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Effect of *Rhizobium* and Boron Application on Yield of Mung Bean, Nutrients Uptake and Fertility Status Grown in Red Soils of Mirzapur

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ABSTRACT

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A field experiment was conducted during 2008-09 and 2009-10 at agriculture research farm of Rajeev Gandhi South Campus (RGSC) Barkacachha, Mirzapur of Banaras Hindu University to study the effect of graded levels of B application (0.0-3.0 kg B ha⁻¹) with and without *Rhizobium* inoculation with recommended dose of fertilizer (RDF) on Yield, harvest index and total nutrient uptake by mung bean and fertility status of post harvest soil. The experiment was laid out under randomized block designed with three replications. It was found that application of graded levels of B fertilization with *Rhizobium* inoculation with RDF favorably influence grain, stover yield and harvest index as well as total N, P, K, S and B uptake by mung bean and also influence soil physico-chemical environment and nutrient availability, such as pH, organic carbon, available-N, P, K, S and B over the RDF alone applied in plot. Among all the treatment combination, the RDF and *Rhizobium* with 1.50 kg ha⁻¹ B application was found to be superior in improving yield, harvest index, nutrient uptake and also improve soil health over the other treatments.

Introduction

Micronutrients deficiencies have emerged as one of the major constraints in successful crop production in Indian soils. During the last three decades, micronutrient deficiencies have grown in both magnitude and extent due to increased use of high analysis fertilizers, high yielding crop varieties and increase in

cropping intensity. This situation has aggregates a major constraint in reduction of productivity of cereal, oilseeds and pulses. Thus, there is an urgent need for correction of individual nutrient deficiency for arresting its further spread. Availability of micronutrients is closely related on physico-chemical nature of different soils type and plays an important role in sustaining higher crop productivity.

Boron is one of the essential micronutrient for plant growth. Its deficiency is much more common in crops that are grown in soils containing higher amount of free carbonates, low organic matter, and high pH (Goldberg, *et al.*, 2005). Fertilizer use in the country predominantly pertains to Nitrogen (N) and Phosphorus (P). Potassium (K) use is confined to a crops and Boron use is negligible. Many introduced crop varieties are more susceptible to Boron deficiency (Chaudhry *et al.*, 1976). Hence, soil conditions and agronomic practices are conducive to the incidence of Boron deficiency in plants.

The adequate management of Boron in soil-plant system is usually difficult because the range between B deficiency and toxicity is relatively narrow. Thus, knowledge of the chemical behavior of B in the soil is particularly important. In order to recommend, the correct amount of Boron, it present in the soil and needs to the plants should be determined. The availability of it depends upon adsorption-desorption processes, which are influenced by various physicochemical properties of soils (Arora and Chahal, 2005).

The extent of it adsorption in soils depends on solution pH, soil texture and mineral composition. The soil pH has been reported as the main factor affecting the B adsorption in the soil (Saltali *et al.*, 2005; Soares *et al.*, 2008). Pulse crops meet a major portion of their nitrogen requirement through biological fixation of atmospheric nitrogen. Seed treatment with crop specific strain of *Rhizobium* bacteria promotes N-fixation and improves crop yields by 10 to 20 %. Use of *Rhizobium* inoculants in pulse crops is an integral part of improved package of practices for pulses. It is also important for sustainability of our agricultural production system through biological nitrogen fixation

process in soil and nutritional security of weaker section of the society, especially the children and lacting woman. Crops are strongly influenced by application of the nutrients. The magnitude of yield losses is due to nutrient deficiency and varies among the nutrients.

Since, micronutrient availability for the plant depends, among other factors, soil texture, organic matter and soil pH. The response to added fertilizers application varied with soil type, soil moisture and management practices, besides the seasons in different areas particularly in rainfed agro-ecosystem. The major causes of Boron deficiency of in Indian soils are coarse textured, low pH and low organic matter content. In Boron deficient soil, both yield and quality of pulses are poor. The inclusion of this nutrient is essential in the fertilization scheduled. Thus Boron has become a key nutrient to increase productivity in B deficient light textured soil. Neglecting the B nutrient, will lead to a low yield, inferior crop quality and reduce efficiency of plant nutrient. The boron requirement of pulse is fairly high in comparison to oil seeds, cereal and millet crops (Murphy and Walsh, 1972).

Materials and Methods

The experiment was conducted at agriculture research farm of Rajeev Gandhi South Campus (RGSC), Barkachha Banaras Hindu University during the 2008-09 and 2009-10. The experiment was laid out in Randomized Block Design (RBD) with three replications consisted of graded levels of boron application *i.e.* 0.0, 0.75, 1.5 and 3.0 kg B ha⁻¹ with and without *Rhizobium* application along with recommended dose of fertilizer. The soil of the experimental field was coarse in texture having pH 5.48 and 5.53, organic carbon 3.8 g kg⁻¹ and 3.5, available N 162.54 and 169.87 kg ha⁻¹,

available P 9.17 and 9.31 kg ha⁻¹, available K 182.5 and 169.87 kg ha⁻¹, available S 9.34 and 9.59 kg ha⁻¹ and available B 0.32 and 0.29 mg kg⁻¹, respectively for year 2008-09 and 2009-10. The crop was harvested when it attained full maturity. Five plants were selected randomly from each plot at both pod picking and harvesting stages to serve as a substrate for analysis of concentration of nutrient contents in French bean pods and stover at pod picking stage and seed and stover at harvesting stage.

The selected samples were cleaned with tap water, dilute HCl (5 ml litre⁻¹ of water) and distilled water. The cleaned samples were separated into pods, seeds and stover and finally subject to oven drying at 65°C, till the material exhibited constant weight (Tandon, 1993). The dried material was ground to powder in Wiley grinding mill. For estimating N concentration, the powdered material (0.5 g) was digested in concentrated H₂SO₄ in presence of digestion mixture K₂SO₄, FeSO₄ and CuSO₄ in the ratio of 10:1:0.5 with 1 g Selenium powder (Jackson, 1973). The digest was cooled and diluted to 100 ml with distilled water. 20 ml of the digest was taken for N estimation.

For estimation of P, K, and S the powdered material (0.5 g) was digested in di-acid (HNO₃ and HClO₄) in the ratio of 9:4 (Jackson, 1973). The digested material was filtered and volume made up to 100 ml with distilled water and 5 ml of the digest was used for P, K and S estimation respectively. For estimation of boron concentration the powdered material (0.5 g) was digested by dry ashing technique (Chapman and Pratt, 1961). The digested material was treated with 20% HCl to dissolve it, filtered and volume made up to 25 ml with distilled water. 1 ml of aliquot was used for B estimation. Nutrient uptake at pod picking and harvesting stage was worked out by multiplying nutrient

contents by respective dry matter contents. Soils were analysed by using standard procedures as described for available N (Subbiah and Asija, 1956), available phosphorus (Bray and Kurtz, 1945), available potassium (Jackson, 1973) and available sulphur (Williams and Steinbergs, 1959). Soil available B was extracted with boiling water in 1:2 suspensions for 5 minutes (Berger and Truog 1944).

Boron in soil and plant extracts was estimated using azomethine-H reagent as suggested by John *et al.*, (1975). Total N in grain was determined by micro-Kjeldhal method. The significance of the difference among the treatment means was estimated by the least significant difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Crop yield and harvest index

Grain yield (Table 1) of mung bean was influenced significantly by the application RDF+ *Rhizobium* + 1.5 kg B ha⁻¹ over RDF and RDF+ *Rhizobium*, RDF+0.75 kg boron ha⁻¹ during both the years. It was also found that different levels of boron (0.75-1.5 kg ha⁻¹) with *Rhizobium* inoculation increased significantly grain yield and decreased at 3.0 kg ha⁻¹ of boron application in first year experiment. However linear increasing trend of grain yield was obtained with increasing in the level of boron from 0.75-3.0 kg ha⁻¹ without inoculation of *Rhizobium* in second year of field experiment.

The highest grain yield was obtained with conjugative use of *Rhizobium* + 1.5 kg B ha⁻¹ along with RDF in both the years. The increase in grain yield was noticed upto 67.19, 89.71 per cent, respectively over control during both the years. Stover yield of mung bean was also influenced significantly

by application of boron level with and without inoculation *Rhizobium*. The highest stover yield was recorded with RDF+ *Rhizobium* + 1.5 kg B ha⁻¹ of application over RDF, RDF+ *Rhizobium* during 2008-09 and 2009-10 except with RDF + 0.75 kg B ha⁻¹. It also clear from the table that level of boron with *Rhizobium* inoculation decreased stover yield at 3.0 kg B ha⁻¹ of application. A linear increase in stover yield was obtained with an increase in the level of boron application upto increasing level of B at 3.0 kg B ha⁻¹ without inoculation of *Rhizobium* in both the years. Increase in grain and stover yield of mung bean was also reported by Singh *et al.*, (2006) Valenciano *et al.*, (2010) and Kumar *et al.*, (2006).

Total N, P, K, S and B uptake by mung bean

Data pertaining to total N,P and K uptake by mung bean crop are depicted in table 2. Results revealed that total N, P, and K uptake by the crop was influenced significantly by the application of graded level of B with *Rhizobium* inoculation and close of N. P. K.

The total nitrogen uptake in mung bean was found to increase with increasing in the level of B upto the 1.5 kg B ha⁻¹ with *Rhizobium* inoculation and further increase in the B level @ 3.0 kg B ha⁻¹ reduced nitrogen uptake by crop. However, a linear increase of N uptake by crop was recorded with graded level of B application from 0.75 to 3.0 kg ha⁻¹ without *Rhizobium* inoculation during both the years of field experimentation.

The pooled higher total nitrogen uptake by crop (73.91 kg ha⁻¹) was noticed with application of RDF+ *Rhizobium*+ 1.5 Kg B ha⁻¹ of application both the year over control (37.21 kg N ha⁻¹). Application of RDF+ *Rhizobium* + 1.5 Kg B ha⁻¹ also gave significant increase in the total phosphorus

uptake by mung during both the years. The results further indicate that total phosphorus uptake by crop was found to increase with increasing in the level of B upto the 1.5 kg B ha⁻¹ and declined with further increase in the boron level(3.0 kg ha⁻¹) with *Rhizobium* inoculation Total phosphorus uptake by crop increased linearly with added B level from (0.75 to 3.0 kg B ha⁻¹) without *Rhizobium* inoculation in both the years.

The pooled highest of total potassium uptake (55.36 kg ha⁻¹) by mung bean crop was noted with application of RDF+ *Rhizobium*+ 1.5 Kg B ha⁻¹ with *Rhizobium* inoculation over rest of the treatments in both the years. Increase in the total N, P and K uptake by the crop may be attributed to the increased availability of these nutrients in soil solution and better utilization by plant roots. It is evident from Table 3 total uptake of S and B is significantly affected by graded levels of Boron and highest uptake of S and B was noticed with RDF+ *Rhizobium*+ 1.5 Kg B ha⁻¹.

Increase in grain, stover yields and Harvest Index of mung bean and also total uptake of N,P, K,S, and Boron by mung bean is directly related with adequate supply of B level in B deficient acidic upland red soils. The evidence suggests the role of B in metabolic function (Hunt, 2003). Effects of B deprivation may exert multiple direct and indirect effects on membrane-bound processes. A direct role of B in maintaining membrane structure is likely through *cis-diol* complexation with glycoproteins, which are structural constituents of the plasma membrane (Goldbach *et al.*, 2001; Brown *et al.*, 2002). Effects of B deficiency, pointing to a structural role of B in membrane stabilization, are an altered permeability for potassium (K) and sugars (Parr and Loughman, 1983; Goldbach, 1985; Cakmak *et al.*, 1995).

Post-harvest soil properties

Soil pH, electrical conductivity and organic carbon in post-harvest soil

Changes in pH, EC and organic carbon due to application of boron and *Rhizobium* application in mung bean crops post-harvest soils in the years 2008-09 and 2009-10 in graded levels have presented in table 4. It was observed that neither soil pH nor electrical conductivity of post-harvest soil significantly change by the application of boron and *Rhizobium* application in mung bean crops. Soil Organic Carbon also remained unaffected by the application of boron and *Rhizobium* application in mung bean crops, which could be due to the reason that mung bean is short duration crop, since no extra organic matter added in experimental plot and changes in Carbon stock is very slow process in cultivated lands. It is surmised that the boron-containing oxides may have provided a pre-condition for absorption of elements, *i.e.*, a condition to better utilize Ca, Mg and other elements. Ren, *et al.*, (2009) was found the non-significant correlation between boron and calcium and magnesium content in the soil with application of boron in soil.

Availability of major nutrient in post-harvest

Data pertaining to available nitrogen in post-harvest soil is presented in table 5. A close examination on the data revealed that availability of nitrogen in post-harvest soil significantly increased with graded levels 0-3.0 kg ha⁻¹ of boron and *Rhizobium* application in red soils of Mirzapur in both of the experimentation year. The highest availability of nitrogen recorded with RDF + *Rhizobium*+ 1.50 kg ha⁻¹ application for both of experimentation year, which is significantly superior over the control (Recommended dose of fertilizer) and at par

with rest of treatment. It was also observed that in second year of field experiment has greater nitrogen availability as compare to first year of experimentation. Increasing in nitrogen availability in post-harvest soil due the biological nitrogen fixation process, boron play an important role in biological nitrogen fixation it enhance the number of effective nodule (Bolaños *et al.*, 1994) and produce singling compound during the *Rhizobia* infection on roots of legume crop (Spaink, 2000). A critical data perusal on availability of phosphorus in post-harvest soil shows that availability of phosphorus in soil increased with application of graded levels of boron and *Rhizobium* application. The highest availability of phosphorus in experimentation year 2008-09 was recorded as 12.99 kg ha⁻¹, while in year 2009-10 it was 13.01 kg ha⁻¹ and pooled value is 13.00 kg ha⁻¹ recorded with application of RDF + *Rhizobium*+ 1.50 kg ha⁻¹, while minimum recorded with RDF for the both of experimentation. Application of RDF + *Rhizobium*+ 1.50 kg ha⁻¹ significantly increasing the availability of phosphorus in red soils over the control(RDF) and *Rhizobium* inoculation alone while at par with rest of treatment. The increasing in availability of phosphorus due the enhancement in enzymatic activity (Phosphatase) in soil which is leads the release of phosphorus in soil (Bline *et al.*, 2011).

The availability of potassium in post-harvest increased with increasing in levels of boron and *Rhizobium* inoculation in both of the experimentation, but it could not attained upto the levels of significance. The availability of NPK in RDF and *Rhizobium* with 1.50 kg ha⁻¹ boron application plots may be attributed to its biological nitrogen fixation and the red soil requirement of sufficient micronutrient as boron application, which the process of mineralization of organically bound micronutrients present in native soil.

Table.1 Grain yield, stover yield and harvest index of mung bean as influenced by application of Boron and *Rhizobium* in red soils of Mirzapur

| Treatments | Grain Yield(q ha ⁻¹) | | | StoverYield(q ha ⁻¹) | | | Harvest Index(%) | | |
|---|----------------------------------|---------|--------|----------------------------------|---------|--------|------------------|---------|--------|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| RDF (Control) | 6.43 | 6.02 | 6.23 | 15.86 | 16.10 | 15.98 | 28.84 | 27.15 | 27.99 |
| RDF + <i>Rhizobium</i> | 7.15 | 7.55 | 7.35 | 16.16 | 16.63 | 16.40 | 30.67 | 31.05 | 30.86 |
| RDF + <i>Rhizobium</i> + 0.75 Kg ha ⁻¹ B | 8.01 | 8.96 | 8.49 | 18.33 | 19.16 | 18.74 | 30.47 | 31.75 | 31.11 |
| RDF + <i>Rhizobium</i> + 1.50 Kg ha ⁻¹ B | 10.75 | 11.42 | 11.09 | 18.62 | 20.56 | 19.59 | 36.60 | 35.67 | 36.13 |
| RDF + <i>Rhizobium</i> + 3.00 Kg ha ⁻¹ B | 8.94 | 9.76 | 9.35 | 18.07 | 18.78 | 18.43 | 32.98 | 34.18 | 33.58 |
| RDF + 0.75 Kg ha ⁻¹ B | 7.74 | 8.19 | 7.97 | 17.74 | 19.44 | 18.59 | 30.40 | 29.67 | 30.04 |
| RDF + 1.50 Kg ha ⁻¹ B | 8.36 | 9.39 | 8.88 | 18.32 | 19.05 | 18.68 | 31.28 | 33.03 | 32.15 |
| RDF + 3.00 Kg ha ⁻¹ B | 9.32 | 10.16 | 9.74 | 18.56 | 20.42 | 19.49 | 33.30 | 33.29 | 33.30 |
| SEm± | 0.63 | 0.80 | 0.29 | 0.61 | 0.75 | 0.28 | - | - | - |
| CD(P=0.05) | 1.85 | 2.34 | 0.60 | 1.94 | 2.19 | 0.57 | NS | NS | NS |

RDF = Recommended dose of fertilizer

Table.2 Total N, P and K uptake by mung bean crop as influenced by application of Boron and *Rhizobium* in red soils of Mirzapur

| Treatments | Total Nitrogen uptake(kg ha ⁻¹) | | | Total Phosphorus uptake(kg ha ⁻¹) | | | Total Potassium uptake(kg ha ⁻¹) | | |
|---|---|---------|--------|---|---------|--------|--|---------|--------|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| RDF (Control) | 37.77 | 36.65 | 37.21 | 4.47 | 4.30 | 4.39 | 29.81 | 37.91 | 33.86 |
| RDF + <i>Rhizobium</i> | 43.11 | 44.47 | 43.79 | 5.51 | 6.24 | 5.87 | 34.88 | 44.86 | 39.87 |
| RDF + <i>Rhizobium</i> + 0.75 Kg ha ⁻¹ B | 53.61 | 56.37 | 54.99 | 6.64 | 6.80 | 6.72 | 40.05 | 52.67 | 46.36 |
| RDF + <i>Rhizobium</i> + 1.50 Kg ha ⁻¹ B | 72.86 | 74.97 | 73.91 | 7.90 | 9.37 | 8.63 | 48.68 | 62.05 | 55.36 |
| RDF + <i>Rhizobium</i> + 3.00 Kg ha ⁻¹ B | 59.31 | 60.22 | 59.76 | 6.63 | 6.52 | 6.58 | 41.33 | 52.20 | 46.77 |
| RDF + 0.75 Kg ha ⁻¹ B | 48.21 | 52.89 | 50.55 | 5.80 | 5.81 | 5.81 | 39.06 | 52.02 | 45.54 |
| RDF + 1.50 Kg ha ⁻¹ B | 55.46 | 58.01 | 56.74 | 6.90 | 6.87 | 6.88 | 43.23 | 54.90 | 49.07 |
| RDF + 3.00 Kg ha ⁻¹ B | 57.93 | 63.76 | 60.85 | 7.50 | 7.24 | 7.37 | 41.41 | 55.14 | 48.27 |
| SEm ± | 2.62 | 3.24 | 0.85 | 0.50 | 0.40 | 0.13 | 1.51 | 1.26 | 0.40 |
| CD(P=0.05) | 7.65 | 9.49 | 2.46 | 1.46 | 1.17 | 0.38 | 4.41 | 3.67 | 1.16 |

Table.3 Total S and B uptake by mung bean as influenced by application of Boron and *Rhizobium* application in red soils of Mirzapur

| Treatments | Total Sulphur uptake (kg ha ⁻¹) | | | Total Boron (g ha ⁻¹) | | |
|---|---|---------|--------|-----------------------------------|---------|--------|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| RDF (Control) | 4.59 | 4.09 | 4.34 | 215.92 | 195.15 | 205.53 |
| RDF + <i>Rhizobium</i> | 5.04 | 5.23 | 5.13 | 240.02 | 219.92 | 229.97 |
| RDF + <i>Rhizobium</i> + 0.75 Kg ha ⁻¹ B | 6.14 | 6.57 | 6.36 | 312.62 | 325.64 | 319.13 |
| RDF + <i>Rhizobium</i> + 1.50 Kg ha ⁻¹ B | 7.98 | 8.20 | 8.09 | 636.76 | 638.20 | 637.48 |
| RDF + <i>Rhizobium</i> + 3.00 Kg ha ⁻¹ B | 6.51 | 6.27 | 6.39 | 445.37 | 401.09 | 423.23 |
| RDF+ 0.75 Kg ha ⁻¹ B | 5.06 | 5.31 | 5.19 | 239.14 | 252.05 | 245.60 |
| RDF+ 1.50 Kg ha ⁻¹ B | 5.58 | 5.68 | 5.63 | 417.67 | 425.32 | 421.49 |
| RDF+ 3.00 Kg ha ⁻¹ B | 5.91 | 6.63 | 6.27 | 440.75 | 453.78 | 447.26 |
| SEm ± | 0.34 | 0.22 | 0.08 | 75.09 | 65.83 | 20.38 |
| CD(P=0.05) | 1.00 | 0.64 | 0.24 | 219.72 | 192.62 | 59.05 |

Table.4 Effect of Boron and *Rhizobium* application on pH, EC and organic carbon content of post-harvest experimental soil

| Treatments | pH | | | EC(dsm ⁻¹) | | | Organic carbon (g kg ⁻¹) | | |
|--|---------|---------|--------|------------------------|---------|--------|--------------------------------------|---------|--------|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| RDF(Control) | 5.49 | 5.57 | 5.53 | 0.20 | 0.19 | 0.20 | 4.10 | 4.30 | 4.20 |
| RDF + <i>Rhizobium</i> | 5.50 | 5.58 | 5.54 | 0.20 | 0.19 | 0.19 | 4.13 | 4.33 | 4.23 |
| RDF+ <i>Rhizobium</i> + 0.75 Kg ha ⁻¹ B | 5.49 | 5.58 | 5.54 | 0.19 | 0.18 | 0.18 | 3.90 | 4.10 | 4.00 |
| RDF+ <i>Rhizobium</i> + 1.50 Kg ha ⁻¹ B | 5.50 | 5.58 | 5.54 | 0.20 | 0.20 | 0.20 | 4.03 | 4.23 | 4.13 |
| RDF+ <i>Rhizobium</i> + 3.00 Kg ha ⁻¹ B | 5.50 | 5.58 | 5.54 | 0.18 | 0.17 | 0.18 | 3.97 | 4.17 | 4.07 |
| RDF+0.75 Kg ha ⁻¹ B | 5.50 | 5.58 | 5.54 | 0.19 | 0.18 | 0.18 | 3.80 | 4.00 | 3.90 |
| RDF+1.50 Kg ha ⁻¹ B | 5.50 | 5.58 | 5.54 | 0.19 | 0.18 | 0.19 | 4.10 | 4.30 | 4.20 |
| RDF+3.00 Kg ha ⁻¹ B | 5.50 | 5.58 | 5.54 | 0.22 | 0.21 | 0.22 | 4.10 | 4.30 | 4.20 |
| SEm ± | - | - | - | - | - | - | - | - | - |
| CD(0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

RDF=Recommended dose of fertilizers

Table.5 Effect of Boron and *Rhizobium* application on available N, P and K content of post-harvest experimental soil

| Treatment | Available Nitrogen(kg/ha) | | | Available phosphorus (kg/ha) | | | Available potassium (kg/ha) | | |
|--|---------------------------|---------|--------|------------------------------|---------|--------|-----------------------------|---------|--------|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| RDF(Control) | 164.62 | 191.87 | 178.25 | 9.28 | 9.43 | 9.35 | 180.62 | 184.90 | 182.76 |
| RDF + <i>Rhizobium</i> | 179.33 | 208.26 | 193.80 | 9.32 | 9.47 | 9.40 | 180.64 | 186.06 | 183.35 |
| RDF+ <i>Rhizobium</i> + 0.75 Kg ha ⁻¹ B | 199.01 | 208.97 | 203.99 | 10.90 | 10.89 | 10.90 | 185.90 | 179.23 | 182.57 |
| RDF+ <i>Rhizobium</i> + 1.50 Kg ha ⁻¹ B | 218.41 | 236.48 | 227.44 | 13.01 | 12.99 | 13.00 | 196.36 | 188.60 | 192.48 |
| RDF+ <i>Rhizobium</i> + 3.00 Kg ha ⁻¹ B | 201.37 | 194.77 | 198.07 | 11.30 | 11.31 | 11.30 | 191.88 | 183.14 | 187.51 |
| RDF+0.75 Kg ha ⁻¹ B | 196.92 | 216.21 | 206.56 | 10.21 | 10.28 | 10.24 | 201.27 | 192.78 | 197.02 |
| RDF+1.50 Kg ha ⁻¹ B | 201.94 | 231.34 | 216.64 | 11.15 | 11.13 | 11.14 | 189.57 | 189.87 | 189.72 |
| RDF+3.00 Kg ha ⁻¹ B | 198.42 | 194.44 | 196.43 | 10.75 | 10.85 | 10.80 | 187.47 | 183.96 | 185.72 |
| SEm ± | 10.49 | 5.79 | 2.45 | 0.71 | 0.68 | 0.20 | - | - | - |
| CD(0.05) | 30.69 | 16.94 | 7.08 | 2.09 | 1.98 | 0.58 | NS | NS | NS |

Table.6 Effect of Boron and *Rhizobium* application on available S and B content of post-harvest experimental soil

| Treatment | Available sulphur (mg/kg) | | | Available Boron (mg/kg) | | |
|--|---------------------------|---------|--------|-------------------------|---------|--------|
| | 2008-09 | 2009-10 | Pooled | 2008-09 | 2009-10 | Pooled |
| RDF(Control) | 9.71 | 9.84 | 9.78 | 0.310 | 0.313 | 0.313 |
| RDF + <i>Rhizobium</i> | 10.60 | 10.77 | 10.68 | 0.327 | 0.340 | 0.340 |
| RDF+ <i>Rhizobium</i> + 0.75 Kg ha ⁻¹ B | 11.45 | 11.62 | 11.53 | 0.360 | 0.370 | 0.370 |
| RDF+ <i>Rhizobium</i> + 1.50 Kg ha ⁻¹ B | 13.54 | 14.02 | 13.64 | 0.413 | 0.433 | 0.433 |
| RDF+ <i>Rhizobium</i> + 3.00 Kg ha ⁻¹ B | 12.21 | 12.36 | 12.29 | 0.390 | 0.377 | 0.377 |
| RDF+0.75 Kg ha ⁻¹ B | 11.56 | 11.67 | 11.61 | 0.360 | 0.353 | 0.353 |
| RDF+1.50 Kg ha ⁻¹ B | 12.09 | 12.19 | 12.14 | 0.360 | 0.393 | 0.393 |
| RDF+3.00 Kg ha ⁻¹ B | 12.46 | 12.59 | 12.51 | 0.407 | 0.407 | 0.407 |
| SEm ± | 0.62 | 0.59 | 0.18 | 0.021 | 0.024 | 0.007 |
| CD(0.05) | 1.81 | 1.74 | 0.52 | 0.062 | 0.071 | 0.019 |

The increased availability is also due to the formation of organic chelate of high stability with organic legends, which have lower susceptibility to adsorption, fixation and precipitation in the soil (Kushwaha *et al.*, 2009).

Available Sulphur and boron in post-harvest soil

Data pertaining available sulphur and boron presented in table 6. It is evident from the availability of sulphur in post-harvest soil increased with adding of boron and *Rhizobium*, highest sulphur recorded with the application of RDF+ *Rhizobium*+ 1.5 kg B ha⁻¹, 13.54 and 14.02 mg kg⁻¹, respectively for the year of 2009-09 and 2009-10 with the pooled value 13.64 mg kg⁻¹. Application of RDF+ *Rhizobium*+ 1.5 kg B ha⁻¹ improvement in availability of sulphur over the control and at par with rest of treatment for the both year of experiment. On pooled base RDF+ *Rhizobium*+ 1.5 kg B ha⁻¹ proved significantly improve over rest of treatment. This is might be due change in microbial activity in soil which is influence the enzymatic activity in soil (Bilen *et al.*, 2011).

The availability of boron in post-harvest soil significantly increased with increasing in levels of boron and application of *Rhizobium*. The highest availability of boron recorded in application of RDF+*Rhizobium*+1.5 kg boron ha⁻¹, 0.413 and 0.433 mg kg⁻¹, respectively for the year of 2008-09 and 2009-10 with the pooled value 0.423 mg kg⁻¹. The application of RDF+ *Rhizobium*+ 1.5 kg B ha⁻¹ has significantly improvement over the RDF and RDF+ *Rhizobium* and at par with rest of treatment.

The increasing of availability of boron might be due to application of external boron in red soils. This could be due to more vegetative growth and root growth, which release root

exudates resulted in increased boron availability in soil (Hellal, *et al.*, 2009). The results of the investigation are in consonance with the findings of Diab (1992) found a positive relationship between B and the concentration of B, N, P and K in wheat plants.

On the basis of above finding we can say inclusion of boron fertilization in mung bean with *Rhizobium* inoculation enhance the Crop yield, harvest index total nutrient uptake and availability of N, P, K, S and B in red soils of Mirzapur. Therefore, it is common recommendation for red soils of Mirzapur the application of RDF+ *Rhizobium* + 1.5 kg B ha⁻¹ is beneficial for build the soil health.

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