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# AGRO-ECONOMIC OPTIMIZATION OF FERTILIZER LEVEL AND *RHIZOBIUM* STRAINS FOR ENHANCED GRAIN YIELD IN MUNGBEAN (*VIGNA RADIATA* L.)

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**Abstract**

To explore the effect of PGPR for improvement in grain yield of mungbean, different levels of fertilizer (00:00, 20:50 and 20:70 kg N:$P_2O_5$ kg $ha^{-1}$) were tested on four strains (CB 1015 Australia, Vm-L1, Vm-M1 and Vm-M2) at Agricultural Research Institute, Dera Ismail Khan. A Randomized Complete Block Design with split plot arrangement was used to conduct the experiment by keeping three fertilizer levels in the main plot and *Rhizobium* strains in sub-plot. The data were recorded for different parameters like number of branches $plant^{-1}$, number of clusters plant $^{-1}$, number of pods $plant^{-1.}$, number of grain $pod^{-1}$, pod length (cm) and grain yield kg $ha^{-1}$. The response of fertilizer levels and inoculation with *Rhizobium* strains were found significant in most of the parameters under study. The strain Vm-M1 produced the highest number of branches $plant^{-1}$ (5.42), number of clusters $plant^{-1}$ (22.92), number of pods $plant^{-1}$ (77.64), pod length (8.37 cm) when applied in combination of N:$P_2O_5$ @ 20:70 and 20:50 kg $ha^{-1}$. Although the grain yield (1421 kg $ha^{-1}$) recorded in treatment (20:70 kg N:$P_2O_5$ $ha^{-1}$ + Inoculation with strain Vm M1) was highest but economically the treatment (20:50 kg N:$P_2O_5$ $ha^{-1}$+Inoculation with strain Vm M1) with net return of Rs. 13618 $ha^{-1}$and BCR of 2.52 was on top.

**Key word:** Mungbean, *Rhizobium* strains, Grain yield, Economic analysis, BCR.

## Introduction

Mungbean not only plays an important role in human diet but also it improves soil fertility by fixing the atmospheric nitrogen. Levels of organic carbon, total N, available N, P, K and micronutrients increased significantly and substantially due to inclusion of mungbean in Rice Wheat Cropping System. Simultaneously the soil micro-biological properties, viz., microbial biomass carbon, microbial biomass N and enzymatic (Alkaline phosphatase, acid phosphatase, dehydrogenase, glucosidase, etc.) activities were also significantly higher in soils of rice-wheat-mungbean cropping system (RWMCS) than in RWCS (Kumar, 2014). In year 2013-14, total production of mungbean was recorded 92.9 ton in KPK on an area of 130.9 hectares (Anon., 2013-14). There are many factors of low grain yield of mungbean, however, nutritional imbalance and ineffective nodulation appears to be the distinct one. Although use of fertilizer is increasing rapidly, but crop production is still stagnation, which could be due to improper use of fertilizer (Ali *et al*., 2012).

The requirement for phosphorus is increasing with time for healthy crop growth for efficient root system and effective nodulation. Phosphorus plays a key role in pod filling and ultimately enhances the grain production (Xavier & Germida, 2002). Ali *et al.,* (2014) reported that phosphorus application significantly increased the grain yield of mungbean. Phosphate is needed, especially in early plant growth for root development and to improve grain size. Almost all soils in Pakistan are alkaline and calcareous, i.e. with free lime. Phosphate becomes unavailable for crop plant under such conditions. Phosphatic fertilizer is therefore required nearly all over the Pakistan to support efficient plant growth. Much of the phosphate applied is fixed in the soil due to alkaline and calcareous nature of Pakistani soils (Arshad *et al.*, 2002). To avoid economic loss and soil depletion, it is necessary to work out the proper dose of $P_2O_5$ required for mungbean crop. Asghar *et al.* (2002) mentioned that grain yield of mungbean was increased by the application of 20 kg N $ha^{-1}$ and 40 kg $P_2O_5$ $ha^{-1}$. Biswas *et al.* (2000) also reported significant increase in yield of mungbean with application of phosphorus.

Mungbean have the ability to fix the atmospheric nitrogen for its own use and for residual carry over in association with *Rhizobium* strains. To achieve maximum yield of legume crop and soil improvement, the crop should be inoculated with suitable *Rhizobium* strain before planting. The most cost effective method to meet the nitrogen requirement of crops particularly leguminous crops is to inoculation with some compatible *Rhizobium* strains. It has been reported that mungbean responses remarkably to artificial inoculation with *Rhizobium* strains. Thus, it seems essential to evaluate mungbean cultivars for their genetic potential to produce maximum number of nodules for the nitrogen fixation potential as well as rhizobial strains should also be tested for their efficiency in nitrogen fixation in mungbean. The best suitable *Rhizobium* strain should meet the following criteria: it should have an ability to colonize in the soil and tolerate environmental stresses, ability to form effective nodules, ability to compete with population of background rhizobia for nodule formation and should have no deleterious effects on non-targeted hosts.

Under agro-ecological conditions of Pakistan, the nodulation of mungbean is poor (Mirza *et al.*, 2007; Mehboob *et al.*, 2008). The nitrogen fixation potential is exercised through two distinct pathways viz. nodule formation and nodule effectiveness (Zahir *et al.*, 2003 ;Zahir *et al.*, 2010). Inoculation of mungbean with

*Rhizobium* increased the grain yield, photosynthetic activity and dry matter production. Raza *et al.* (2004) and Ahmed *et al.* (2006) reported that seed inoculation and application of NP fertilizer significantly increased the grain yield of mungbean. Similarly the results of Khalid *et al.* (2004) and Khalid *et al.* (2006) also showed an increase in the number of nodules and grain yield by seed inoculation with single and multiple strains. Dobbelaere *et al.* (2003) conducted a trial on *Vigna mungo* applying 0, 20, 30 kg N and 20, 40, 60 kg $P_2O_5$ $ha^{-1}$ along with seed inoculation with *Rhizobium* strain and concluded that grain yield increased by seed inoculation, grain yield increased when N was applied @ 20 kg $ha^{-1}$. Biswas *et al.* (2000) observed that the highest number of nodules and grain yield were obtained by inoculating the mungbean seeds with *Rhizobium* and applying urea @ 25 kg $ha^{-1}$ as starter dose. Khalid *et al.* (2001) observed in field trials conducted at Uzbekistan that inoculation of mungbean seeds with *Bradyrhizobium* increased the herbage mass by 6%, seed mass by 3.6%, mass of 1000 seeds by 0.8%, nitrogen content in seeds by 8.9%, starch content in seeds by 5.5% and number of nodules by 2.54%. Ryan *et al.* (2007) reported that *Bradyrhizobium* inoculation and NPK fertilization significantly increased the grain and straw yields of mungbean and the highest grains yield was obtained by application of 0-30-20 NPK + inoculum. Zarrin *et al*. (2007) and Lubna *et al.* (2006) revealed that seed inoculation + 20 kg $P_2O_5$ $ha^{-1}$ to mungbean produced more growth, seed yield and dry matter accumulation. They further reported that the highest grain yield was recorded in plots fertilized with 50-50-0 kg NPK $ha^{-1}$ + seed inoculation. Ghulam *et al.* (2014) also reported that *Rhizobium* seed inoculation and phosphorus application at the rate of 120 kg $ha^{-1}$ enhances the performance of mashbean and should be used for the betterment of crop productivity.

Keeping in view the importance of phosphatic fertilizers and *Rhizobium* strain for yield maximization and higher net returns, present study was designed to assess indigenous strains for mungbean production under climatic conditions of Dera Ismail Khan, Khyber Pakhtunkhwa Province.

## Materials and Methods

The trial was conducted at Agricultural Research Institute, Dera Ismail Khan during, 2009. The experiment was laid out in Randomized Complete Block design (RCBD) with split plot arrangements replicated four times. The phosphatic fertilizer doses were kept in main plots while *Rhizobium* strains were kept in sub-plot. The sub plot size was 1.8 x 4 $m^2$. Mungbean genotype NM-98 was planted with a single row hand drill @ 25 kg $ha^{-1}$ in 30 cm apart rows with plant to plant distance of 10 cm. All other cultural practices were kept uniform in all treatments from sowing till harvesting. The seed was inoculated with four strains of inoculums (CB 1015 Australia, Vm-L1, Vm-M1 and Vm-M2). Fertilizer @ (00:00, 20:50 and 20:70 kg N: $P_2O_5$ kg $ha^{-1}$) was applied at the time of sowing.

The agronomic data were recorded for number of branches $plant^{-1}$, number of clusters plant $^{-1}$, number of pods $plant^{-1}$, number of grain $pod^{-1}$, pod length (cm) and grain yield kg $ha^{-1}$. The data collected were analyzed statistically using statistical package MSTATC and LSD at 5% probability level to compare the differences among the fertilizer levels and *Rhizobium* strains (Steel & Torrie, 1980).

## Results and Discussion

Number of branches $plant^{-1}$, an important secondary yield component was affected significantly ($p$=0.05) by fertilizer doses and various *Rhizobium* strains but their interaction was non-significant (Fig. 1). Strain Vm-M1 produced the highest number of branches $plant^{-1}$ (5.42) followed by strain CB 1015 Australia and strain Vm L1, which produced 5.08 and 4.48 branches $plant^{-1}$. The interaction effect of $P_2O_5$ levels and *Rhizobium* strains was non-significant for number of branches $plant^{-1}$, however, the highest number of branches (5.88) was recorded in plots where $P_2O_5$ dose of 70 kg $ha^{-1}$ was applied along with inoculation of Vm-M1 strain. The lowest number of branches $plant^{-1}$ (3.73) was recorded where neither fertilizer was applied nor inoculation with any *Rhizobium* strain. Arshad *et al.* (2002), studied the effect of different planting methods and level of phosphorus on yield of Mungbean and reported that different yield components were affected by the phosphorus level significantly but number of branches per plant were not affected by level of phosphorus. This difference may be due to different climatic conditions of the area in which the trials were conducted.

A significant difference existed in number of clusters $plant^{-1}$ by the application of *Rhizobium* strains and fertilizer levels (Fig. 2). The highest number of clusters $plant^{-1}$ (22.92) was recorded in plots where N:$P_2O_5$ was applied @ 20:70 kg $ha^{-1}$ and the seed was inoculated with Vm-M1 *Rhizobium* strain. The lowest number (18.08) of clusters $plant^{-1}$ was recorded in the plots without fertilizer and inoculation. Khan *et al.* (2002) reported that inoculation treatments, gave maximum increase in number of pods per plant, total Biomass, straw yield and grain yield with phosphorus @ 75 kg $ha^{-1}$ P2O5. Further increase in phosphorus (100-kg $ha^{-1}$ P2O5) application decreased the number of pods, total Biomass, straw and grain yield. There is a difference of 5 kg $ha^{-1}$, which may be due to difference in soil status.

The interaction effect of fertilizer doses and various *Rhizobium* strains was significant ($p$=0.05) for number of pods $plant^{-1}$ (Fig. 3). The highest number of pods (87.77) was recorded in plants receiving N:$P_2O_5$ @ 20:70 kg $ha^{-1}$ along with inoculated with Vm-M1 *Rhizobium* strain. The lowest number of pods $plant^{-1}$ (43.71) was recorded in plots where neither $P_2O_5$ was applied nor inoculation with any *Rhizobium* strain was done. Zahir *et al.* (2010), also reported an increase in number of pod $plant^{-1}$ by seed inoculation. Their results also showed an increase in number of pods $plant^{-1}$ significantly with increasing fertilizer level up to 30-60 kg N-$P_2O_5$ $ha^{-1}$. Under agro-climatic conditions of Faisalabad in a trial conducted by Ashraf *et al.* (2003) maximum number of pods (32.9) was recorded in plots where seed was treated with *Rhizobium phaseoli* and fertilized @ 50-50 kg NP $ha^{-1}$.

The interaction of fertilizer doses and various *Rhizobium* strains was significant at P=0.05 for number of pods cluster$^{-1}$ (Fig. 4). The highest number of pods cluster$^{-1}$ was recorded in plots where N:$P_2O_5$ @ 20:70 kg ha$^{-1}$ was applied along with inoculation of Vm-M1 strain. The least number (2.41) of pods cluster$^{-1}$ was recorded where no fertilizer or inoculation was applied. Zahir *et al.* (2010) reported an increase in number of pod cluster$^{-1}$ by seed inoculation. They further added that the increased fertilizer level (up to 30-60 kg N-$P_2O_5$ ha$^{-1}$) significantly increased the number of pods plant$^{-1}$ .

The numbers of grain pod$^{-1}$ were significantly affected by fertilizer levels and various *Rhizobium* strains (Fig. 5). Maximum grains (8.15) pod$^{-1}$ were recorded in plots where N:$P_2O_5$ was applied @ 20:70 kg ha$^{-1}$ along with inoculation of Vm-M1 strain. The lowest number of grains (6.85) pod$^{-1}$ was recorded without fertilizer and inoculation. Ryan *et al.* (2007), also reported that *Bradyrhizobium* inoculation along with NPK fertilization significantly increased the grain and straw yields of mungbean.

The highest yield (1421 kg ha$^{-1}$) was recorded in plots where N: $P_2O_5$ was applied @ 20:70 kg ha$^{-1}$ along with inoculation of strain Vm-M1 (Fig. 6). The lowest grain yield (1048 kg ha$^{-1}$) was recorded in the treatment where neither fertilizer was applied nor the seed was inoculated with any *bacterial* strain. The higher grain yield from the treatment is attributed to higher number of pods plant$^{-1}$, number of grains pod$^{-1}$ and 1000-seed weight. Raza *et al.* (2004) and Ashraf *et al.* (2003) also concluded that seed inoculation and fertilizer application had significant effect on seed yield per hectare. They further reported that for attaining the maximum grain yield the variety NM-98 should be sown after seed inoculation with *Rhizobium* strains and given 30-60 kg N-P ha$^{-1}$. Zahir *et al.* (2010) also reported increase in grain yield with seed inoculation.

**Economic analysis and BCR:** Economic analysis and BCR pertaining to fertilizer doses and *Rhizobium* strains is presented in Table 1. From the data, it can be depicted that maximum net income of Rs.13,731 ha$^{-1}$ was obtained when strain Vm M1 was inoculated to mungbean, without application of fertilizer. Maximum BCR (1.59) was observed by the inoculation of strain Vm M1 without application of fertilizer followed by inoculation with strain Vm L1 without application of fertilizer (with the BRC value of 1.52). It was also observed that any application of the strain (with or without fertilizer) gave somewhat higher net income and BCR than with $S_0$ and no fertilizer application. It was also noted that, application of fertilizer (70 kg ha$^{-1}$) and inoculation with strain Vm M1 showed maximum income than the rest of treatments but due to higher cost of the fertilizer, the difference between the BCR values remained little.

**Table 1. Economic analysis and BCR as affected by different *Rhizobium* strains and the fertilizer doses.**

| Treatment | Grain yield kg ha$^{-1}$ | Total variable cost Rs. ha$^{-1}$ | Gross income Rs. ha$^{-1}$ | Total cost Rs. ha$^{-1}$ | Net income Rs. ha$^{-1}$ | BCR |
|---|---|---|---|---|---|---|
| $N_0$:$P_0$ + S0 | 1048 | 0 | 18316 | 8514 | 9802 | 1.15 |
| $N_0$:$P_0$ + Vm L1 | 1246 | 100 | 21682 | 8614 | 13068 | 1.52 |
| $N_0$:$P_0$ + CB 105 Australia | 1233 | 100 | 21461 | 8614 | 12847 | 1.49 |
| $N_0$:$P_0$ + Vm M1 | 1285 | 100 | 22345 | 8614 | 13731 | 1.59 |
| $N_0$:$P_0$ + Vm M2 | 1190 | 100 | 20730 | 8614 | 12116 | 1.41 |
| $N_{20}$:$P_{50}$ + S0 | 1246 | 1000 | 21682 | 9514 | 11168 | 1.17 |
| $N_{20}$:$P_{50}$ + Vm L1 | 1329 | 1100 | 23093 | 9614 | 12479 | 1.30 |
| $N_{20}$:$P_{50}$ + CB 105 Australia | 1261 | 1100 | 21937 | 9614 | 11323 | 1.28 |
| $N_{20}$:$P_{50}$ + Vm M1 | 1396 | 1100 | 24232 | 9614 | 13618 | 1.42 |
| $N_{20}$:$P_{50}$ + Vm M2 | 1293 | 1100 | 22481 | 9614 | 11687 | 1.22 |
| $N_{20}$:$P_{70}$ + S0 | 1263 | 1400 | 21971 | 9914 | 10657 | 1.07 |
| $N_{20}$:$P_{70}$ + Vm L1 | 1359 | 1500 | 23603 | 10014 | 12189 | 1.22 |
| $N_{20}$:$P_{70}$ + CB 105 Australia | 1306 | 1500 | 22702 | 10014 | 11288 | 1.13 |
| $N_{20}$:$P_{70}$ + Vm M1 | 1421 | 1500 | 24657 | 10014 | 13243 | 1.32 |
| $N_{20}$:$P_{70}$ + Vm M2 | 1277 | 1500 | 22209 | 10014 | 10795 | 1.08 |

Price of single super phosphate (SSP) @ Rs. 400 per 100 kg Bag, Application charges of fertilizer ha$^{-1}$ (1 man day) @ 280.00, Hand weeding @ Rs. 1040 ha$^{-1}$ (13 man days @ Rs. 280 day$^{-1}$), Price of 20 kg seed of NM-98 ha$^{-1}$ @ Rs. 37 kg$^{-1}$, Price of inoculum packet of 250 g ha$^{-1}$ @ Rs. 100 per 250 g Packet, Application charges of inoculum ha$^{-1}$ (1/2 man day) @ 140.00 Income (straw) = Rs. 3000 ha$^{-1}$

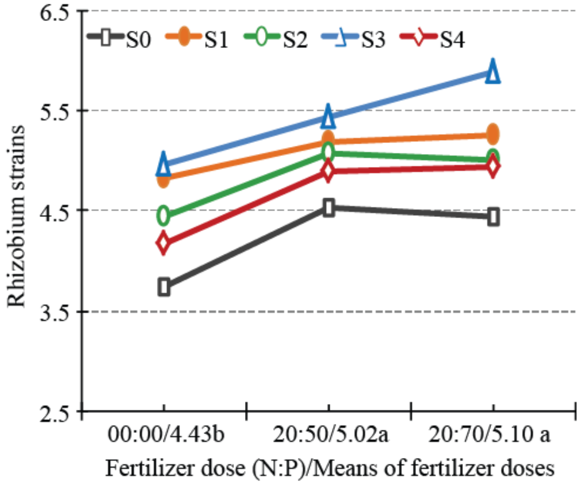


Fig. 1. Number of branches plant $^{-1}$ as affected by different *Rhizobium* strains and the fertilizer levels.

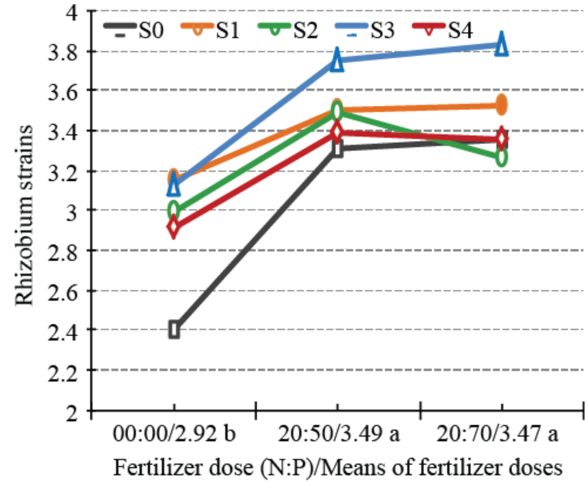


Fig. 4. Number of pods cluster$^{-1}$ as affected by different *Rhizobium* strains and the fertilizer levels.

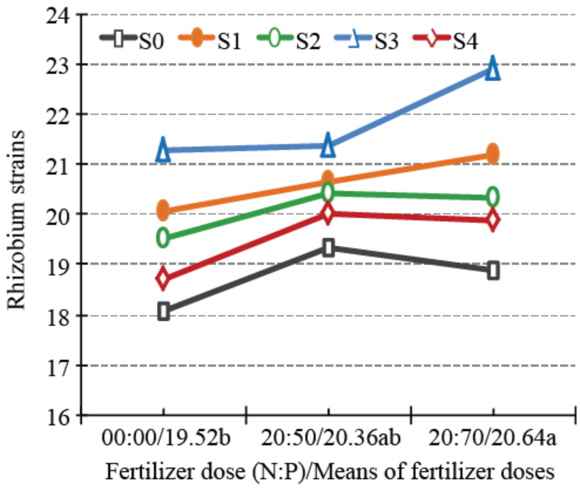


Fig. 2. Number of clusters plant $^{-1}$ as affected by different *Rhizobium* strains and the fertilizer levels.

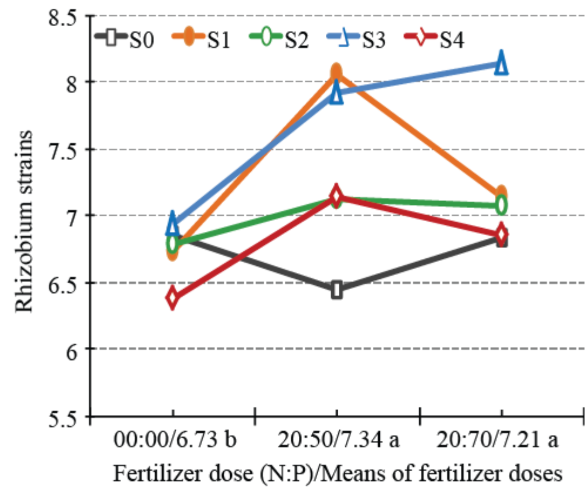


Fig. 5. Number of grain pod–1 as affected by different *Rhizobium* strains and the fertilizer levels.

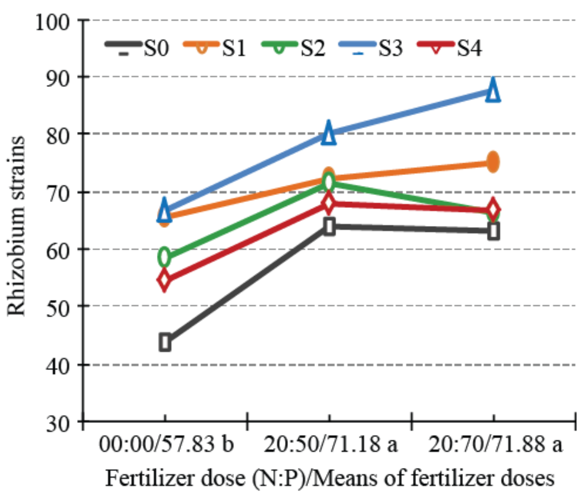


Fig. 3. Number of pods plant$^{-1}$ as affected by different *Rhizobium* strains and fertilizer levels.

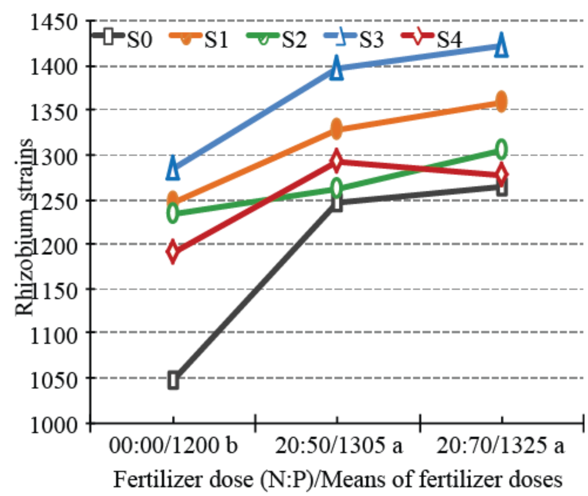


Fig. 6. Grain yield (kg ha$^{-1}$) as affected by different *Rhizobium* strains and fertilizer levels.

## Conclusion

It can be concluded from this study that under agro-ecological conditions of Dera Ismail Khan, the production of grain yield of mungbean can be increased using the best combination of fertilizer level as N:$P_2O_5$ @ 20:70 kg ha$^{-1}$ along with inoculation of Vm-M1 *Rhizobium* strain.

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