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Effect of potassium and zinc solubilizing microorganism on growth, yield and quality of mungbean

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Abstract
A Field experiment was conducted in *kharif* season 2016-17 at experimental farm of Department of Soil Science and Agril. Chemistry, College of Agriculture, Badnapur using mungbean as a test crop to studies on effect of potassium and zinc solubilizing microorganism on growth, yield and quality of mungbean. The experiment was laid out on Vertisols with five treatment combination, replicated four times in randomized block design. The treatment consists of T_1 Absolute control (No fertilizer application), T_2 RDF (25:50:00 N, P_2O_5 and K_2O ha^{-1} kg ha^{-1}), T_3 (RDF + *Rhizobium* + PSB + KSB), T_4 (RDF + *Rhizobium* + PSB + KSB + ZSB), T_5 (RDF + *Rhizobium* + PSB + KSB + ZSB). The results emerged out clearly indicated that various growth parameters like, germination percentage, number of pods, number of nodules, dry matter, and seed yield was increased due to application of potassium and zinc solubilizing microorganism. It was inferred from the results that application RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) found superior over control application. The KSB and ZSB application showed synergistic effects on other nutrients (N, P, K) uptake. Soil fertility was also found to be improved due to application of potassium and zinc solubilizing microorganism to mungbean.

Keywords: Mungbean, Yield, Quality, Potassium and Zinc solubilizing microorganism

Introduction

Mungbean [*Vigna radiata* (L.) Wilezek syn. *Phaseolus mungo*] is cultivated in many region of the world because of its considerable nutritional value, particularly for people encountering malnutrition (Allahmoradi *et al*., 2011) [4]. Mungbean content bioactive compounds with antioxidant, antimicrobial and insecticidal properties (Madhujith *et al*., 2004; Ahmad *et al*., 2008) [18, 3]. The seed contain 25-28 per cent protein, 1.0-1.5 per cent fats, 3.5-4.5 per cent fibers, 60-65 per cent carbohydrates and are rich in lysine, ascorbic acid, potassium, iron, phosphorus and calcium (Lambrides and Godwin, 2007) [17]. Mungbean can play the major role in national economy of India due to their wider adaptability, easy digestability, better palatability and higher market price (Miah *et al*., 2009; Reddy, 2009) [21, 29].

Mineral potassium solubilization by microbes which enhances crop growth and yield when applied with a cheaper source of rock potassium may be agronomically more useful and environmentally more feasible than soluble K (Rajan *et al.*, 1996) [28]. Potassium solubilizing bacteria are capable of solubilizing rock K, mineral powder such as mica, illite and orthoclases through production and excretion of organic acids (Fridrich *et al.*, 1991) [12].

Microorganisms play a key role in the natural K cycle. Some species of rhizobacteria are capable of mobilizing potassium in accessible form in soils. There are considerable population of Potssium Solubilizing Bacteria (KSB) in soil and rhizosphere (Sperberg, 1958) [34]. Silicate bacteria were found to dissolve potassium, silicon and aluminium from insoluble minerals (Aleksandrov *et al*., 1967) [1]. It has been reported that most of potassium in soil exists in the form of silicate minerals. The potassium is made available to plants when the minerals are slowly weathered or solubilized (Bertsch *et al*., 1985) [8] are the major soil groups in the state. In general, black soils are high, red soils medium and lateritic soils lows in available K. Lateritic, shallow red and black soils have been found to show decline in K fertility over the years under intensive cultivation and imbalanced fertilizer application. Since K is a costly nutrient, India ranks 4th in consumption of potassium fertilizers. On an average 1.7 million tons of K is being imported annually (Anonymous, 2003) [2]. Currently, very little information is available on mineral potassium solubilization by bacteria, their mechanisms of solubilization and their effect on growth, K uptake and yield of several crops.

Therefore the present investigation was undertaken to study the influence of selected efficient mineral potassium solublizing bacteria on growth, of Mungbean (Vigna radiata). Archana *et al*., (2008) [5] reported that the KSMs was isolated from rock and rhizosphere soils of green gram (*Vigna radiata*) reported that these KSMs enhanced the solubilisation of K in acid leached soil as well as increased seedling growth and yield of green gram.

Zinc solubilizing bacteria also exhibit other traits beneficial to plants like phosphate solubilization. Phosphorus is vital to seed formation and its content is higher in seeds than in any other part of the plant. It helps plants to survive winter rigors and also contributes to disease resistance in some plants. It is also known to improve quality of many fruits, vegetables and grain crops.

Zinc is present in the enzyme system as co-factor and it is metal activator of many enzymes (Parisi *et al*., 1969) [23]. Many bacterial enzymes contain zinc in the active center or in a structurally important site. In soil, it undergoes a complex dynamic equilibrium of solubilization and precipitation that is greatly influenced by soil pH and microflora and that ultimately affects its accessability to plant roots for absorption (Goldstein, 1995) [13]. The solubility of zinc is highly dependent on soil pH and moisture and hence arid and semi-arid areas of Indian agro-ecosystems are often zinc deficient. It can be corrected through exogenous application of soluble zinc sources but only 20% of applied zinc is available for plant uptake and rest of the zinc is converted to various unavailable forms. Zinc thus made unavailable is converted back to available form by inoculating bacterial strains which can solubilize it by release of organic acids and decrease in pH.

Marathwada region of Maharashtra state is known for the *kharif* pulse particularly Red gram, black gram and green gram. The soils of this region are low in N, low in phosphorus and high in K and hence the agronomic recommendation includes only N, P and K application @ 25:50:00 kg ha^{-1} respectively. However, from last few years it was found that crops are responding for K application. The response for K application might be due to continuous mining of K, from soil by various crops and by the lowered K status of soil. It is estimated that every year nearly 2,095939 tonnes of K is removed from Maharashtra soil as against only 177,191 tones of K is added. So there is net 3,67,132 tonnes of negative balance of K every year (Patil *et al*., 2001) [25], therefore due to continuous mining of K, K reserves are depleted and hence they respond for K application.

Material and methods

A field experiment was conducted during *kharif* season 2016-2017 to entitled "Studies on effect of potassium and zinc solubilizing microorganism on mungbean" at Departmental farm of Soil Science and Agril. Chemistry, College of Agriculture, Badnapur. The details of materials used and methods adopted during the course of present investigation are explained in this chapter with appropriate heads. The experimental soil had clay structure, moderately calcareous in nature and slightly alkaline in reaction, normal in salt content. Before sowing, initial soil sample is collected randomly from 0-30 cm depth covering experimental area which was analysed for various physio-chemical charecteristics. An experiment was laid out in Randomized Block Design with four replication and five treatments. Treatments consisted of absolute control (no fertilizer application) (T_1), RDF (25:50:00 N, P_2O_5, K_2O kg ha^{-1}) (T_2), (RDF + *Rhizobium* + PSB + KSB) (T_3), (RDF + *Rhizobium* + PSB + KSB + ZSB) (T_4), (RDF + *Rhizobium* + PSB + KSB + ZSB) (T_5).

Mungbean veriety BM 2002-1 was selected for sowing. The germination test was carried out before sowing. The sowing was done at spacing 30 cm X 10 cm. Gap filling was done, wherever it is necessary to maintain the plant population in each plot. Periodical intercultural operations like thinning and weeding were carried out and plots were maintain for good crop growth.

Germination: The germination percentage was recorded from net plot of experimental unit using following formulae.

Germination (%) = Total no. of seeds germinated / Total no. of seeds sown × 100

Number of pods: Number of pods from five selected plants were counted and average number of pods per plant was worked out.

Number of nodules: five plants from observations plot were randomly removed with the help of the fork without damaging the roots at flowering and harvesting stage of mungbean. The roots were washed carefully to remove the soil stucking to them and nodules were counted.

Dry matter: Five plants uprooted from the observation unit for recording the dry matter weight. After removing the roots, plant samples were kept in well labeled brown paper bag. First the samples are dried in shade and after that kept in oven at 65^0 C ± 2^0 C, and then weight of dry matter was taken and expressed on per plant basis.

Seed yield: The plants from each net plot were harvested and seeds were separated by threashing, after sundrying the pods seed yields obtained in each net ploy were weighted (kg) and further it was calculated on the hectare basis (kg ha^{-1}).

Protien content: The total nitrogen content of grain sampls were determined by Micro-kjeldahl method (Tecator, 1991). Nitrogen and crude protein (CP) contents were worked out using following formulae.

Nitrogen (%) = (Volume of acid used × 0.0014 × 250 × 100) / sample weight × 10 ml

Crude protein (%) = % nitrogen × 6.25

Result and Discussion

Germination (%)

The data on the effect of potassium and zinc solubilizing microorganism on germination percentage of mungbean are presented in Table 1.

The results revealed that maximum germination count (582) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) which was at par with the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (577.25) and RDF + *Rhizobium* + PSB + KSB (T_3) (576). While, minimum germination count (552) was obsereved in the control plot.

Prajapati (2016) [27] reported that inoculation with selected potassium solubilizing bacteria (KSB), significantly increased seed germination, root and shoot length and number of leaves gain yield over uninoculated control in the presence of feldspar in Aleksandrov's agar medium. Vijya and Ponnuswamy (1998) [37] reported that $ZnSO_4$ significantly increased green gram and black gram seed germination.

Number of pods

The data on the effect of potassium and zinc solubilizing microorganism on number of pods of mungbean are presented in Table 1.

The results indicated that maximum number of pod per plant at flowering (11.8) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (10.1) and RDF + *Rhizobium* + PSB + KSB (T_3) (9.6). While, minimum number of pod per plant (7.8) was obsereved in the control plot.

Similarly, at harvesting maximum number of pod per plant (13.20) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (12.27) and RDF + *Rhizobium* + PSB + KSB (T_3) (11.20). While, minimum number of pod per plant (8.8) was obsereved in the control plot.

Improvement in pod bearing capacity of crop could be possibly because of improved N and P fertilization efficiency in the presence of K and Zn. Increased rate of photosynthetic and symbiotic activity following balanced application of NPK stimulated better vegetative and reproductive growth of the crop resulting in higher green pod yield. Thenua *et al*., (2010) reported that application of 40 kg K_2O ha^{-1} recorded higher pod yield in soybean. Similar observation was recorded by Thesiya *et al*., (2013) [36] in black gram, Kushwala (2001) [16] in field pea and Asghar *et al*., (1994) [6] in black gram. Nomen *et al*., (2015) [22] reported that effect of zinc solubilizer was significant on pod and haulms yields and found to improve the pod yield by 4.7% and haulm yield by 6.2%.

Number of nodules

The data on the effect of potassium and zinc solubilizing microorganism on number of nodules of mungbean are presented in Table 1.

The results indicated that maximum number of nodules per plant at flowering (45.36) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (42.06) and RDF + *Rhizobium* + PSB + KSB (T_3) (34.94). While, minimum number of nodules per plant (22.07) was obsereved in the control plot.

Similarly, at harvesting maximum number of nodules per plant (22.72) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (21.47) and RDF + *Rhizobium* + PSB + KSB (T_3) (21.01). While, minimum number of nodules per plant (17.23) was obsereved in the control plot.

The data on nodulation of green gram revealed that there was significant variation in nodule number at all stages.Potassium is required by adenosine S-triphosphate phosphohydrolyse (ATP) for the movement of sugars from the apoplast between the cells of the phloem. In depth scrutiny of data influenced by growth stages showed that there was continuous decrease in number of nodules per plant from flowering (45.36) to harvest (22.72). Highest number of nodules was observed at 45 kg K_2O ha^{-1} in groundnut by Salve and Gunjal (2011) [31]. Das *et al*., (2012) [10] reported that *Rhizobium* inoculation in combination with different micronutrients recorded higher nodulation. Similar findings reported by Patra *et al*., (1999) [26] in groundnut.

Dry matter

The data on the effect of potassium and zinc solubilizing microorganism on dry matter production of mungbean are presented in Table 1.

The results revealed that maximum dry matter production (kg ha^{-1}) at flowering (1965.50) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (1857.26) and RDF + *Rhizobium* + PSB + KSB (T_3) (1612.80). While, minimum dry matter production (kg ha^{-1}) (865.61) was obsereved in the control plot.

Similarly, at harvesting maximum dry matter production (kg ha^{-1}) (3951.73) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (3593.88) and RDF + *Rhizobium* + PSB + KSB (T_3) (3518.51). While, minimum dry matter production (kg ha^{-1}) (1805.50) was obsereved in the control plot.

The results revealed that various treatments resulted in increase in mean dray matter yield with advancement in crop growth stages i.e. from flowering (1504.98 kh ha^{-1}) to harvest (3190.78 kg ha^{-1}). This was due to the effect of K and Zn nutrition on cell elongation, turger potential in leaves. Such results were also observed in soybean plants as by Mengal and Arneke (1982) [20]. Patil and Dhonde (2009) [24] observed that highest dry matter kg ha^{-1} with the application of 50 kg K_2O in green gram. Salam *et al*., (2005) [30] studied the effect of micronutrients (Zn, Mo, Fe) on fertilization and productivity potential of mungbean and urdbean gave the highest dry matter accumulation, pods per plant, seeds per pod, 100 seed weight, seed yield per plant, pod and seed weight per plant, harvest index and production efficiency.

Seed Yield

The data on the effect of potassium and zinc solubilizing microorganism on seed yield of mungbean are presented in Table 2.

The results revealed that highest seed yield (kg ha^{-1}) (1229.0) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (1091.75) and RDF + *Rhizobium* + PSB + KSB (T_3) (1036.75). While, lowest seed yield (kg ha^{-1}) (764.0) was obsereved in the control plot.

Similarly, highest seed yield (gm/plant) (3.65) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (3.23) and RDF + *Rhizobium* + PSB + KSB (T_3) (3.05). While, lowest seed yield (gm/plant) (2.28) was obsereved in the control plot.

The positive effect of K and Zn on crop yield might also be due to its requirement in carbohydrate synthesis and translocation of photosynthesis and also may be due to improved yield attributing charecters, shots groth and nodulation. Billore *et al*., (2009) [9] observed seed yield of soybean increase 35.6% over control with the application of 49.8 kg K_2O ha^{-1}. Similar findings were observed by Thesiya *et al*., (2013) [36] in lentil, Patil and Dhonde (2009) [24] in green gram, Salve and Gunjal (2011) [31] in groundnut, Balai *et al*., (2005) [7].

Malewar *et al*., (1990) [19] showed that the grain yield of mungbean increased with increasing levels of Zn upto 15 kg ha^{-1} and then decreased at 20 kg ha^{-1}. The increae in grain yield of legumes and its attributes due to Zn application were reported by Kushwaha (1993) [15]. Khurana *et al*., (1996) [14] reported that zinc application inceased the grain and straw yield of rice.

Quality

The data on the effect of potassium and zinc solubilizing microorganism on protein content of mungbean are presented in Table 2.

The results revealed that highest protein content (19.19) observed in the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) followed by the plot which is inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_4) (18.68) and RDF + *Rhizobium* + PSB + KSB (T_3) (18.29). While, lowest protein content (17.27) was obsereved in the control plot.

Potassium involved in physiological and biochemical functions of plant growth i.e. enzyme activation and protein synthesis and its application in legumes might have improved the nitrogen use efficiency which leads to increase the protein content of crop. Similar findings were obtained by Farad *et al*., (2010) [11] and Salve and Gunjal (2011) [31].

Singh and Manohar (1987) [33] indicated that foliar application of zinc sulphate was most effective in improving protein content of mungbean. Singh and Badhoria (1986) [32] obtained highest content of crude protein at 10 mg Zn kg ha^{-1} of soil in green gram.

Table 1: Growth parameters of mungbean as influenced by various treatments

Treatments	Germination (%)	Number of pods		Number of nodules		Dry matter	
		Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1 (Control)	552.0 (92%)	7.8	8.8	22.07	17.23	865.61	1805.50
T_2 (Only RDF)	554.25 (92.37%)	8.9	10.17	29.07	19.24	1223.72	3084.32
T_3 (RDF + *Rhizobium* + PSB + KSB)	576.0 (96%)	9.6	11.20	34.94	21.01	1612.80	3518.51
T_4 (RDF + *Rhizobium* + PSB + KSB + ZSB)	577.25 (96.20%)	10.1	12.27	42.06	21.47	1857.26	3593.88
T_5 (RDF + *Rhizobium* + PSB + KSB + ZSB)	582.0 (97%)	11.8	13.20	45.36	22.72	1965.50	3951.73
SEm±	6.70	0.29	0.20	0.46	0.39	19.85	21.74
C.D. (at 5 %)	20.67	0.92	0.63	1.44	1.20	61.17	67.01

Table 2: Yield and quality of mungbean as influenced by various treatments

Treatments	Seed yield		Protien (%)
	(kg ha^{-1})	(gm/plant)	
T_1 (Control)	764.0	2.28	17.27
T_2 (Only RDF)	932.75	2.75	18.19
T_3 (RDF + *Rhizobium* + PSB + KSB)	1036.75	3.05	18.29
T_4 (RDF + *Rhizobium* + PSB + KSB + ZSB)	1091.75	3.23	18.68
T_5 (RDF + *Rhizobium* + PSB + KSB + ZSB)	1229.0	3.65	19.19
SEm±	11.88	0.04	0.03
C.D. (at 5 %)	36.61	0.13	0.11

Conclusion

Maximum germination, number of pods, number of nodules, dry matter was observed in the seed which was inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) is superior over the control. Also, seed yield and protein content was highest recorded in the seed which was inoculated with RDF + *Rhizobium* + PSB + KSB + ZSB (T_5) is superior over the control.

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