Original Research Article

Evaluation of Different Microbial Inoculum on Mung b~~B~~ean (*Vigna radiata* L.) Growth, Development~~,~~ and Nutrient Availability~~.~~

Abstract

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A field experiment was conducted on Kharif Mung Bean (*Vigna radiata* L.) during the *kharif* season of 2020-21 at Technology Park of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). ~~Field~~ The field was low in organic carbon and available nitrogen, medium in available phosphorus, potassium and zinc. The experiment was ~~analysed~~ laid out in ~~RBD Design~~randomized complete block design (RCBD). Results revealed that the growth parameters of mung bean *viz*., n~~N~~umber of (331229 plants/ha), p~~P~~lant height (67.7 cm/plant), t~~T~~rifoliate leaves/plant (12.7), n~~N~~umber of branches/plant (4.5), d~~D~~ry matter accumulation (18.7 g/plant),l ~~L~~eaf a~~A~~rea i~~I~~ndex (5.72), CGR (7.6 g/m^2/day) 50-at harvest and g~~G~~rain yield of (1,106 k~~K~~g/ha) improved by various treatment over control, being highest under NPK Consortia+ZSB, each @ 20 ml/kg. Similarly, this treatment also produced an accumulation of 59.8 % more dry matter/plant than control. However, application of NPK Consortia+ZSB, each @ 20 ml/kg recorded higher available N, P, K and Zn followed by NPK Consortia @ 20 ml/kg and RDF (20:40 kg/ha).

Keywords: KSB, Liquid biofertilizer, Microbial inoculum, NPK Consortia, PSB, ZSB

INTRODUC~~A~~TION

Pulses are an excellent source of dietary proteins and can play an important role in fulfilling requirements of rapidly increasing population. Pulse production is very low and has become a challenging problem against the requirement of increasing population of our country. On ~~an~~ average, pulses contain 22-25 % proteins as against 8-10 % in cereals. A good amount of lysine is also present in the pulses. Mung bean (*Vigna radiata* L.Wilczek) belongs to the family fabaceae or leguminaceae. Being a short duration crop and having wider adaptability, it can be grown in *kharif* as well as in summer season (reference).

The yield of summer green gram is comparatively more than that of *kharif* crop mainly because of controlled moisture conditions through irrigation, abundant sunshine and less pest and disease infestation. It is a short duration crop therefore has less water requirement as compared to summer crops. Moreover, it is drought resistant that can withstand adverse environmental conditions, and hence successfully be grown in rainfed areas. Mung bean is a good source of protein (25 %) with good amount of lysine content (460 mg/g) and tryptophan (60 mg/g). It also has remarkable quantity of ascorbic acid when sprouted and also bear riboflavin (0.21 mg/100 g) and minerals (3.84 g/100 g). Mung bean sprouts are a rich source of vitamin C (8 mg/100 g). The total area covered under *kharif* mung bean in India during 2019 was 3.13 mha with a total production of 1.83 m tonnes and a productivity of 585 kg/ha (Anonymous, 2020). Phosphorus like nitrogen is an essential nutrient. Currently, 5 % of Indian soils have appropriate available P, while 49.3% are in the low category 48.8 % are in the medium category and 1.9% are in the high category. Plants are only available with 25 % to 30 % of applied P and the remaining P is converted into insoluble P (Sharma and Khurana, 1997). The phosphate-solubilizing microorganisms increased phosphorus uptake as compared to controls with and without chemical fertilizers. Bio-fertilizers play an important role in increasing availability of nitrogen and phosphorus. Inoculation of seeds with *Rhizobium* culture is a low-cost method of nitrogen fertilization in legume and has been found beneficial to enhance the soil quality by providing more biological fixation of atmospheric nitrogen which may be helpful in boosting up production (Pathak *et al*., 2001). In recent year, several strains of fungi and phosphate solubilizing bacteria have been isolated. The mechanism of actions of these microorganisms involves secretion of organic acids which lower the pH and increase the availability of sparingly soluble phosphorus sources. Inoculation of seed with PSB culture may increase the production and productivity of mungbean crop (Balachandran *et al*., 2005). NPK Consortia is a liquid biofertilizer which contains combination of *Azotobacter*, *Acetobacter*, *Azospirillum*, *Rhizobium*, PSB and Potassium mobilizing bacteria to facilitate availability of nitrogen, phosphorus and potassium to crops. Liquid biofertilizers are a good alternative to chemical fertilizers. It aids in the preservation of organisms, their delivery to their destination, and the enhancement of their activity. Liquid biofertilizers are liquid mixtures that include not only the desired microbe and its nutrients, but also particular cell protectants or compounds that promote the creation of resting spores or cysts for prolonged shelf life and resistance to adverse conditions. Liquid biofertilizers have a longer shelf life than chemical fertilizers (Mandale *et al*., 2021). In Western U.P., wheat is harvested in the month of April, after that most probably rice/sorghum/pearl millet is grown in this zone. Instead of growing these cereals during this period growing of *kharif* mungbean may be a good option for effective utilization of the land and inputs, besides improving the soil fertility and productivity. Further, the present soil management techniques/practices largely depend~~s~~ on inorganic chemical-based fertilizer application which caused a serious threat to environment and human health. KSB and ZSB application showed synergistic effects on N, P and K uptake. Further, soil fertility was also found to be improved due to application of potassium and zinc solubilizing microorganism in mungbean (Navsare *et al*., 2018). KSB has the potential to increase K availability in soils making it a valuable tool for crop establishment in K-limited soils. ZSB has the potential to convert the insoluble form of zinc in the soil to a soluble form making it easily ~~bio-~~ bio-available to plants for growth development and final yield while also retaining soil health and fertility.

MATERIALS AND METHODS

Comment [B2]: Make scientific and attractive
Follow the correction and rewrite

The field experiment was conducted at Technology Park, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.) in 2020-21 located at a latitude of 29° 4’ North and longitude of 77° 42' East with an elevation of 228 meter above the mean sea level. Plant population counted from each plot area at the time of harvesting was considered for recording the plant population at harvest stage. The height of previously tagged five plants were measured in centimeters at harvest stage. Height of main shoot base from the ground surface up to growing tip of main stem was measured by using meter scale. The average plant height was calculated by taking the mean of heights of 5 plants and expressed in cm. The total number~~s~~ of trifoliate leaves from 5 tagged plants were counted and thus the average number~~s~~ of trifoliate leaves/plant was recorded by dividing it ~~with~~ by five~~5~~. Total number of branches/plant was recorded at harvest time from the previously five tagged plants. The number of branches/plant excluding main axis were recorded from the total number of branches in all selected plants and by dividing it ~~with~~ by five~~5~~. Five random plant samples from outer row of each plot were uprooted and washed thoroughly at harvest. Thereafter, samples of different plants were ~~sun~~ sun-dried and then put in an oven at 65 ± 2°C for 48 hours or till the constant dry weight is attained and the dry weight of individual plant was recorded by dividing the total dry weight ~~with~~ by five~~5~~. It is the ratio between leaf area and land area. It was recorded at harvest stage of crop. For this purpose, five plants were selected randomly in second row of each treatment plot. Their leaf area was measured with the help of leaf area meter and then leaf area index was calculated with the help of following formula given by Watson (1958):

$$\text{LAI} = (\text{Leaf area } (\text{cm}^2))/(\text{Land area } (\text{cm}^2))$$

CGR was worked out through the standard procedures as:

$$\text{CGR} = (W_2 - W_1)/(T_2 - T_1)$$

Where,

W_1 and W_2 are dry weight (g/plant) at Time T_1 and T_2, respectively.

Produce of each net plot was threshed and obtained grains were winnowed, cleaned and weighed. The yield recorded in kg/plot was standardized to 12~~ per cent~~% moisture and then converted into kg/ha. Soil samples were collected from 0-15 cm depth from whole plot. These samples were processed and analyzed for various chemical properties in the laboratory of Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Estimation of total organic carbon was done to assess the amount of organic matter in the soil. To determine the organic carbon content, soil sample of 0.5-1 gm was taken and treated with chromic acid as given by Walkley and Black using wet oxidation method (Jackson, 1973). Available Nitrogen was determined by alkaline potassium permanganate ($KMnO_4$) method given by Subbiah and Asija (1956). Before estimation of Available phosphorous, pH of soil sample was determined using pH meter. The pH of soil sample was 7.73 which is in alkaline range so, 0.5M $NaHCO_3$ extractable method was used (Olsen *et al*., 1954).

The concentration of available phosphorus in soil was expressed in kg/ha as,

Available P (kg/ha) = ppm of P calculated from standard curve x dilution factor × 2.24

Available soil potassium was extracted using neutral normal ammonium acetate and the content of K in the solution was estimated by a flame photometer (Sparks *et al*., 1996). The concentration of available potassium in soil was expressed in kg/ha as,

Available K (kg/ha) = ppm of K calculated from standard curve x dilution factor × 2.24

Available Zn will be estimated by using DTPA as an extractant (Lindsay and Norvell, 1978) and their concentration will be read on Atomic Absorption Spectrophotometer (GBC-Avanta PM Model).

Available Zinc (mg/kg) = A × 2

Where, A stands for the Zn concentration in aliquot as read from X-axis of standard curve against the sample reading.

RESULTS AND DISCUSSION

Comment [B3]: Table should be incorporated with text in appropriate locations.

A perusal of the data showed that plant population at harvest did not varied significantly due to microbial inoculation in the mung bean. Highest plant population at harvest (3,31,229/ha) was recorded in treatment T_{10} (NPK Consortia+ZSB, each @ 20 ml/kg) and lowest plant population was recorded under control treatment (2,93,370/ha). These results are in accordance with the results obtained by Jat *et al.* (2012) in mung bean. The highest plant height (67.7 cm) at the time of harvest was recorded with the NPK Consortia+ZSB, each @ 20 ml/kg (T_{10}) which was significantly higher over control (53.2 cm) and statistically *on par* treatment T_9 (67.1 cm), T_2 (66.9 cm), T_8 (65.2 cm), T_7 (64.6 cm) and T_6 (64.1 cm). Moreover, the increment in height over control was 27.2 %. Further at harvest, the highest number of trifoliate leaves (12.7) were noticed with NPK Consortia+ZSB, each @ 20ml/kg (T_{10}), which was significantly more over T_5 (10.8) and control (9.8), however rest of the treatments were statistically *on par* with each other. Similar finding was also reported by (Shende *et al.* 1977). Moreover, the lowest number of trifoliate leaves/plant was recorded in control at all the stages of crop growth. Almost similar trend was also recorded at 50 DAS stage. Dual inoculation in mung bean also remained statistically alike at all the stages of crop growth. However, maximum numbers of branches/plant at 50 DAS (3.2) was recorded in treatment receiving NPK Consortia+ZSB, each @ 20 ml/kg (T_{10}) which remained *on par* to treatment T_2 (3.1) and T_9 (3.1) and significantly superior over rest of the treatments. At harvest, treatment with NPK Consortia+ZSB, each @ 20 ml/kg (T_{10}) resulted into highest number of branches/plant (4.5) followed by T_9 (4.3), which were statistically superior to control. The crop inoculated with NPK Consortia+ZSB, each @ 20 ml/kg (T_{10}) had highest accumulation of dry matter/plant, though it remained *on par* with NPK Consortia @ 20 ml/kg (T_9) and RDF (20:40 kg/ha) but significantly superior over rest of the treatments. Almost similar trend was observed at all the crop growth stages. Further, the rate of increment in RDF, NPK Consortia and NPK Consortia+ZSB applied treatments over control was 55.5, 57.2 and 59.8 %. Maximum leaf area index at harvest was recorded in treatment receiving NPK Consortia+ZSB, each @ 20ml/kg (T_{10}) followed by T_9 and T_2 (5.72 and 5.63, respectively) which were statistically superior to control. However, under control the lowest leaf area index at 50 DAS and harvest stage was noted. However, between 50 DAS to harvest stage, significantly higher crop growth rate was noted under treatment T_{10} (7.6 g/m^2/day) followed by T_9 (7.5 g/m^2/day) and T_2 (7.4 g/m^2/day) which were *on par* to each other and statistically superior to control. Although, the lowest crop growth rate was recorded under control between 25 to 50 DAS and 50 DAS to harvest stage (9.8 and 2.1 g/m^2/day, respectively) And maximum grain yield (1106 kg/ha) was observed with NPK Consortia+ZSB, each @ 20ml/kg (T_{10}) which remained *on par* with treatments T_9 (1053 kg/ha), T_2 (1024 kg/ha), T_7 (970 kg/ha) and T_6 (947 kg/ha) while significantly superior to rest of the treatments. Similar findings were also reported by Yadav *et al*. (2007) and Sharma and Borah (2021) in mung bean. Data presented in Table 2 indicated that application of NPK Consortia+ZSB, each @ 20 ml/kg (T_{10}) resulted into highest available nitrogen (205.4 kg/ha) which was statistically *on par* with treatments T_9 (204.2 kg/ha), T_7 (187.7 kg/ha), T_6 (196.3 kg/ha), T_5 (190.5 kg/ha) and T_2 (200.6 kg/ha) and was superior to rest of the treatments. However, the lowest available nitrogen (170.5 kg/ha) was recorded under control. Further data presented indicated that mung bean grown under different microbial inoculums measured higher soil available phosphorus in comparison to control. Crop inoculated with NPK Consortia+ZSB, each @ 20 ml/kg (T_{10}) recorded the maximum available phosphorus (19.8 kg/ha) in soil followed by T_9 (19.0 kg/ha) and T_2 (18.5 kg/ha) being *on par* each other and statistically superior to control. While the minimum available phosphorus (13.0 kg/ha) was recorded in control followed by T_8 (14.5 kg/ha). Data presented in Table 2 revealed that there was significant increase in available potassium under different microbial inoculums in comparison to control. The highest available potassium (214.4 kg/ha) was recorded with the NPK Consortia+ZSB, each @ 20ml/kg (T_{10}) followed by T_9 and T_2 (210.4 kg/ha). However, the rest of the treatments were statistically *on par* to each other in this regard. Moreover, lowest available potassium (180.2 kg/ha) was found under control. Further data presented in Table 2, indicated that there was a significant increase in available zinc among different microbial inoculums, except PSB/KSB/NPK Consortia @ 20ml/kg alone in comparison to control. The maximum available zinc (0.84 mg/ha) was recorded with NPK Consortia+ZSB, each @ 20ml/kg (T_{10}) which was statistically significant over T_9 (0.76 mg/ha), T_3 (0.73 mg/ha) and T_2 (0.74 mg/ha). However rest of the treatments were statistically *on par* to each other, but the minimum available zinc was found in control (0.72 mg/kg). Perusal of data presented in Table 2 revealed that all the microbial inoculums increased organic carbon in soil significantly over control. The crop inoculated with NPK Consortia+ZSB, each @ 20ml/kg (T_{10}) recorded highest organic carbon (0.57 %) which was *on par* with treatments T_9 (0.56 %), T_6 (0.54 %) and T_2 (0.55 %) while significantly superior over rest of the treatments. However, the lowest organic carbon (0.45 %) was recorded in control. Highest value of soil available nutrients NPK, zinc and organic carbon was obtained with inoculation of mung bean *viz* NPK Consortia+ZSB, each @ 20 ml/kg. Available nitrogen in soil significantly increased after harvest of crop, which might be possibly due to more atmospheric nitrogen fixed in the soil due to higher bacterial population in rhizosphere under inoculated condition. Also, application of NPK Consortia enhances the microbial activity which reflected the possible increase in overall nutrient status of soil. These research findings are similar to those of Shukla *et al.* (2013), and Nama *et al.* (2021) in mung bean.

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Conclusion

It can be concluded that in western U.P. circumstances, an application of NPK Consortia+ZSB, each @ 20ml/kg, resulted in significantly higher growth and development with higher grain yield of (1106 kg/ha), as well as improved availability of accessible nutrient, than a control.

Comment [B4]: Your results must be supported with recent references.

Comment [B5]: What is your suggestion for end users of this technology?

Table 1.: Evaluation of microbial inoculums on Number of plants/ha, Plant height (cm/plant), Trifoliate leaves/plant, Number of branches/plant , Dry matter accumulation (g/plant), Leaf Area Index, CGR ($g/m^2/day$) 50-at harvest

Comment [B6]: Act according the above given comments

Treatments	Number of plants/ha At harvest	Plant height (cm/plant) At harvest	Trifoliate leaves/plant At harvest	Number of branches/plant At harvest	Dry matter accumulation (g/plant) At harvest	Leaf Area Index At harvest	CGR ($g/m^2/day$) 50-at harvest	Grain Yield Kg/ha
T_1 : Control	293370	53.2	9.8	3.2	11.7	3.86	2.1	701
T_2 : RDF (20:40kg/ha)	326596	66.9	12.3	4.2	18.2	5.63	7.4	1,024
T_3 : PSB @ 20 ml/kg	311063	59.2	12.0	4.0	14.4	4.36	4.0	910
T_4 : KSB @ 20 ml/kg	304396	58.6	11.6	3.8	13.9	4.49	4.2	821
T_5 : ZSB @ 20 ml/kg	306696	59.7	10.8	3.9	14.2	4.56	4.6	887
T_6 : PSB +KSB, each @ 20 ml/kg	315530	64.1	11.8	4.1	14.8	4.59	5.2	947
T_7 : PSB + ZSB, each @ 20 ml/kg	319096	64.6	11.7	3.8	16.2	4.54	4.6	970
T_8 : KSB+ ZSB, each @ 20 ml/kg	313363	65.2	12.1	4.0	14.6	4.32	4.3	925
T_9 : NPK Consortia @ 20 ml/kg	328796	67.1	11.7	4.3	18.4	5.68	7.5	1,053
T_{10} : NPK Consortia+ZSB, each @ 20 ml/kg	331229	67.7	12.7	4.5	18.7	5.72	7.6	1,106
SEm (±)	11235.6	2.7	0.5	0.2	0.7	0.22	0.5	59
C.D. (P=0.05)	NS	8.0	1.4	0.5	2.2	0.65	1.6	176

Comment [B7]: Not commonly used parameter

Table:2. Evaluation of microbial inoculums on Available Nitogen, phosphorus, Potassium, Zinc, and organic carbon, in soil

Treatments	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)	Available Zinc (mg/k)	Organic Carbon (%)
T_1 : Control	170.5	13.0	180.2	0.72	0.45
T_2 : RDF (20:40kg/ha)	200.6	18.5	210.4	0.74	0.55

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T_3 : PSB @ 20 ml/kg	178.4	15.4	191.3	0.73	0.48
T_4 : KSB @ 20 ml/kg	182.6	15.8	195.9	0.78	0.49
T_5 : ZSB @ 20 ml/kg	190.5	17.2	200.5	0.83	0.52
T_6 : PSB +KSB, each @ 20 ml/kg	196.3	17.7	205.6	0.80	0.54
T_7 : PSB + ZSB, each @ 20 ml/kg	187.7	16.6	198.7	0.81	0.51
T_8 : KSB+ ZSB, each @ 20 ml/kg	176.3	14.5	185.4	0.83	0.46
T_9 : NPK Consortia @ 20 ml/kg	204.2	19.0	212.5	0.76	0.56
T_{10} : NPK Consortia+ZSB, each @ 20 ml/kg	205.4	19.8	214.4	0.84	0.57
SEm (±)	7.4	0.7	7.1	0.03	0.02
C.D. (P=0.05)	21.8	2.0	21.1	0.08	0.05

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