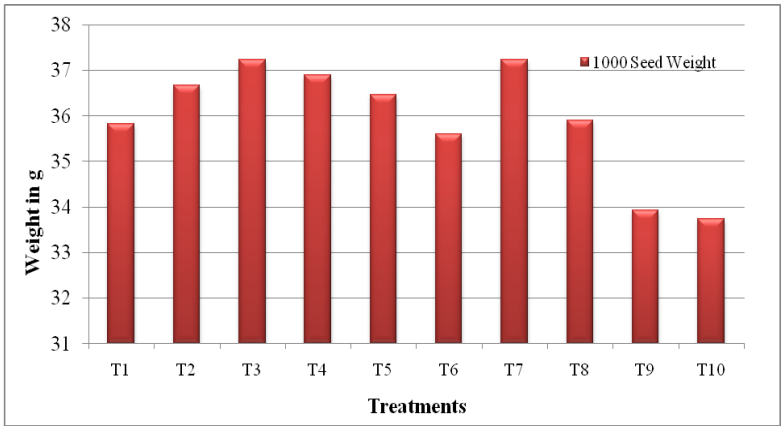


Fig.10 Effect of liquid formulations of PSB inoculation on *PSB* population in mung bean

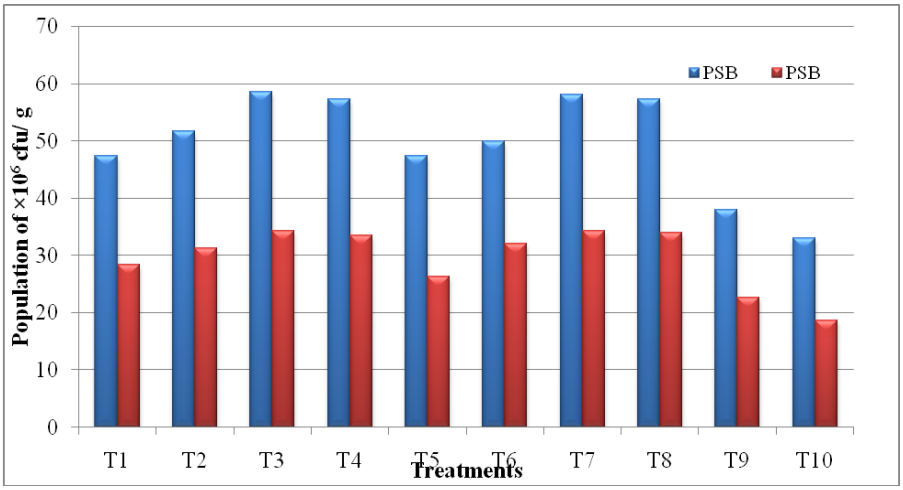


Fig.11 Effect of liquid formulations of PSB inoculation on available N in soil of mung bean

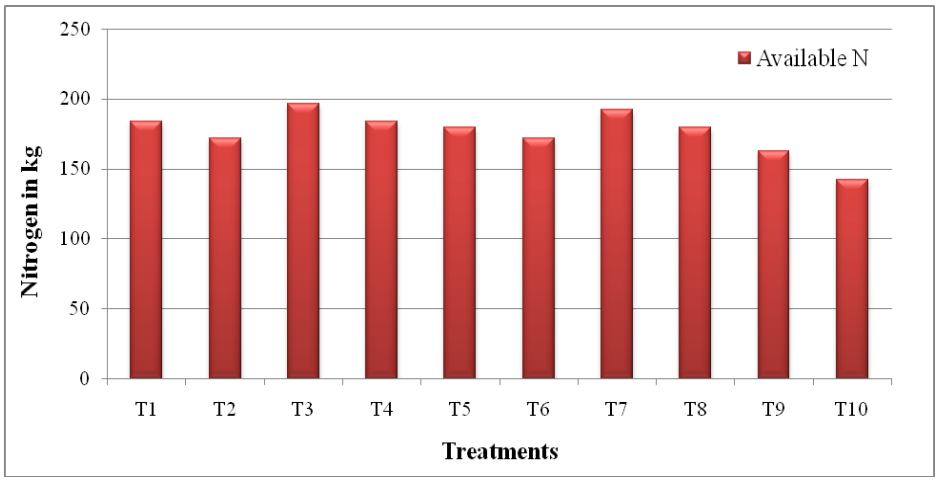


Fig.12 Effect of liquid formulations of PSB inoculation on available P in soil of mung bean

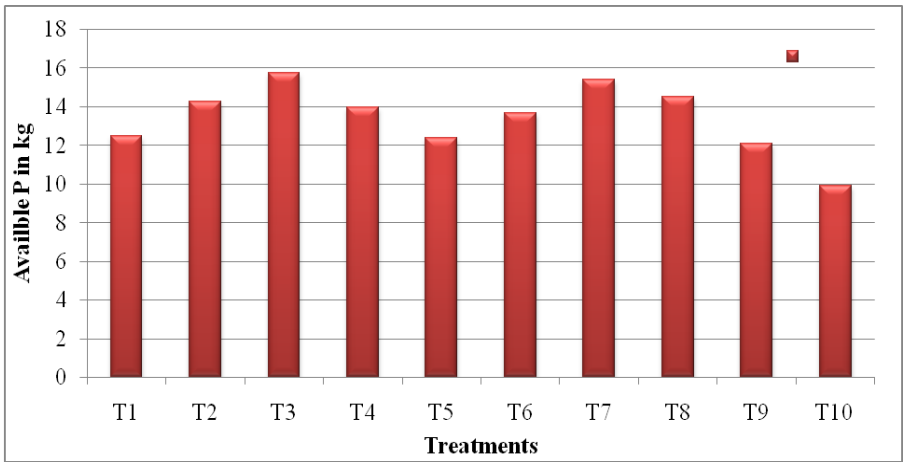


Fig.13 Effect of liquid formulations of PSB inoculation on total N in soil of mung bean

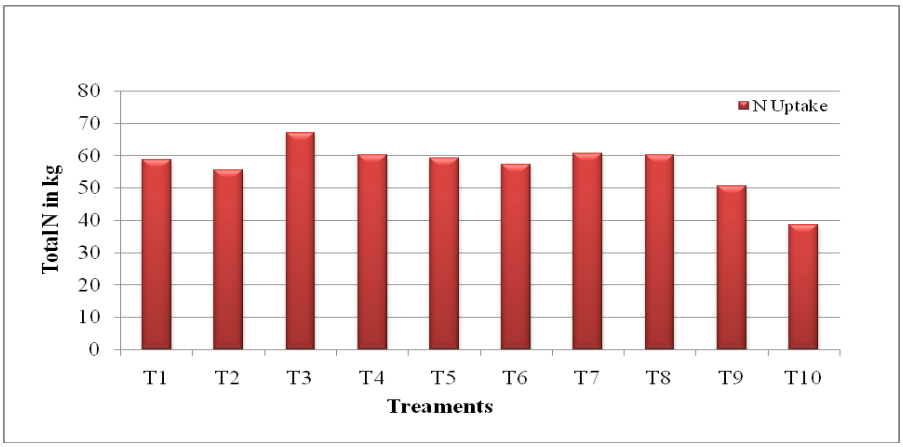


Fig.14 Effect of liquid formulations of PSB inoculation on total P in soil of mung bean

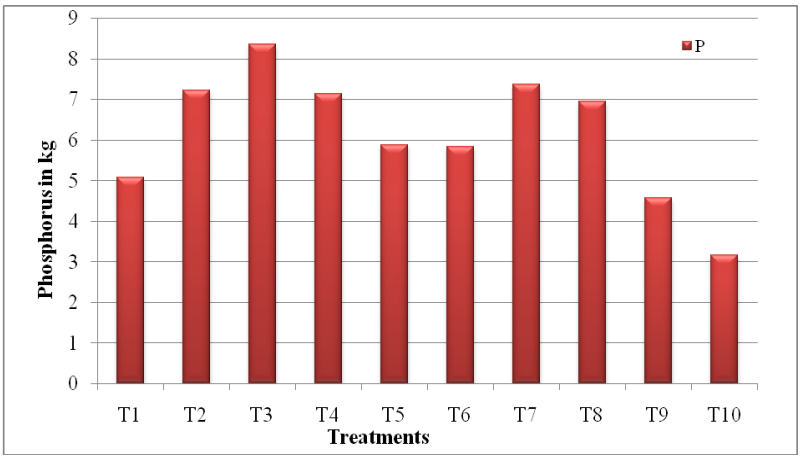


Fig.15 Effect of liquid formulations of PSB inoculation on B:C ratio in soil of mung bean

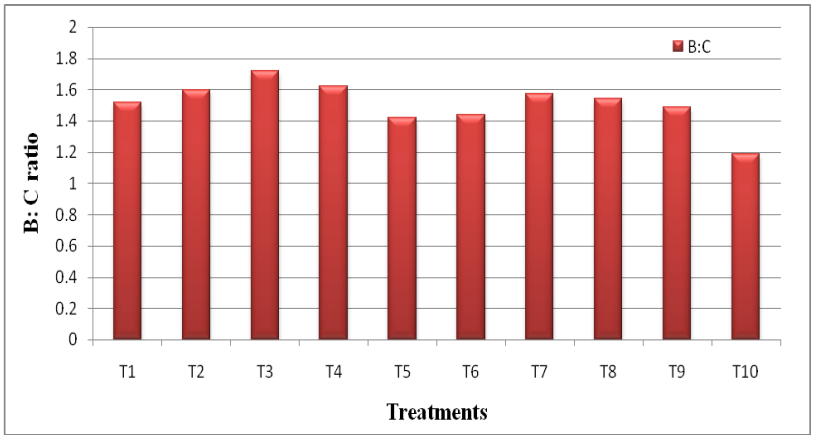


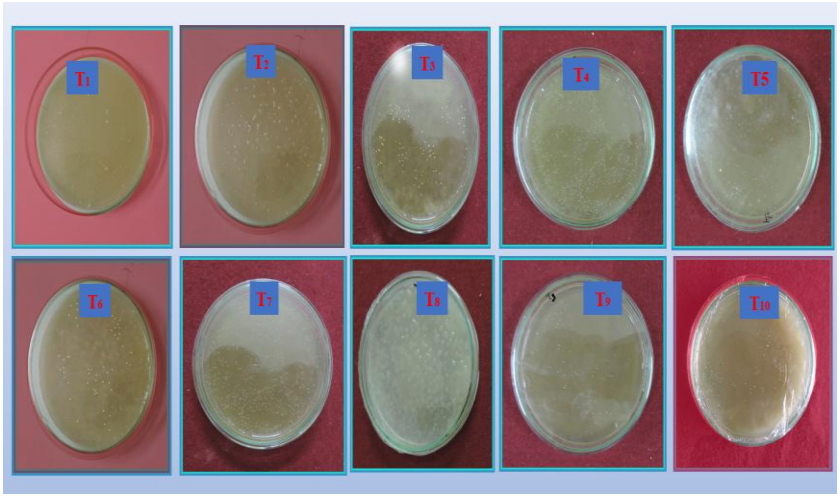
Plate.1 Effect of liquid formulations oh PSB inoculation on root nodules of mung bean

T_3: S.T.L. *PSB* @ 25 ml/kg of seed each T10: absolute control

Plate.5 Effect of liquid formulations of PSB inoculation on pods of mung bean

T_3: S.T.L. *PSB* @ 25 ml/kg of seed each T10: absolute control

Plate.7 Effect of liquid formulations of PSB inoculation on PSB population at 30 days after sowing



Effect of Liquid PSB Inoculation on Microbial Population Dynamics of Mung bean

Effect on PSB Population: PSB population was enumerated at 10^{-6} dilution by serial dilution and pour plate technique. Selective media Pikovaskaya's media was prepared and used. The PSB population showed upward trend during initial period of crop growth and then decline towards harvest of the crop.

PSB Population 30DAS: The PSB population as influenced by PSB inoculation ranged from 33× 10^6 cfu/ g to 58.56 × 10^6 cfu/ g. All the imposed treatments had significantly higher PSB population over T_{10}: absolute control (33 × 10^6 cfu/ g).

The treatments with co-inoculation of PSB were significant over T_9: recommended dose of fertilizers/ control (38 × 10^6 cfu/ g). Highest numerical value was obtained for T_3: S.T.L. PSB @ 25 ml/ kg of seed each (58.56 × 10^6 cfu/ ml). Among carrier-based treatments highest numerical value was recorded for T_7: S.T.C.B. PSB @ 25 g/ kg of seed each (58.00× 10^6 cfu/ g). Higher numerical values of PSB were obtained for PSB co-inoculated treatments for both carrier-based as well as liquid formulations of the biofertilizers.

PSB Population 60DAS: The population of PSB declined at this stage of crop growth as compared to population at 30 days after sowing. All the treatments as inoculated with PSB showed significantly higher population of PSB over T_{10}: absolute control (18.67 × 10^6 cfu/ g).

The highest numerical value was recorded for T_3: S.T.L. PSB @ 25 ml/ kg of seed each+ 75% RDF (34.33 × 10^6 cfu/ g). It was statistically at par with all other inoculated treatments. Among carrier-based biofertilizers highest numerical value was recorded for T_7: S.T.C.B. PSB @ 25 g/ kg of seed each+ 75 % RDF (33.89× 10^6 cfu/ g). The average PSB count for liquid treatments was found higher as compared to carrier-based biofertilizers.

Sundara *et al.*, concluded that application of 10 kg/ha PSB along with P fertilizer significantly enhanced PSB population in rhizosphere of sugarcane crop. The results of

present findings concur with this. Among inoculated treatments *Rhizobium* inoculated treatments had lower PSB values as compared to other PSB inoculated treatments. Awasthy *et al.*, (2017) 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 PSB to mung bean seeds as a seed treatment before sowing of the crop.

Effect of PSB inoculation on chemical properties of soil

Initial Nitrogen in soil: 135.7 kg/ ha; 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 12.

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. PSB @ 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. PSB @ 25 ml/ kg of seed each (15.73 kg/ha), but it was statistically at par with T_7: seed treatment with carrier-based PSB @ 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 PSB 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 13 and graphically represented in Fig. 11 and 12.

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. PSB @ 25 ml/ kg of seed (55.55 kg/ 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. PSB @ 25 ml/ kg of seed each (67.16 kg/ ha) had numerically high value, but was statistically at par with other *Rhizobium* inoculated treatments (Fig. 13).

Effect on P uptake: The P uptake as influenced by PSB 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 PSB 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. PSB @ 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. PSB @ 25 ml/ kg of seed each (7.37 kg/ha). But it was at par with T_7: S.T.C.B. PSB @ 25 g/ kg of seed each + 75% RDF (6.95 kg/ ha) and T_2:T_7: S.T.L. PSB @25 ml/ kg of seed (7.22 kg/ ha).

Jat and Ahlawat (2008) inoculated chickpea with PSB. They observed that inoculation of PSB significantly enhanced N and P uptake by plant over control. The results of present study concur with these findings. Goswami *et al.,* (2016) used different bioinoculants in mung bean and found higher nutrient uptake for co-inoculation of PSB and *T. viride*. Similar results for PSB were observed in present study. Hasan *et. al.* (2017) inoculated PSB to mung bean and found out that it enhanced the N and P uptake in mung bean which is similar to 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 (Fig. 14).

Benefit cost ratio: Cost benefit economics of treatments was calculated after harvest of the crop. The values were enumerated in Table 14. The cost of cultivation for mung bean as influenced by PSB 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. PSB @ 25 g/ kg of seed each (Rs. 1, 26,490). Net returns were highest for T_7: S.T.L. PSB @ 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. PSB @ 25 ml/ kg of seed each (1.72) and least for T_{10}: absolute control (1.19) (Fig. 15).

Kumar *et al.,* (2017) during their trial with different sources of P on mung bean found that PSB in combination with 100% SSP gave net returns of 47002.14 rupees/ ha and B:C ratio of 1.89. The result of present findings showed similar values. Rana *et al.,* (2014) concluded that inoculation of PSB increased B: C ratio in mung bean. Similar results were seen in present investigation. Meena *et al.,* (2015) 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.

In conclusion the present investigation was carried out to study effect of liquid biofertilizers on growth and yield of mungbean. The study shows that growth, yield attributing characters and yield itself is increased by inoculation of PSB inoculants. PSB are capable of increasing soil physical, chemical and biological characteristics. *PSB* fixes nitrogen and PSB solubilizes phosphorous 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 PSB. The yield per plot was recorded after harvest of the crop. Total

Rhizobia and PSB count were 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 PSB25g/kg of seed each (90.96%), Seed treatment with liquid PSB@ 25 ml/kg of seed each (90.35%), Seed treatment of carrier based PSB25g/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 *PSB* or PSB or both 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 PSB@ 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 PSB 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 PSB@ 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 PSB@ 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 PSB@ 25 ml/kg of seed each (4.933) and Seed treatment with liquid PSB@ 25ml/kg of seed (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 PSB25g/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 PSB. Highest number of pods for Seed treatment with liquid PSB @ 25 ml/kg of seeds each (28.440), which is at par with Seed treatment of carrier-based PSB25g/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 PSB @ 25 ml/kg of seed each (17.895Qtl/ha) and Seed treatment of carrier-based PSB25g/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

Inoculation of liquid formulation of PSB significantly enhanced soil microbial population of PSB leading to nitrogen fixation and P solubilisation respectively.

Inoculation of liquid formulations of PSB enhanced N and P uptake by mung bean plant as well as availability of N and P in soil.
Application of liquid formulations of PSB 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.

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