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EFFICACY OF MICRONUTRIENT APPLICATION ON POTENTIAL OF *BRADYRHIZOBIUM* IN ENHANCEMENT OF GROWTH AND YIELD OF SOYBEAN

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ABSTRACT

A field experiment was carried out using Randomized Block Design (RBD) with three replications for two consecutive years to investigate the efficiency of inoculated *Bradyrhizobium japonicum* (*B. japonicum*) on the soil nutrient status, growth and yield of soybean. Ten different treatments were taken into consideration which included different levels of micronutrients with and without *B. japonicum* inoculation. Inoculation with *B. japonicum* significantly increased the biological and grain yield of soybean over control by 18.1 and 8.83 % respectively. Due to inoculation of *B. japonicum* along with Zinc@ 5 kg ha^{-1}, the biological yield and grain yield gave significantly higher values of 6999.03 and 2775.71 kgha^{-1} respectively. Application of Molybdenum with *B. japonicum* inoculation gave a biological yield and grain yield of 6321.4 and 2441.18 kgha^{-1} respectively. The maximum grain yield, biological yield and straw yield (2789.64 kg ha^{-1}, 7020.60 kg ha^{-1} and 2426.47 kg ha^{-1} respectively) were recorded with the treatment *B. japonicum* + 5 kg Zn ha^{-1} + 0.5 kg B ha^{-1} + 4 g Mo kg^{-1}. Thus the inoculation with *B. japonicum* along with micronutrients improved plant growth, nutrient acquisition and yield.

INTRODUCTION

Soybean (*Glycine max* (L.) *Merill*), a grain legume, plays an essential role in ensuring nutritional security and environmental safety, as they have inbuilt mechanism to fix atmospheric di-nitrogen. Thus it is the best source of protein and oil and has now been recognized as a potential supplementary source of nutritious food (Wilcox and Shibles, 2001). It has been found to substitute other sources of good quality protein such as milk, meat and fish, therefore has become very suitable to some areas where other protein sources are scarce or too expensive to afford (Anwar et al., 2010). Soybean contains a good quality protein of around 42% and 19.5% oil (Wilcox and Shibles, 2001). Different protein of soybean is considered complete, because it supplies sufficient amounts of the types of amino acids that are required by the body for building and repair of tissues. Essential amino acids found in soybean are methionine, isoleucine, lysine, cystine, phenylalanine, tyrosine, threonine, tryphophan as well as valine (Laswai *et al.,* 2005). In soybean seed, there is a protein, which contains amino acids required for human nutrition and livestock (Zarei *et al.,* 2012). Soybean has been found to have different uses; for example in food industry, soybean is used for flour, oil, cookies, candy, milk, vegetable cheese, lecithin and many other products (Coskan and Dogan, 2011). The demand for N in a deficient soil is normally achieved by the use of chemical fertilizers. However, the high cost of mineral N fertilizers may be counteracted by other alternative means to meet the N demand through the use of beneficial bacteria such as *Rhizobium* (Ndakidemi *et al.,* 2006). Legume plants particularly soybean are unique for their ability to fix nitrogen from atmosphere by symbiotic relationship with *Rhizobium* bacteria (Coskan and Dogan, 2011). Nutrient limitations to legume production result from deficiencies of not only major nutrients but also micronutrients such as molybdenum (Mo), zinc (Zn) and boron (B) (Bhuiyan *et al.,* 1999 and Choudhary *et al.,* 2014). However, the effect depends on the micronutrient status and effectiveness of *Rhizobium* strain in the soil. Zinc (Zn), Boron (B) and Molybdenum (Mo) are the most important micronutrients, as they perform several physiological functions in the plant to cause adequate infection for good nodulation, N_2-fixation and growth of the crop. Several studies indicate that there is a necessity of application of micronutrients wherever deficient under intensive cultivation of legumes as it is directly involved in biological nitrogen fixation through activity of nitrogenase enzyme (Gupta and Sahu, 2012; Meena and Ghasolia, 2013). With the above backdrop, this paper emphasizes on the impact of micronutrient application on the efficacy of *Bradyrhizobium japonicum* in soybean.

MATERIALS AND METHODS

A field experiment was conducted at Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand, India during *Kharif* seasons of the two consecutive years to evaluate the effect of Mo, Zn and B with or without *Bradyrhizobium japonicum* (*B. japonicum*) inoculation on nodulation, plant dry weight, nutrient content, nutrient uptake, yield and yield attributes of soybean var. PS 1347 under Mollisol. The experimental soil was well drained Aquic Hapludoll silty clay loam having pH 7.4, high in organic carbon (0.86%), medium in available phosphorus (19.19 kg ha^{-1}) and low in available potassium (130.71 kg ha^{-1}) and available nitrogen (240.17 kg ha^{-1}) content respectively. The soil was low in zinc and molybdenum (0.42 and 0.028 ppm, respectively) but medium in boron (0.035 ppm) content. The experiment comprised of ten treatments *viz.* T_1- Uninoculated control, T_2- *B. japonicum*, T_3- Local strain, T_4- *B. japonicum* + B (Borax) @ 0.5 kg ha^{-1}, T_5- *B. japonicum* + Zn (zinc sulphate) @ 5kg ha^{-1}, T_6- *B. japonicum* + Mo (Sodium molybdate) @ 4 g kg^{-1} seed, T_7- B (borax) @ 0.5 kg ha^{-1}, T_8- Zn (zinc sulphate) @ 5kg ha^{-1}, T_9- Mo (Sodium molybdate) @ 4 g kg^{-1} seed and T_{10}- *B. japonicum* + B (borax) @ 0.5 kg ha^{-1} + Zn (zinc sulphate) @ 5kg ha^{-1} + Mo (Sodium molybdate) @ 4 g kg^{-1} seed treatment combinations replicated thrice in randomized block design (RBD).

Each plot measured 2.75 m × 4 m and soybean seed was sown at 45 cm row to row spacing. Basal dose of N, P and K @ 20, 40 and 60 kg ha^{-1}, respectively was applied through urea, single super phosphate and muriate of potash while Zn (@ 2. 5 kg ha^{-1}) as zinc sulphate, B (@ 0. 5 kg ha^{-1}) as borax and Mo (@ 4 g kg^{-1} seed) as sodium molybdate was applied through seed treatment at the time of sowing. *B. japonicum* inoculants (3.52×10^{-8} c.f.u g^{-1}) obtained from Division of Microbiology, IARI, New Delhi was applied through seed treatment (@ 500g 75 kg^{-1} seed. Observations were recorded on nodulation and growth parameters at 30 DAS, 60 DAS and 90 DAS. Five plants were randomly selected from each plot, uprooted and nodules were carefully separated from the washed roots and counted. The nodules of each replication after counting were dried in open glass petridishes at 65 ± 2ºC for 48 hours in hot air oven till constant weight and plant dry weight was also recorded in the same manner. Nitrogen and phosphorus content in plant was determined by modified Kjeldahl and vanadomolybdo phosphoric yellow colour method in nitric acid system respectively (Jackson, 1973). Available nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus was extracted from the soil with 0.5M $NaHCO_3$ (pH 8.5) as described by Olsen *et al.* (1954) and determined by ammonium molybdate blue color method using spectrophotometer. For determination of available potassium the soil was equilibrated with 1N neutral ammonium acetate (Hanway and Heidel, 1952) and available potassium in the soil extract was estimated using Systronic type 120 Flame photometer. The harvest index (HI) was calculated as suggested by Singh and Khangrot (1987).

$$HI = \frac{\text{Economice Yield}}{\text{Biological Yield}} X\ 100$$

N and P uptake of plant was computed to express the results.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content in plant (\%) X Dry weight of plant}}{\text{X 100}}$$

After threshing and proper cleaning, the grain yield of individual plot was recorded with single pan balance and expressed as kg per hectare after conversion. The experimental data were analyzed statistically by using standard procedure for Randomized Block Design (RBD) applying analysis of variance (ANOVA) technique (Snedecor and Cochron, 1971).

RESULTS AND DISCUSSION

Effect of *Rhizobium* inoculation

Inoculation of *B. japonicum*, improved nodule number and their dry weights at different growth intervals (Table 1). The number of nodules was higher by 13.12, 14.6 and 36 % and nodule dry weight by 18.76, 31.67 and 16.53 % due to seed inoculation with *B. japonicum* at 30, 60 and 90 DAS, respectively over the un-inoculated control. Viayapriya et al. (2003) also found the similar trend. Inoculation of *B. japonicum* also gave numerical increment of 7.31 to 25.93 % in plant dry weight at different intervals (Table 1). The results are in conformity of the results of Suryantini *et al.* (2014). The non significant response of *B. japonicum* inoculation could be because of high population of native *rhizobia* nodulation soybean in soil because of its cultivation from time immortal. Similar findings were also obtained by Gupta (2006) and Singh and Kumar (2008). Seed inoculation with *B. japonicum* numerically increased N, P content in plant, grain, available

Table 1: Effect of micronutrients with *B. japonicum* inoculation on nodulation in soybean (Pooled data for two years)

Treatments	Nodule number $plant^{-1}$			Nodule dry weight(mg $plant^{-1}$)			Plant dry weight (g $plant^{-1}$)		
	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS	30DAS	60DAS	90DAS
T_1 - Control	17.83	34.50	25.00	96.41	228.62	126.44	2.66	37.85	31.00
T_2 - *B. japonicum*	20.17	39.50	34.00	114.50	300.88	152.31	3.35	40.62	33.73
T_3 - Local strain	19.16	34.67	28.83	122.56	380.29	129.23	2.98	35.53	35.69
T_4 - T_2 + B (borax) @ 0.5 kg ha^{-1}	21.33	34.33	28.67	132.19	331.69	128.68	3.07	39.21	35.86
T_5 - T_2 + Zn (zinc sulphate) @ 5kg ha^{-1}	25.17	50.50	33.17	159.66	423.49	139.36	3.57	38.86	38.45
T_6 - T_2 + Mo (Sodium molybdate) @ 4 g kg^{-1} seed	21.83	59.83	32.67	142.12	400.07	137.80	2.80	42.12	35.00
T_7 - B (borax) @ 0.5 kg ha^{-1}	21.50	51.33	31.67	133.56	374.04	146.62	3.23	45.39	35.50
T_8 - Zn (zinc sulphate) @ 5kg ha^{-1}	20.33	53.83	29.33	135.83	363.51	140.36	3.20	38.22	36.50
T_9 - Mo (Sodium molybdate) @ 4 g kg^{-1} seed	23.50	54.83	31.16	140.20	379.24	152.21	3.06	53.00	37.03
T_{10} - *B. japonicum* + 7 + 8 + 9	29.00	65.50	37.83	166.02	536.83	174.31	4.30	45.47	40.73
SEm (±)	2.16	2.88	2.91	12.70	33.73	11.98	0.37	4.93	2.95
CD at 5%	5.58	7.00	9.41	26.69	99.87	34.37	1.05	10.45	7.39

NPK status of soil at harvest and protein content in soybean seed by 6.73, 5.88, 2.88, 25.0, 15.78, 16.15, 7.12, 10.13 and 7.57 % over un-inoculated control, respectively (Table 2). It could be attributed to competitiveness and effectiveness of introduced strain of *rhizobia*, which might have fixed higher amount of atmospheric nitrogen over the native *rhizobia*. Results are supported by work done by Singh and Kumar (2008) and Das *et al*. (2012). The inoculation of *B. japonicum* significantly increased biological and grain yield of soybean by 18.1 and 8.83 % than un-inoculated control (Table 3). It could be due to more availability of nitrogen through biological nitrogen fixation by *rhizobia* from atmosphere and increased the plant growth and plant vigor. Similar results were reported by Das *et al*. (2012) who reported that the inoculation of *Rhizobium species* significantly increased grain yield and straw yield by 23.75 and 29.71 % in chickpea. The numerical increment in straw yield, harvest index and 100-grain weight was also found with the inoculation of *B. japonicum* over un-inoculated control.

Sole application of Zinc

Application of zinc @ 5 kg ha^{-1} as zinc sulphate produced more nodule number of 14.02, 56.02 and 17.32 % over the uninoculated control at 30, 60 and 90 DAS, respectively (Table 1). These results were corroborating with the results of Mishra *et al*. (2002). Similar results were observed and explained by Ahlawat *et al*. (2007) who reported that the fertilization of zinc enhanced root growth; nodulation and nodule dry weight in soybean. Application of zinc @ 5 kg ha^{-1} significantly increased grain yield by 9.50 % over un-inoculated control. It might be due to zinc activates certain enzymes which are responsible for the cell division and elongation which is major source of increase in plant height (Nadergoli *et al*. 2011). Similar results were also reported by Khodadad (2012), Beg *et al*. (2013) in urdbean, Nalini *et al*. (2013) in blackgram and Vaseghi et al. (2013) in soybean. Similarly, straw yield due to application of zinc @ 5 kg ha^{-1} were numerically higher over un-inoculated control, respectively. An increase in grain and straw yield due to supply of Zn in soil leading to better plant growth, nodulation and N_2 - fixation. Similar results were also reported by Ahlawat *et al*. (2007). Harvest index and 100-seed weight were numerically also increased with the application of zinc @ 5 kg ha^{-1} over uninoculated control. The above results were in the conformity with the results of Mhedi and Danial (2014) and Muhammad *et al*. (2014)

Combined application of Zinc with *Rhizobium sp.*

Combined application of *Bradyrhizobium japonicum* with zinc found better than *Bradyrhizobium japonicum* and Zn alone application. Inoculation of *Bradyrhizobium japonicum* with Zn @ 5 kg ha^{-1} gave significantly higher by 41.16, 46.37, 65.60 and 85.23 % nodule number and their dry weight than uninoculated control at 30 and 60 DAS respectively (Table 1). The results are in agreement with Singh *et al*. (2004). Combined application of *Bradyrhizobium japonicum* with Zn @ 5 kg ha^{-1} gave 34.21, 2.66 and 24.03 % higher plant dry weight over un-inoculated control and at par with application of Zn @ 5 kg ha^{-1} (Table 1). These results are in the close proximity with the data reported by Singh *et al*. (2004). Grain yield and biological yield in case of *B. japonicum* inoculation with Zn @ 5 kg ha^{-1} were significantly higher by 15.31 and 11.76 % over *B. japonicum* alone inoculation.

Sole application of Boron

Application of boron @ 0.5 kg ha^{-1} as borax produced more nodule number of 20.58, 48.78 and 26.68 % over the un-inoculated control during each growth stage (Table 1). The increase in nodule number might be due to optimum dose of boron, which increases the rate of transportation of sugars (which are formed by photosynthesis in mature plant leaves) which are required for soybeans. Similarly B applications @ 0.5 kg ha^{-1} produced 38.53, 63.60 % significantly higher nodule dry weight than the un-inoculated control at 30 and 69 DAS, respectively. These results corroborates with the findings of Tahir *et al*. (2014). Grain yield due to application of B @ 0.5 kg ha^{-1} were significantly higher by 11.78 % over control treatment (Table 3). The above resulted were in conformity with the results of Tahir *et al*. (2014) who reported highest seed yield (1757 kg ha^{-1}) of soybean with the application of 2 kg ha^{-1} boron over without application of B. Straw yield due to B application was numerically higher by 6.25 and 3.15 % over un-inoculated control. These results are in accordance with Devi *et al*. (2012) and Kaisher *et al*. (2010) findings. Application of B @ 0.5 kg ha^{-1} gave 5.0 and 8.0 % more harvest index and 100-seed weight over un-inoculated control. Results corroborates with the findings of Tahir et al. (2014).

Combined application of boron and *Bradyrhizobium*

B. japonicum inoculation along with B @ 0.5 kg ha^{-1} also favored the nodule number registering 5.75, 37.11 and 15.41 % more nodule number, nodule dry weight and plant dry weight over B. *japonicum* application alone respectively (Table 1). These results are in agreement with the findings of Bharti *et al*. (2002). *B. japonicum* inoculation with B @ 0.5 kg ha^{-1} also favored the total N and P uptake by 20.89 and 10.31 % more than seed inoculation by local strain of *rhizobia* alone (Table 2). Similar response has also been reported by Bharti *et al*. (2002). Results were also in agreement with Singh *et al*. (2004). Thus B plays an important role in establishment of the symbiosis between host and *Rhizobium*. Grain yield due to *B. japonicum* inoculation with B @ 0.5 kg ha^{-1} was numerically higher by 5.39 % over B @ 0.5 kg ha^{-1} alone (Table 3). Similar, results were also reported by Bharti *et al*. (2002).

Sole application of Molybdenum

Application of Mo (Sodium molybdate) @ 4 g kg^{-1} seed increased nodule number significantly by 31.80 and 58.92, % over uninoculated control at 30 and 60 DAS, respectively (Table 1). Nutrient content in plant (N and P) numerically increased by 17.30 and 20.58 % with the application of Mo (Sodium molybdate) @ 4 g kg^{-1} seed over un-inoculated control. Similarly, N and P uptake by plant was also increased by 29.53 and 11.93 % over uninoculated. Das *et al*. (2012) also reported that the applications of 0.5 kg Na2MoO4 ha^{-1} was found slightly better than 1.0 kg Na2MoO4 ha^{-1} registering 12.28 % more N uptake than the uninoculated control. However, yield attributes were also numerically increased with the application of same treatment over uninoculated control (Table 2). These findings were corroborates with the results of Kumar *et al*. (2005). Grain yield due to seed treatment with 0.5 kg Na2MoO4 kg^{-1} seed were significantly increased by 12.10 over uninoculated control. Similarly biological and straw yield

Table 2: Response of *B. japonicum* along with micronutrients on nutrient content and uptake by plant (Pooled data for two years).

Treatments	N, P content in stem (%)		N, P content in grain (%)		N, P uptake by plant (kg ha^{-1})		Available soil nutrient status(kg ha^{-1})		Seed protein content	
	N	P	N	P	N	P	N	P	K	(%)
T_1 - Control	1.04	0.34	5.90	0.28	60.20	21.11	236.42	20.12	105.63	36.84
T_2 - *B. japonicum*	1.11	0.36	6.07	0.35	69.70	24.52	253.27	22.16	113.63	37.91
T_3 - Local strain	1.09	0.40	6.08	0.32	61.02	21.32	249.50	20.93	124.77	37.97
T_4 - T_2 + B (borax) @ 0.5 kg ha^{-1}	1.25	0.39	6.03	0.37	73.77	23.52	264.37	22.42	130.95	37.69
T_5 - T_2 + Zn (zinc sulphate) @ 5kg ha^{-1}	1.15	6.08	6.08	0.37	78.35	27.90	259.53	24.77	153.05	38.00
T_6 - T_2 + Mo (Sodium molybdate) @ 4 g kg^{-1} seed	1.14	0.40	5.78	0.36	71.83	25.34	261.25	23.23	134.13	36.09
T_7 - B (borax) @ 0.5 kg ha^{-1}	1.23	0.39	6.15	0.32	73.35	24.64	255.30	24.03	136.17	38.41
T_8 - Zn (zinc sulphate) @ 5kg ha^{-1}	1.20	0.37	6.13	0.34	71.99	21.27	262.75	21.71	137.43	38.31
T_9 - Mo (Sodium molybdate) @ 4 g kg^{-1} seed	1.22	0.41	6.10	0.34	77.98	23.63	261.62	25.40	136.25	38.13
T_{10} - *B. japonicum+7+8+9*	1.44	0.45	6.33	0.39	100.64	31.49	282.18	28.56	163.23	39.56
SEm (±)	0.10	0.16	0.26	0.04	7.15	2.20	5.76	2.00	16.21	1.63
CD at 5%	0.59	0.24	1.50	0.09	14.50	6.38	16.85	5.58	32.50	28.13

Table 3: Effect of micronutrients with *B. japonicum* inoculation on yield and yield attributes of soybean (Pooled data for two years)

Treatments	Biological yield	Grain yield	Straw yield	Harvest Index (%)	100-seed
	kg/ha	kg/ha	kg/ha		weight (g)
T_1 - Control	5599.72	2211.76	1845.72	39.50	10.76
T_2 - *B. japonicum*	6261.19	2407.06	2186.08	38.44	11.26
T_3 - Local strain	5982.47	2378.59	1751.59	39.76	11.15
T_4 - T_2 + B (borax) @ 0.5 kg ha^{-1}	5972.99	2605.75	1712.14	43.63	11.32
T_5 - T_2 + Zn (zinc sulphate) @ 5kg ha^{-1}	6999.03	2775.71	2420.33	39.66	11.09
T_6 - T_2 + Mo (Sodium molybdate) @ 4 g kg^{-1} seed	6321.40	2441.18	1936.85	38.62	10.60
T_7 - B (borax) @ 0.5 kg ha^{-1}	5964.74	2472.42	1903.88	41.45	11.62
T_8 - Zn (zinc sulphate) @ 5kg ha^{-1}	5862.27	2422.05	1834.47	41.32	10.76
T_9 - Mo (Sodium molybdate) @ 4 g kg^{-1} seed	5869.29	2479.52	1850.08	42.25	11.05
T_{10} - *B. japonicum+7+8+9*	7020.60	2789.64	2426.47	39.74	10.84
SEm (±)	357.75	95.92	171.24	-	2.70
CD at 5%	600.00	180.00	469.77	-	5.35

were higher by 4.81 and 0.23 % over uninoculated control. Chandra and Kothari (2002) also reported beneficial effect of the application of Mo with increasing doses on the grain yield, protein content of grain and available N content.

Combined application of Molybdenum and *Bradyrhizobium*

Seed treatment with 0.5 kg Na2MoO4 kg^{-1} seed significantly increased nodule number and nodule dry weight by 51.46 and 32.96 % at 60 DAS over *B. japonicum* inoculation alone. Similarly, plant dry weights were more by 3.69 and 3.76 % at 30 and 60 DAS over *B. japonicum* inoculation alone (Table 1). These results are also in agreement with Brkiæ *et al.* (2004), who reported more plant dry weight with *Rhizobium* inoculation + Mo application than *Rhizobium* alone. Seed inoculation of *B. japonicum* showed better result with 0.5 kg Na2MoO4 kg^{-1} seed by producing 2.70 and 1.11 % more N and P content in plant and 3.05 and 3.34 % more N and P uptake by plant over *Rhizobium* alone inoculation (Table 2). Similar response has also been reported by Brikiae *et al.* (2004). Seed inoculation of *B. japonicum* with 0.5 kg Na_2MoO_4 kg^{-1} seed also gave 1.41 and 1.00 % more grain yield and biological yield than *Rhizobium* alone inoculation. It could be due to be because of their synergistic interaction with inoculated and native rhizobia nodulating chickpea by helping in survival in rhizosphere, root colonization, root hair infection and efficiency of N_2-fixation. Similar results were reported by Das *et al.* (2012).

Application of Micronutrients (Zn, B and Mo) with Bradyrhizobium

Inoculation of *B. japonicum* + 5 kg Zn ha^{-1} + 0.5 kg B ha^{-1} + 4g Mo kg^{-1} seed resulted maximum nodule number, nodule dry weight and plant dry weight when compared with all the applied treatments, respectively (Table 1). The maximum N and P content in plant (1.44 and 0.45 %) was found with the application of inoculation of *B. japonicum* + 5 kg Zn ha^{-1} + 0.5 kg B ha^{-1} + 4 g Mo kg^{-1} seed. Similarly, the application of inoculation of *B. japonicum* + 5 kg Zn ha^{-1} + 0.5 kg B ha^{-1} + 4 g Mo kg^{-1} seed significantly increased N uptake over all the treatments. However, this treatment also increased P uptake significantly over all the treatments except *B. japonicum* + 5 kg Zn ha^{-1} and *B. japonicum* +4 g Mo kg^{-1} seed. The maximum grain yield, biological yield and straw yield (2789.64 kg ha^{-1}, 7020.60 kg ha^{-1} and 2426.47 kg ha^{-1}, respectively) was recorded by the application *B. japonicum* + 5 kg Zn ha^{-1} + 0.5 kg B ha^{-1} + 4 g Mo kg^{-1} seed.. It may be due to application of micronutrient along with *B. japonicum* Mo, is the part of nitrogenase enzyme and responsible for the increase biological nitrogen fixation and zinc shows beneficial effect on chlorophyll content and so it indirectly influenced the photosynthesis and reproduction. These findings corroborate with the findings of Sonene *et al.* (2007) and Saxena and Chandel (1997). Inoculation of *B. japonicum* with Zn @ 5 kg ha^{-1} and Mo @ 4 g kg^{-1} seed numerically increased available

N, P and K in soil after harvest over control. *B. japonicum* inoculation helps in the increase of available nitrogen in soil through nitrogen fixation because of less uptake of soil nitrogen. These results were in conformity with Shirpurkar *et al.* (2006).

The data obtained indicate that the combined application of micronutrients and *B. japonicum* inoculum resulted in maximum straw and grain yield, nutrient content and uptake and also enhanced the soil nutrient status. It may thus be concluded that the treatment consisting of micronutrients and *B. japonicum i.e. B. japonicum* + 5 kg Zn ha^{-1} + 0.5 kg B ha^{-1} + 4 g Mo kg^{-1} is superior among all treatments used for the experiment.

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