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EFFECT OF MOLYBDENUM AND MICROBIAL INOCULANTS ON YIELD, NUTRIENT CONTENTS, UPTAKE AND QUALITY OF SOYBEAN GROWN IN A VERTISOL

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Abstract- A field experiment was conducted to evaluate the effect of molybdenum and microbial inoculants on yield, nutrient contents, uptake and quality of soybean during the *Kharif* season of the year 2013 at research farm of JNKVV, Jabalpur. The experiment was laid out in randomized block design with four replications and nine treatments *viz.*, T_1 (control), T_2 (*Rhizobium*), T_3 (PSB), T_4 (*Rhizobium*+PSB), T_5 (0.5 kg Ammonium molybdate ha^{-1}), T_6 (T_5 + *Rhizobium)*, T_7 (T_5 + PSB), T_8 (T_6 + PSB) and T_9 (1.0 g Ammonium molybdate kg^{-1} seed as seed treatment). The result revealed that the application of Mo with Rh+PSB gave the highest grain (1.85 t ha^{-1}) and stover yield (3.52 t ha^{-1}) and protein content (39.05%) in seed over control. Significant increase of N and P content in grain and stover and its uptake by soybean as well as protein content registered best with the application of Mo with Rh+PSB. This treatment also brought about substantial improvement in available nutrients (N, P, K and Mo) in soil.

Keywords- Molybdenum, Microbial inoculants, *Rhizobium*, Nutrient uptake, soybean.

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Introduction

Soybean (*Glycine max* L. Merill) is grown on an estimated 6% of the world's arable land, and since the 1970s, the area in soybean production has the highest increase compared with other major crops [1]. The crop continues to rank number one oilseed crop of India, grown in about 10.33 million ha with the production of 12.55 million tonnes [2]. In the country, the state of M.P. is ranks first in soybean cultivation with an area 5.66 m ha, annual production of 6.28 m tonnes and having national productivity of 1109 kg ha^{-1} [3]. Nutritionally, it contains protein (40-42%) and oil (18-20%) along with calcium, iron, glycine and iso-flavones; helps in preventing heart diseases, cancer and HIVs.

Being a high protein and energy rich crop its productivity is limited due to imbalanced fertilization. In addition, due to intensive cultivation of soybean and chickpea in a Vertisol of M.P. and use of high analysis fertilizers has resulted in depletion of essential plant nutrients from the soils and their residues deteriorate the physical properties of the soil, imparting improper aeration and soil-water-plant relationship, resulting in decreased productivity.

Molybdenum is the cofactor for the enzyme nitrate reductase, which involved in nitrogen assimilation [4]. Its application in deficient soil encouraged nitrogen fixation and nodule formation especially for legumes [5, 6] thus increase the yield. The deficiency of Mo in soils is widespread and a serious agricultural problem that induces yield and quality losses in many crop species worldwide [7] and the most of the phosphorus (75 to 90 per cent) combine with iron, calcium and aluminum in soil. Therefore, the use of efficient strains of phosphate solubilizing bacteria namely *Bacillus megatherium, Biovar phosphaticum, Bacillus polymyxa, Pseudomonas striata, Aspergillus awamori* and *Penicillium digitatum* , have the capability to solubilize the residual or fixed soil P and increase the availability of P in the soil [8, 9]. In the present context of growing concerns on deteriorating soil health, decreasing yield and escalating costs of fertilizer.

MaterialsandMethods

A field experiment was conducted during the *Kharif* season of the year 2013 at research farm of JNKVV, Jabalpur. The soil was clayey in texture having pH 7.42 with low organic carbon (6.4 g kg^{-1}), available nitrogen (197.56 kg ha^{-1}), Phosphorus (23.73 kg ha^{-1}), Potassium (309.88 kg ha^{-1}) and Molybdenum (0.23 mg ha^{-1}). The experiment was laid out in randomized block design with four replications and plot size 4m x 4m. Nine treatments comprising *viz.*, T_1 (control), T_2 (*Rhizobium*), T_3 (PSB), T_4 (*Rhizobium*+PSB), T_5 (0.5 kg Ammonium molybdate ha^{-1}), T_6 (0.5 kg Ammonium molybdate ha^{-1} + *Rhizobium)*, T_7 (0.5 kg Ammonium molybdate ha^{-1} + PSB), T_8 (0.5 kg Ammonium molybdate ha^{-1} + *Rhizobium* + PSB), T_9 (1.0 g Ammonium molybdate kg^{-1} seed as seed treatment) and *Rhizobium* inoculant @ 5 g kg^{-1} seed was applied as seed treatment, whereas phosphate solubilizing bacterial inoculant as soil application @ 3 kg ha^{-1} prior to sowing. The crop was sowing (06/07/2013) and harvested (30/10/2013). Standard procedure were followed for plant analysis-N [10], P [11], K [12], Mo [13], Nutrient uptake (kg ha^{-1}) by using the following formula - {Nutrient uptake (kg ha^{-1}) =Nutrient content (%) X yield (kg ha^{-1}) /100} and {Mo uptake (g ha^{-1}) = Nutrient content (mg kg^{-1}) X yield (kg ha^{-1}) /1000}, Protein and Oil content in seed [14] and statistical analysis by using critical difference [15].

Results and Discussion

Yield attributes

Soil application @ 0.5 kg Ammonium molybdate ha^{-1} with *Rhizobium* and PSB and *Rhizobium* + PSB significantly increased the plant height over T_1 - control and T_2 - PSB alone at 30, 45 and 60 DAS, respectively. T_4 (*Rhizobium* + PSB), was found significant at 30 and 45 DAS whereas use of 0.5 kg ammonium molybdate ha^{-1} as alone was significant at 30 DAS. The treatment T_8 was found at par with T_2, T_4, T_5, T_6, T_7 and T_9 at 30, 45 and 60 DAS, respectively [Table-1]. The highest number of pods (85.25 pods plant^{-1}) was recorded under T_8, which was closely followed by T_4 -*Rhizobium* + PSB (80.50 pods plant^{-1}) and T_6 - 0.5 kg ammonium molybdate ha^{-1} + *Rhizobium* (79.75 pods plant^{-1}). The treatment T_4 and T_8 were recorded higher pods plant^{-1} than T_7. However, T_7 was equally effective with T_6. The highest number of seeds pod^{-1} (2.50) was recorded under T_8 while the lowest mean number of seeds pod^{-1} (1.75) under control and rest of the produced identical number of seeds pod^{-1}. This might be due to Mo is a structural component of

nitrogenase, helps in root nodulation and N_2 fixation by root nodule bacteria of leguminous crop. The increase of plant height, growth, number of pod plant^{-1} with Mo application was also reported by [16-18].

Table-1 *Effect of Mo and inoculants on yield attributes parameter, yield and quality of soybean*

Treatments	Plant height (cm)			pods per plant	seeds per pod	Yield (t ha^{-1})		Seed quality (%)	
	30 DAS	45 DAS	60 DAS			Seed	Stover	Protein	Oil
T_1	19.88	30.1	36.18	64	1.75	1.48	2.89	33.27	17.23
T_2	22.73	34.83	41.88	67.25	2.25	1.64	3.15	36.02	18.63
T_3	21.23	32.6	38.85	69.25	1.75	1.61	3.06	35.19	18.6
T_4	23.58	36.05	42.4	80.5	2.25	1.75	3.4	38.48	19.41
T_5	23.43	34.65	42.13	70.25	2	1.63	3.16	37.14	18.08
T_6	24.05	36.75	44.68	79.75	2.25	1.78	3.45	37.84	19.56
T_7	23.83	36.38	42.68	72.25	2.25	1.69	3.24	37.27	18.61
T_8	24.98	38.25	47.9	85.25	2.5	1.85	3.52	39.05	20.22
T_9	22.53	34.55	42.4	70	2	1.71	3.2	36.61	18.6
SEm±	**1.168**	**1.819**	**2.123**	**2.767**	**0.234**	**0.081**	**0.145**	**1.095**	**0.547**
LSD (p=0.05)	**3.437**	**5.35**	**6.245**	**8.14**	**0.683**	**0.235**	**0.424**	**3.221**	**1.609**

Seed and stover yield

Data presented in [Table-1] showed that the treatments T_8, T_6 and T_4 significantly increased the seed and stover yield of soybean (1.85 t ha^{-1} and 3.52 t ha^{-1}), (1.78 and 3.45 t ha^{-1}) and (1.75 and 3.40 t ha^{-1}), respectively over control (2.89 t ha^{-1}) except of T_2, T_3, T_5, T_7 and T_9. The increase in yield might to be attributed to the increased availability of N and P in soil and also due to synergistic effect of Mo and both the inoculants by virtue of N_2 - fixing potential of the inoculant rhizobia and phosphate solubilizing nature of *Bacillus megatherium,* both functioning simultaneously in the rhizosphere. These results confirm to the findings by [19-23,].

Content and uptake of nutrients

Nitrogen

It is evident from [Table-3] that the soil application @ 0.5 kg Ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed maximum nitrogen content in seed and stover (6.25 and 1.86 %) and its uptake by seed (115.77 kg ha^{-1}), stover (65.40 kg ha^{-1}) and total (181.17 kg ha^{-1}) closely followed by T_4, T_6 and T_9 and these were significantly superior over control. The treatments T_5 and T_7 were significantly increased the N content in seed. While, T_2 and T_3 were found non-significant over the un-inoculated control.

Table-3 *Fertility status of soil after harvest of soybean crop*

Treatments	pH	E.C. (dSm^{-1})	O.C. (g kg^{-1})	Available Nutrients (kg ha^{-1})			Ava. Mo (mg kg^{-1})
				N	P	K	
T_1	7.61	0.19	5.92	197.76	21.29	271.67	0.245
T_2	7.62	0.21	6.55	211.5	22.25	285.67	0.246
T_3	7.59	0.2	6.52	209.01	25.5	287.49	0.242
T_4	7.65	0.21	6.67	232.06	26.48	288.08	0.251
T_5	7.57	0.19	6.15	207.57	22.91	263.38	0.254
T_6	7.63	0.22	6.70	226.77	23.85	302.51	0.255
T_7	7.65	0.2	6.52	210.36	27.27	271.56	0.254
T_8	7.7	0.22	6.77	233.45	28.14	303.21	0.257
T_9	7.6	0.19	6.07	206.97	23.7	268.51	0.252
SEm±	0.046	0.012	0.22	5.635	1.28	11.116	0.006
LSD(p=0.05)	NS	NS	NS	16.574	3.765	NS	NS
Initial value	7.7	0.16	6.40	197.56	23.73	309.88	0.233

Phosphorus

The highest P content in seed and stover (0.79 and 0.20 %) was analyzed which was closely followed by T_7 - 0.5 kg ammonium molybdate ha^{-1} + PSB, T_4 - *Rhizobium* + PSB and T_3 – PSB alone over the control. The highest P uptake by seed, stover and total (14.62, 6.80 and 21.42 kg ha^{-1}) was found with 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB. Further, the treatments T_3, T_4, T_7 and T_6 were recorded significantly higher P uptake than that of control.

Potassium

The highest K content in seed and stover (1.75 and 1.34%) was recorded in T_8, whereas the lowest K content in seed and stover (1.60 and 1.18%), respectively under control. However, the uptake of K by seed, stover and its total uptake increased significantly due to treatments *viz.*, T_4, T_6 and T_8. Moreover, T_8 i.e. 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB recorded the highest K uptake by seed, stover and total uptake (32.34, 46.94 and 79.28 kg ha^{-1}) respectively. The lowest K- uptake (23.63, 33.63 and 57.26 kg ha^{-1}) by seed, stover and its total uptake, respectively under control.

Molybdenum

The maximum Mo content in seed and stover (1.85 and 1.25 mg kg^{-1}) was observed with the application 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB followed by T_7, T_5 and T_6. The application of 1.0 g kg^{-1} seed treatment was noted identical with T_3 and T_4 and the rest of treatments *viz.*, T_5, T_6, T_7 and T_8 were found on par with each other [Table-2]. The Mo uptake by seed, stover and total (3.44, 4.39 and 7.83 g ha^{-1}) increased significantly due to treatments *viz.*, T_4, T_5, T_6, T_7, T_8 and T_9. The content of N, P, K and Mo in seed, stover and uptake by seed and stover were significantly influenced by the application of 0.5 kg AM ha^{-1} with *Rhizobium* + PSB. The significant increase of N, P, K and Mo content in seed, stover and its uptake by soybean might be due to synergistic effect of Mo application with *Rhizobium* and PSB on N, P, K and Mo availability in soil. [24-28, 21, 20].

Seed quality

The application of 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* + PSB protein (39.05%) and oil (20.22%) content in seed was significantly higher than control. The increase might due to be attributed to favorable effect of Mo along with *Rhizobium* + PSB on nitrogenase and nitrate reductase activities resulting in increased BNF and N assimilation [30]. The increased of oil content in soybean

Table- 2 *Effect of Molybdenum and inoculants on Major nutrients and Mo content and uptake of soybean*

Treatments	Nutrients (%)						Mo (mg kg^{-1})		Nutrients Uptake (kg ha^{-1})									Mo uptake (g ha^{-1})		
	N		P		K				N			P			K					
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total	Seed	Stover	Total
T_1	5.32	1.36	0.66	0.15	1.6	1.18	1.35	0.94	78.72	39.2	117.92	9.66	4.31	13.97	23.63	33.63	57.26	1.99	2.7	4.69
T_2	5.76	1.46	0.69	0.16	1.7	1.31	1.42	0.98	94.58	45.66	140.23	11.28	4.99	16.27	27.93	41.1	69.03	2.3	3.08	5.38
T_3	5.63	1.45	0.77	0.19	1.68	1.31	1.42	0.99	91	44.1	135.1	12.47	5.89	18.37	26.93	40.47	67.39	2.28	3.02	5.3
T_4	6.16	1.69	0.78	0.19	1.7	1.33	1.54	1	107.96	57.23	165.19	13.73	6.71	20.44	29.62	45.15	74.77	2.7	3.39	6.09
T_5	5.94	1.46	0.72	0.16	1.63	1.21	1.82	1.2	96.81	46.19	143	11.67	4.88	16.55	26.49	38.15	64.64	2.97	3.77	6.74
T_6	6.05	1.74	0.7	0.16	1.74	1.34	1.8	1.24	108.73	59.88	168.61	12.32	5.56	17.88	31.04	46.53	77.57	3.17	4.27	7.44
T_7	5.96	1.45	0.78	0.2	1.65	1.27	1.83	1.2	100.07	46.58	146.65	13.16	6.1	19.27	27.78	40.95	68.73	3.07	3.87	6.93
T_8	6.25	1.86	0.79	0.19	1.75	1.34	1.85	1.25	115.77	65.4	181.17	14.62	6.8	21.42	32.34	46.94	79.28	3.44	4.39	7.83
T_9	5.86	1.56	0.67	0.16	1.64	1.26	1.64	1.16	99.94	49.87	149.81	11.35	5.08	16.43	28.05	40.23	68.28	2.82	3.72	6.54
SEm±	0.175	0.066	0.031	0.007	0.077	0.06	0.08	0.027	6.238	2.592	8.83	0.693	0.365	1.058	1.921	2.59	4.511	0.191	0.165	0.356
LSD(p=0.05)	0.515	0.193	0.092	0.022	NS	NS	0.235	0.08	18.35	7.626	25.975	2.039	1.073	3.112	5.65	7.62	13.27	0.56	0.485	1.046

with Mo application was also reported by [16, 19, 18, 30, 23].

Fertility status in soil after harvest of crop

Data indicated that the, little change in the pH and EC was recorded but statistically non-significant. The highest OC was recorded by T_8 (6.77 g kg^{-1}) and the lowest by T_5 - 0.5 kg ammonium molybdate ha^{-1} (5.92 g kg^{-1}). The highest N content (233.45 kg ha^{-1}) was recorded under 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB followed by T_4, T_6 and the lowest under control (197.76 kg N ha^{-1}). The application of 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB accorded significantly higher available P (32.14 kg ha^{-1}) followed by T_7, T_4 and T_3 and K (303.21 kg ha^{-1}) over control. The availability of Mo was highest (0.257 mg kg^{-1}) under T_8, followed by T_6, T_7 and T_5. The soil inoculated with *Rhizobium* might be due to increased their biological activity and hence increasing the amount of available nutrients in the soil [31-35].

Conclusions

Soil application @ 0.5 kg ammonium molybdate ha^{-1} with *Rhizobium* and PSB showed significant influence on yield attributes, yield, nutrient content and uptake (N and P), quality in term of protein and oil content and favorable effect on availability of N and P in soil.

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