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EFFECT OF P, S, ZN AND BIO-INOCUALNTS ON GROWTH AND YIELD OF SUMMER MUNGBEAN [*VIGNA RADIATA* L.]

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ABSTRACT

A field experiment was conducted during summer season of 2011-12 and 2012-13 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to study the response of phosphorus, sulphur, zinc and bioinoculants on yield, yield attributes, nutrient uptake, net returns and B:C ratio of summer mungbean. The results showed that application of 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1} along with PSB + *Trichoderma* recorded the highest value of growth attributes *viz.* plant height, branches $plant^{-1}$, dry matter production, number of nodules $plant^{-1}$, grain yield, stalk yield and nutrient uptake. Application of 25 and 50 kg P_2O_5 ha^{-1} along with 25 kg S ha^{-1} or 3 kg Zn ha^{-1} were found to be significantly superior over phosphorus alone. Increasing levels of phosphorus upto 50 kg P_2O_5 ha^{-1} was found to be significantly superior over 25 kg P_2O_5 ha^{-1} and control. Among the bioinoculants *i.e.* dual inoculation of PSB + *Trichoderma* significantly produced higher growth attributes, grain and stalk yield, nutrient uptake and economics which were significantly superior over PSB and *Trichoderma* alone.

INTRODUCTION

Grain legumes are nature's precious gift to mankind. They provide not only nutritious food and feed but also improve soil health and sustain crop productivity (Ali and Kumar, 2009). The crude fibre, protein and lipid components of pulses have a hypocholestrolemic effect, which reduces cholesterol in blood. Being important sources of macro and micro-nutrients they have health promoting substances (White and Brown, 2010). India produced 17.21 mt of pulses from an area of 24.78 mha (Directorate of Economics and Statistics, Department of Agriculture and Cooperation, 2012) of major contributors being Madhya Pradesh (4.16 mt), Uttar Pradesh (2.43 mt), and Rajasthan (2.36 mt).

Among pulses, mungbean (*Vigna radiata* L.) is one of the most important pulse crops of India and ranks third after chickpea and pigeonpea (Sathyamoorthi *et al*., 2008). It fixes an estimated amount of 30 to 74 kg N ha^{-1} (MULLARP- 2011-12) and has wider adaptability to different crop seasons and agro-ecological environments (Kokate *et al*., 2013). But mungbean has not received much attention in proportion to its respective potential in tropical and sub-tropical regions.This can be increased by the judicious use of fertilizers, especially NPK with macronutrients, micronutrients and biofertilizers which have a greater potential in increasing the nutrition of pulses (Sathyamoorthi *et al*., 2013).

Intensification of cropping system with greater use of high analysis chemical fertilizers has resulted in mining of soils leading to deficiencies of secondary and micronutrients, sulphur and zinc in particular and limiting crop production in specific situations. Sulphur and Zinc are essential secondary and micro-nutrients for growth and development of plants. They are required in very small amounts but for critical functions.Considering the significant role of phosphorus, sulphur, zinc and biofertilizers in sustainable production of pulses, an experiment was conducted to study the effect of P, S, Zn and bioinoculants on growth and yield of summer mungbean.

MATERIALS AND METHODS

The field experiment was conducted during the two consecutive summer seasons of 2011-12 and 2012-13 at the Agriculture Research Farm of Banaras Hindu University, Varanasi (U.P.). The soil was sandy clay loam in texture, having a pH of 7.46 and 7.53 respectively and moderately fertile being low in organic carbon (0.34 and 0.37%). The available N, P, K, S and Zn was 188.70, 18.50, 205.30, 19.30 and 1.10 kg ha^{-1} in first year and 194.20, 19.56, 210.64, 21.55 and 1.16 kg ha^{-1} in second year respectively.

The experiment was laid out in a split plot design with three replications keeping P, S, Zn levels (control, 25 and 50 kg P_2O_5 along with 25 kg S ha^{-1} and 3 kg Zn ha^{-1}) in main plots and bio-inoculants (PSB, *Trichoderma* and PSB + *Trichoderma*) in subplot at the same site during both the years. The recommended dose of N and K at 15 and 20 kg ha^{-1} and P_2O_5, S and Zn as per treatment were applied though urea, diammonium phosphate (DAP) and murate of potash, elemental sulphur and zinc oxide (ZnO) respectively. Mungbean seed were inoculated with phosphate solubilizing bacteria (*Paevibacillus polymyxa*), *Trichoderma* (*Trichoderma viridae*) and dual seed inoculation of PSB + *Trichoderma* (*Paevibacillus polymyxa* + *Trichoderma viridae*) before sowing.

Sowing of mungbean (HUM-16) was done in furrows at 30 cm apart at a depth of 3 - 4 cm and at a seed rate of 25 kg ha^{-1} in the same layout/field during mid March of 2011 and 2012. The required plant population (30 cm row to row and 5 cm plant to plant) was obtained after a month of seeding. Thinning was done as per required. Weed control, irrigation and plant protection measures were followed as per the normal package of practices recommended for the zone. Plant observation *viz.*, plant height (cm), dry matter accumulation (g), number of branches, test weight (g), seed (kg) and stalk yield (kg) at harvest along with harvest index (%) were taken. The data were subjected to statistical analysis by adopting appropriate method of analysis of variance. Barlett's test (1937) was applied to test the homogeneity of variance.

RESULTS AND DISCUSSION

Effect of P, S, Zn and bioinoculants on growth attributes and yield

It is obvious from Table 1 that application of 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1} along with PSB + *Trichoderma* significantly increased the growth attributes *viz.*, plant height, branches $plant^{-1}$, dry matter accumulation, number of nodules $plant^{-1}$, grain yield and stalk yield.Amongst the fertility treatments, application of 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1} recorded the highest growth of mungbean over other fertility treatments and was found to be significantly superior over its lower levels *viz.*, 25 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1}. The maximum grain yield (930.05 and 994.38 kg ha^{-1}) and stalk yield (2257.68 and 2415.30 kg ha^{-1}) was obtained with the application of 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1}.

Application of 25 and 50 kg P_2O_5 ha^{-1} along with 25 kg S ha^{-1} or 3 kg Zn ha^{-1} was found to be significantly superior over phosphorus alone. It is also clear from Table 1 that growth attributes and grain yield increases with increasing phosphorus application upto 50 kg P_2O_5 ha^{-1} and was found to be significantly superior over 25 kg P_2O_5 ha^{-1} and control. Improvement in yield components and yield of summer mungbean due to phosphorus fertilization was also observed by Ali *et al*. (2010) and Patil *et al*. (2011). Minimum growth of yield attributes and yield was recorded at control treatments at all the growth stages during both the years of experimentation. Similar results were observed by (Sesode, 2008; Bairwa *et al*., 2012). This might be due to the supply of all the essential mineral nutrients in a balanced proportion and amount which

Table 1 : Effect of phosphorus sulphur zinc and bioinoculants on growth attributes and yield of summer mungbean

Treatment	Growth attributes						Yield (kg ha^{-1})			
P, S, Zn (kg ha^{-1})	Plant height		Dry matter		Number of nodules $plant^{-1}$		Grain yield		Stalk yield	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Control	40.77	40.91	8.78	8.85	16.76	17.57	528.25	553.45	1561.1	1635.75
25	40.91	41.61	9.07	9.18	17.88	18.11	555.09	587.5	1581.19	1646.62
25 P_2O_5 + 25 S	41.59	42.48	9.25	9.54	19.91	20.84	605.42	655.84	1651.15	1763.16
25 P_2O_5 + 3 Zn	41.32	42.19	9.11	9.39	18.25	19.28	580.86	645.45	1567.6	1735.66
25 P_2O_5 + 25 S + 3 Zn	41.89	42.36	9.31	9.49	20.46	21.14	625.8	696.44	1630.53	1786.35
50 P_2O_5	42.2	42.47	9.39	9.59	21.66	22.99	701.5	723.24	1782.72	1837.17
50 P_2O_5 + 25 S	42.54	42.9	9.55	9.96	25.9	26.1	832.47	873.69	2076.61	2233.42
50 P_2O_5 + 3 Zn	42.33	42.73	9.42	9.65	23.47	24.13	770.8	824.77	1989.67	2166.05
50 P_2O_5 + 25 S + 3 Zn	42.88	43.12	10.35	10.71	26.21	27.63	930.05	994.38	2310.44	2496.86
SEm ±	0.73	0.77	0.294	0.323	1.21	1.39	21	35.54	77.34	85.59
CD (P=0.05)	NS	NS	0.883	0.969	3.63	4.18	62.96	106.54	231.87	256.6
Bioinoculants										
PSB	41.8	42.3	9.28	9.47	20.51	20.9	658.97	727.29	1723.6	1904.09
Trichoderma	41.04	41.74	8.54	8.87	18.45	19.61	642.46	661.7	1683.4	1789.11
PSB + *Trichoderma*	42.64	42.88	10.25	10.45	24.54	25.42	741.99	795.92	1976.67	2073.82
SEm ±	0.45	0.37	0.188	0.177	0.53	0.53	8.41	10.77	36.01	40.27
CD (p=0.05)	NS	NS	0.539	0.509	1.53	1.52	24.13	30.9	103.28	115.51
	NS	NS	NS	NS	NS	NS	S	S	S	S

Table 2 : Interaction effect of phosphorus, sulphur, zinc and bioinoculants on grain yield in 2011-12

Treatments	Control	25 kg P_2O_5	25 kg P_2O_5 + 25 kg S	25 kg P_2O_5 + 3 kg Zn	25 kg P_2O_5 + 25 kg S + 3 kg Zn	50 kg P_2O_5	50 kg P_2O_5 + 25 kg S	50 kg P_2O_5 +3 kg Zn	50 kg P_2O_5 + 25 kg S + 3 kg Zn	Mean
PSB	488.85	507.83	564.42	563.08	600.34	688.52	851.47	787.83	878.36	658.97
Trichoderma	517.36	546.38	566.81	558.85	583.6	642.33	719.05	716.95	930.79	642.46
PSB + *Trichoderma*	578.55	611.06	685.03	620.67	693.46	773.64	926.89	807.63	981.01	741.99
Mean	528.25	555.09	605.42	580.86	625.8	701.5	832.47	770.8	930.05	681.14
			SEm±			CD (P=0.05)				
B at same T			25.24			72.38				
T at same/diff B			29.42			86.33				

Table 3 : Interaction effect of phosphorus, sulphur, zinc and bioinoculants on grain yield in 2012-13

Treatments	Control	25 kg P_2O_5	25 kg P_2O_5 + 25 kg S	25 kg P_2O_5 + 3 kg Zn	25 kg P_2O_5 + 25 kg S + 3 kg Zn	50 kg P_2O_5	50 kg P_2O_5 + 25 kg S	50 kg P_2O_5 + 3 kg Zn	50 kg P_2O_5 + 25 kg S + 3 kg Zn	Mean
PSB	512.34	545.55	647.24	593.7	682.33	749.21	939.07	882.26	993.94	727.29
Trichoderma	501.02	542.99	626.76	651.91	638.72	639.41	717.55	688.65	948.33	661.7
PSB + *Trichoderma*	647.01	673.97	693.51	690.73	768.27	781.12	964.46	903.39	1040.88	795.92
Mean	553.45	587.5	655.84	645.45	696.44	723.24	873.69	824.77	994.38	728.31

	SEm±	CD (P=0.05)
B at same T	32.32	92.69
T at same/diff B	44.26	130.66

Table 4: Interaction effect of phosphorus, sulphur, zinc and bioinoculants on stalk yield in 2011-12

Treatments	Control	25 kg P_2O_5	25 kg P_2O_5 + 25 kg S	25 kg P_2O_5 + 3 kg Zn	25 kg P_2O_5 + 25 kg S + 3 kg Zn	50 kg 3 kg Zn	50 kg P_2O_5 + 25 kg S	50 kg P_2O_5 +	50 kg P_2O_5 + 25 kg S + 3 kg Zn	Mean
PSB	1447.89	1469.27	1832.28	1502.94	1732.44	1857.87	2106.2	2066.35	2115.9	1792.35
Trichoderma	1319.18	1333.83	1644.86	1601.57	1714.71	1767.87	1844.6	1783.49	2373.08	1709.24
PSB + *Trichoderma*	1584.66	1656.26	1868.71	1837.24	1929.57	1935.28	2203.57	2093.11	2284.05	1932.5
Mean	1450.58	1486.45	1781.95	1647.25	1792.24	1853.67	2051.46	1980.98	2257.68	1811.36

	SEm ±	CD (P = 0.05)
B at same T	73.53	210.90
T at same/diff B	84.01	246.30

Table 5 : Interaction effect of phosphorus, sulphur, zinc and bioinoculants on stalk yield in 2012-13

Treatments	Control	25 kg P_2O_5	25 kg P_2O_5 + 25 kg S	25 kg P_2O_5 + 3 kg Zn	25 kg P_2O_5 + 25 kg S + 3 kg Zn	50 kg P_2O_5	50 kg P_2O_5 + 25 kg S	50 kg P_2O_5 +3 kg Zn	50 kg P_2O_5 + 25 kg S + 3 kg Zn	Mean
PSB	1395.19	1567.09	1749.55	1662.9	1974.25	2001.31	2223.57	2323.07	2427.61	1924.95
Trichoderma	1671.59	1701.48	1844.61	1721.05	1851.01	1875.27	2006.02	1907.7	2248.34	1869.67
PSB + *Trichoderma*	1582.35	1685.05	1779.05	1745.81	2046.9	2124.98	2470.69	2348.08	2569.96	2039.21
Mean	1549.71	1651.21	1791.07	1709.92	1957.39	2000.52	2233.43	2192.95	2415.3	1944.61

	SEm ±	CD (P = 0.05)
B at same T	88.72	254.45
T at same/diff B	110.26	324.38

Table 6 : Effect of phosphorus, sulphur, zinc and bioinoculants on nutrient uptake

	Nitrogen uptake (kg ha^{-1})				Phosphorus uptake (kg ha^{-1})			
Treatment	Grain		Stalk		Grain		Stalk	
P, S, Zn levels (kg ha^{-1})	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Control	17.19	18.85	20.45	21.15	16.26	17.35	1.9	2.32
25	19.17	20.59	21.48	23.85	18.36	19.55	2.2	2.73
25 P_2O_5 + 25 S	21.27	23.48	26.37	27.62	20.47	22.33	2.9	3.38
25 P_2O_5 + 3 Zn	20.04	22.64	23.45	25.75	19.5	21.25	2.62	3.09
25 P_2O_5 + 25 S + 3 Zn	22.7	25.61	26.67	30.57	22.37	25.05	3.2	3.83
50 P_2O_5	25.86	27.18	28.45	31.51	25.34	26.59	3.48	4.06
50 P_2O_5 + 25 S	31.46	33.71	34.51	39.05	30.59	33.11	4.23	5.06
50 P_2O_5 + 3 Zn	28.57	31.55	31.75	36.15	27.91	30.91	3.86	4.76
50 P_2O_5 + 25 S + 3 Zn	35.73	38.75	38.46	43.32	35.04	38.16	4.77	5.82
SEm ±	0.91	1.46	2.54	3.29	0.9	1.27	0.23	0.28
CD (P = 0.05)	2.71	4.38	7.62	9.86	2.68	3.79	0.69	0.85
Bioinoculants								
PSB	23.31	26.42	28.06	31.71	22.69	25.58	3.04	3.55
Trichoderma	21.86	23.26	24.84	27.64	21.28	21.91	2.73	3.46
PSB + *Trichoderma*	28.83	31.11	30.96	33.63	27.97	30.61	3.95	4.67
SEm ±	0.51	0.5	1.08	1.21	0.51	0.55	0.1	0.15
CD (p = 0.05)	1.46	1.45	3.09	3.46	1.47	1.58	0.3	0.44
Interaction	NS	NS	NS	NS	S	S	NS	NS

resulted in better growth and development of plants. The lowest values of growth attributes were recorded for control due to inadequate nutrient availability.

Dual seed inoculation with bioinoculants proved its superiority over single inoculation with respect to growth attributes *viz.*, plant height, branches plant^{-1} and dry matter production in

Table 6 : Cont......

Treatment P, S, Zn levels (kg ha^{-1})	Potassium uptake (kg ha^{-1}) Grain 2011-12	 2012-13	 Stalk 2011-12	 2012-13	Sulphur uptake (kg ha^{-1}) Grain 2011-12	 2012-13	 Stalk 211-12	 2012-13	Zinc uptake (kg ha^{-1}) Grain 2011-12	 2012-13	 Stalk 2011-12	 2012-13
Control	5.36	5.4	37.8	35.36	1.12	1.24	1.37	1.57	20.8	22.62	143.64	151.83
25	5.91	6.14	40.88	37.03	1.23	1.36	1.49	1.7	22.05	24.15	160.4	74.76
25 P_2O_5 + 25 S	7.17	7.76	45.08	44.38	1.56	1.74	1.99	2.13	25.15	29.69	169.93	188.79
25 P_2O_5 + 3 Zn	6.43	7.02	42.77	40.69	1.42	1.63	1.63	1.97	25.99	28.9	171.22	192.11
25 P_2O_5+ 25 S + 3 Zn	7.45	8.16	49.48	45.13	1.64	1.75	2.06	2.38	27.7	32.65	184.49	211.06
50 P_2O_5	8.35	8.52	51.36	46.63	1.76	1.97	1.96	2.1	33.09	35.94	187.23	198.77
50 P_2O_5 + 25 S	10.52	10.7	58.06	52.44	2.27	2.48	2.84	3.14	41.79	45.73	234.66	254.47
50 P_2O_5 + 3 Zn	9.38	9.92	56.24	50.01	2.03	2.27	2.26	2.62	43.43	50.43	237.88	259.87
50 P_2O_5 + 25 S + 3 Zn	11.58	12.67	62.89	58.51	2.61	2.9	3.11	3.53	56.77	60.42	275.53	297.41
SEm ±	0.94	1.05	3.35	2.21	0.06	0.13	0.21	0.17	2.21	2.37	10.82	8.68
CD (P=0.05)	2.81	3.15	10.05	6.61	0.19	0.4	0.63	0.52	6.63	7.11	32.45	26.03
Bioinoculants												
PSB	7.71	8.38	48.78	44.62	1.68	1.91	1.83	2.28	32.01	37.38	185.79	209.31
Trichoderma	6.76	7.07	46.29	42.17	1.5	1.63	1.39	1.68	28.18	30.5	172.92	191.16
PSB + *Trichoderma*	9.59	9.97	53.12	49.94	2.03	2.25	3.02	3.08	38.73	42.3	229.62	242.54
SEm ±	0.47	0.48	1.19	1.06	0.02	0.04	0.1	0.09	0.67	0.71	4.84	5.1
CD (P=0.05)	1.34	1.39	3.41	3.04	0.07	0.1	0.29	0.27	1.92	2.04	13.88	14.64
Interaction	NS	NS	NS	NS	S	S	NS	NS	S	S	NS	NS

Table 7: Effect of phosphorus, sulphur, zinc and bioinoculants on available nutrients in soil after harvest of mungbean

Treatments P, S, Zn levels (kg ha^{-1})	Available Nutrients (kg ha^{-1}) Available O.C. 2011	 2012	 Available N 2011	 2012	 Available P 2011	 2012	 Available K 2011	 2012	 Available S 2011	 2012	 Available Zn 2011	 2012
Control	0.25	0.28	172.03	169.01	14.77	14.46	186.65	184.88	13.65	12.85	1.1	1.01
25 P_2O_5	0.29	0.31	176.67	177.9	16.03	16.19	190.49	201.56	14.01	14.51	1.57	1.81
25 kg P_2O_5 + 25 S	0.36	0.4	179.75	181.05	16.32	17.24	198.12	204.77	15.26	16.81	1.84	1.89
25 kg P_2O_5 + 3 Zn	0.34	0.34	178.21	180.18	16.04	16.41	194.09	197.43	14.22	14.22	2.4	2.49
25 kg P_2O_5 + 25 S + 3 Zn	0.39	0.42	180.46	182.01	16.78	17.41	202.67	208.87	16.15	16.42	2.45	2.53
50 P_2O_5	0.41	0.43	183.11	183.11	17.6	18.01	205.73	210.51	14.97	16.04	2.31	2.43
50 kg P_2O_5 + 25 S	0.44	0.46	184.54	185.87	18.4	18.94	212.29	217.09	19.56	19.86	2.36	2.47
50 kg P_2O_5 + 3 Zn	0.43	0.43	182.37	184.1	17.91	18.4	210.87	212.89	16.86	17.04	2.51	2.61
50 kg P_2O_5 + 25 S + 3 Zn	0.46	0.48	185.49	187.24	18.64	19.12	222.4	226.29	19.73	20.13	2.6	2.74
SEm. ±	0.02	0.01	2.17	1.71	0.47	0.41	3.46	3.22	0.41	0.57	0.13	0.13
CD (P= 0.05)	0.05	0.04	6.5	5.13	1.4	1.22	10.37	9.66	1.23	1.69	0.39	0.4
Bio- Inoculants												
PSB	0.38	0.41	179.66	180.27	16.88	17.27	198.84	204.76	15.85	16.45	1.97	2.1
Trichoderma	0.31	0.33	175.28	175.62	15.54	15.89	195.08	195.77	14.32	14.54	1.7	1.78
PSB + *Trichoderma*	0.43	0.45	185.94	187.59	18.41	18.9	213.85	220.91	17.97	18.3	2.7	2.79
SEm. ±	0.01	0.01	0.66	0.81	0.18	0.2	1.75	2.08	0.23	0.22	0.06	0.06
CD (P= 0.05)	0.03	0.02	1.9	2.34	0.51	0.58	5.01	5.96	0.65	0.62	0.16	0.17
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

mungbean (Table 1). Combined seed inoculation with PSB + *Trichoderma* recorded the highest value of all the studied growth attributes which were significantly superior over seed inoculation with PSB and *Trichoderma*.

Higher grain and stalk yield were obtained with dual seed inoculation of PSB + *Trichoderma* which was significantly superior over seed inoculation of PSB and *Trichoderma* during both the years of experiment. In addition to biocontrol activity of *T. harzianum* against soil borne fungal pathogens (Windham *et al*., 1986; Vinale *et al*., 2008), the increase in grain yield can be attributed to the reduction in pathogen population.

Interaction effects of P, S, Zn and bioinoculants on grain and stalk yield

The interaction effects of P, S, Zn and bioinoculants on grain and stalk yield was found to be highly significant (Tables 2, 3, 4 and 5) during both the years of experiment. Maximum grain and stalk yield were obtained with the combined application of 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1} along with PSB + *Trichoderma* and this combination was significantly found superior over other combinations and control during both the years of experiment. Adequate supply of N, P, K along with S and Zn application played a vital role in the metabolic process of photosynthesis that resulted in increased flowering and fruiting, thereby improving number of pods plant^{-1}, grains pod^{-1} and ultimately resulting in increased grain yield. It indicated that higher nutrients supply has better potential to translocated food material from vegetative part to reproductive part, whereas, this potential power is relatively less under control. Similar results were also reported by Ali *et al*. (2010) and Rathour *et al*. (2015).

Interaction effects of P, S, Zn and bioinoculants on nutrient uptake

Fertilization of mungbean with application of nutrients *viz.*, phosphorus, sulphur, zinc and bioinoculants increased N, P, K, S and Zn uptake on grain and stalk yield in mungbean (Table 5). Significantly higher N, P, K, S and Zn uptake was recorded for 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1}. Application of 25 and 50 kg P_2O_5 ha^{-1} along with 25 kg S ha^{-1} and 3 kg Zn ha^{-1} recorded higher nutrient uptake over phosphorus alone. It was also observed that the increasing levels of phosphorus upto 50 kg P_2O_5 ha^{-1} increased the N, P, K, S and Zn uptake and was found to be significantly superior over 25 kg P_2O_5 ha^{-1} and control treatment because, term 'uptake' denotes the net movement of minerals from soil to plant. The amount of nutrient uptake in legumes increased markedly with the increasing rate of fertilizers (Bansal, 1991; Patel *et al*., 2010). Similar results were also reported by Bairwa *et al*. (2012) for combined application of 30 kg S ha^{-1} and 5 kg Zn ha^{-1} along with *Rhizobium* inoculation.

Dual seed inoculation with PSB + *Trichoderma* recorded more nutrient uptake than PSB and *Trichoderma* alone. PSB are reported to facilitate phosphorus supply to plant by solubilizing insoluble soil phosphorus. These findings are in consonance with the earlier reports of Patel *et al*. (2013), Prasad *et al*. (2014). They stated that *Pseudomonas* increased the availability and uptake of minerals in chickpea plants. Microorganism activities excrete organic acids and phosphates which release elements from complexes present in soil and increase nutrient availability which increases the uptake of nutrients by plant (Rudresh *et al*., 2005).

Interaction effects of P, S, Zn and bioinoculants on available nutrients in soils

Available nutrient content in soil after the harvest of mungbean influenced significantly application of different nutrients like P, S and Zn along with bioinoculants over initial status (Table 6). Higher values of available nutrients were found with the application of 50 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1} and were found to be significantly superior over the lower levels of phosphorus 25 kg P_2O_5 ha^{-1} + 25 kg S ha^{-1} + 3 kg Zn ha^{-1}. Application of 25 and 50 kg P_2O_5 ha^{-1} along with 25 kg S ha^{-1} or 3 kg Zn ha^{-1} recorded highest available nutrients over phosphorus alone. It was also observed that increasing levels of phosphorus upto 50 kg P_2O_5 ha^{-1} was found to be significantly superior over 25 kg P_2O_5 ha^{-1} and control during both the years of experimentation. These findings are in conformity with the reports of Balaguravaiah *et al*. (1989), Goud *et al*. (2010) and Singh *et al*. (2015).

Dual seed inoculation with PSB + *Trichoderma* recorded significantly higher values of available nutrients in soil after harvest of mungbean over PSB and *Trichoderma* alone during both the years of study. Biofertilizer enhances soil fertility by solubilizing unavailable sources of elemental nitrogen and bound phosphate into available forms in order to facilitate plants in their easy absorption (Singh and Yadav, 2008).

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