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The Effect of Bio and Inorganic Fertilizer on Yield, Nutrient Uptake and Economics of Mungbean (*Vigna Radiata* L. Wilczek) Varieties in Ethiopia

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Abstract

The wide use of mungbean (Vigna radiate) as food crops forages and green manure is mainly associated with their ability to establish symbiotic association with root nodulating rhizobia. The field experiment was conducted at Kemisie Zone Dawachefa district, Ethiopian in 2017 was designed to study the effect of different levels of bio fertilizers and phosphorus on yield, nutrient uptake and economics of mungbean varieties for improving the overall productivity of the crop. The experiment was laid out with split plot design with three replications. Three levels of Rhizobium inoculation rates (0, 400g and 500g) and three level of phosphorus (0, 23 and 46 kg P_2O_5 ha^{-1}) as the sub-plot factor and two different varieties as main plot, thereby, making eighteen treatment combinations. The result showed that Rhizobium and phosphorous had significant ($p < 0.05$) effect on morphological and phonological traits. An increase in the rate of application of Rhizobium and phosphorous linearly increase agronomic, yield and yield component traits. The maximum seed yield (1808 kg ha^{-1}) was obtained when we apply 500g Rhizobium inoculants and 0 kg P_2O_5 ha^{-1}. Thus the application of Rhizobium inoculants at 500g alone or Rhizobium inoculants 500g combined with phosphorus application at the rate of 23 kg P_2O_5 ha^{-1} were economically optimum level for harvesting the highest yield of mungbean for the region. Despite significant increases observed in yield, nutrient uptake, economic response to the recommended rates of bio fertilizer, future studies should focus on multi-locations and seasons to arrive at conclusive results.

Keywords: Nodule; Rhizobium; Nitrogen Uptake; Nutrient Uptake

Introduction

The conversion of N_2 into ammonia is facilitated through biological and chemical fixation, of which 60% is fixed by biological nitrogen fixation (BNF) [1]. The various legume crops and pasture plants is estimated to fix about 200-300kg of N/ha/yr and the global nitrogen fixation by BNF is estimated to be as much as 70 times 10^6 metric tons/yr [2]. The nitrogen thus fixed is the major source of nitrogen to different biological production systems. Consequently, legumes are integrated into various cropping systems such as alley cropping, intercropping and crop rotations [3]. The wide use of legumes as food crops, forages and green manure is mainly associated with their ability to establish symbiotic association with root nodulating rhizobia [4]. These enabled legumes to grow in depleted and exhausted soils in the absence of nitrogen fertilizers. However, all legumes are not capable of nodule formation and nitrogen fixation.

Mungbean (*Vigna radiate*) is a warm season annual seed legume. The crop requires 75 up to 90 days to mature. It is an important pulse crop with global economic importance. Mungbean can also be used as a green manure crop and its green plants are used as fodder after removing the mature pods. The sprouted seeds of mungbean are rich in ascorbic acid (vitamin C), riboflavin and thiamine [5]. It has a special importance in intensive crop production system of the country for its short growing period [6]. It is useful crop in drier areas and has a good potential for crop rotation and relay cropping with cereals using residual moisture. It is one of the shortest duration field crops in the world (can be harvested within two months), soil *Rhizobium* bacteria around the mungbean root zone can symbiotically fix N_2 gas from the air and this makes it among the most popular components in the cropping systems [7].

In Ethiopia these crop also growing in smallholder farmers in drier marginal environments. Mungbean production in Ethiopia has grown three times in a year covering 43,680 hectare with an average yield of 0.78 tone ha^{-1}, which is much lower than that of India and some other countries of the world [8]. Hence, there is a scope for improving the production potential of this crop by use of inorganic manures, and bio-fertilizers. Mungbean being a legume crop does not require much nitrogen except in small quantities in the beginning of its life cycle. Nitrogen is an essential constituent of compounds like amino acid, protein, nucleic acid, prophyrin, flavine, pyridines, nucleotides, enzymes, coenzymes and alkaloids [9]. Phosphorus plays a very significant role in the formation of energy rich phosphate bond (like ADP and ATP), nuclear protein, phospholipids and is also essential for growth of root system. It improves the quality of grains and serves the dual purpose of increasing yield of main crop as well as succeeding crop [10]. Bio-fertilizers play an important role in increasing availability of nitrogen and phosphorus besides increase in biological fixation of atmospheric nitrogen and enhance phosphorus availability to crop. Therefore, introduction of efficient strain of *Rhizobium* in soil enhances the quality of soil by providing more nitrogen fixation and which may be helpful in boosting up production. Inoculation of seeds with *Rhizobium* culture is a very low cost method of nitrogen fertilization in legume and has been found beneficial [11].

Despite the growing demand in the international market there is chronic supply gap in Ethiopia in terms of production. The major contributor to this increase in production is the remarkable improvement in productivity than the expansion in area. Several works showed that most of the rhizobia nodulation of legumes crop are very effective in soil fertility and nitrogen fixation and substantial yield increments have been reported for wheat planted after legume in Ethiopia and other countries [12,13]. Application of such beneficial microbes alone or along with fertilizers are an economically and environmentally promising strategy and can aid in replenishing and maintaining long-term soil fertility by providing good soil biological activity, by suppressing pathogenic soil organisms; by stimulating microbial activity in the rhizosphere and to improve plant health of the various plant nutrients, even though P2O5 is abundant in soil, its availability is limited in plants due to fixation by other soil elements such as insoluble phosphates of iron, aluminum, and calcium [14,15]. So the use and application of rhizobia nodulation and phosphorous seems to be the most effective way for the cultivation of summer mungbean. There was a gap of information on the actual rates of bio fertilizer and phosphorus specifically in the stated region; hence blanket recommendation was still used [16]. Therefore, the research findings could contribute to the development of rhizobial inoculants to fully realize the potential of BNF in low input agriculture in the country. In light of this the present study is aimed to study the effect of different levels of bio fertilizers and phosphorus on yield, nutrient uptake and economics of mungbean varieties for improving the productivity and overall production of the crop.

Materials and Methods

Description of the Study Area

Field experiment was conducted in Amhara Region, Oromiya Zone Dawachefa district on farmers training center field near Kemisie during the 2016 main cropping season (Figure 1). The area is characterized by moisture deficit environments. The average annual minimum and maximum temperatures are 20^{0}C and 32^{0}C, respectively [16]. The experiment was carried out under rain-fed conditions. Weeding was done at two weeks after emergence and three weeks after the first weeding manually.

Plant Materials

Two mungbean varieties namely *N-26* and *Shewarobit* were used. The varieties were planted in July with a row-to row distance of 30 cm with total of four rows with plot size of (0.8 m^{2}).The recommended agronomic packages for the location was applied for growing a successful crop.

Experimental Design and Treatments

A split plot design with three replications was used. Mungbean varieties (N-26, Shewarobit) where taken as the main plot, whereas *Rhizobium* at the rate (0, 80 and 100 % inoculation) and phosphorus at the rate (0, 23 and 46 kg P_2O_5 ha^{-1}) where adjusted as the sub- plot treatments.

Seeds Inoculation and Experimental Procedure

Mungbean seeds were inoculated with legume fix inoculants /*Rhizobium*/ using the Slurry method outlined by Woomer PL, et al. [17]. The seeds of N-26 and Shewarobit varieties were each divided into three bowls with each one weighing 1 kg. The inoculum was then poured over the 1 kg seeds of each mungbean variety in the bowl after sprinkling water over the seeds. The seeds and inoculum in the bowl were mixed carefully until seeds were coated with black film of inoculants and allowed to dry for a minute after which they were planted in the rows. The full recommended rate of inoculation (100 % inoculation) was done at the rate of 5.4g of *Rhizobium* inoculants per 270g of seed just before planting while the inoculation rate was done by mixing 4.32g of *Rhizobium* inoculant with 270g of the seeds.

Soil sampling preparation and analysis was considered using the standard laboratory procedures. Seed and leaf nitrogen content was done as per the procedure of Fischer RA, et al. [18]. The percentage of nitrogen uptake was calculated as described by Ryan MG, et al. [19]. Seed and leaf phosphorus content analysis was done as per protocol [18]. The percentage phosphorus uptake was calculated as described by Ryan MG, et al. [19].

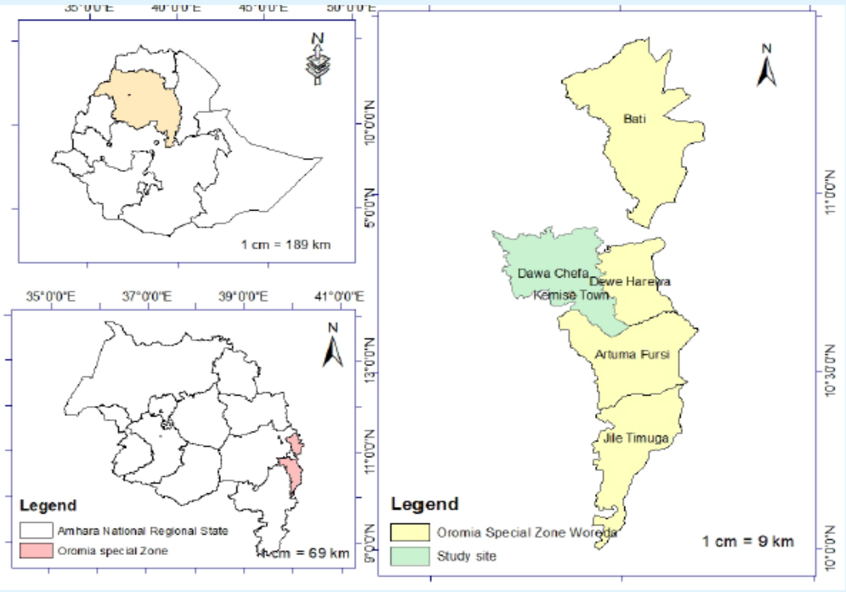

Figure 1: Geographical position of the experimental sites.

Days to flowering, Days to maturity, root length, number of nodules, number of branches plant^{-}, number of pods plant^{-1}, number of seedspod^{-1}, 1000-seed weight (g), plant height (cm), leaf biomass plant^{-1}, total biomass plot^{-1} (g), seed yield (g plot^{-1}), harvest index, seed nitrogen uptake (kg ha^{-1}), leaf nitrogen uptake (kg ha^{-1}), total nitrogen uptake (kg ha^{-1}), seed phosphorus uptake (kg ha^{-1}), leaf phosphorus uptake (kg ha^{-1}), and total phosphorus uptake (kg ha^{-1}) were considered in the data collection.

Statistical Analysis

All the data collected were subjected to statistical analysis using SAS software. All treatment means were compared using the Duncan multiple range test at 5 % level of significance.

Result and Discussion

Physical and Chemical Characteristics of the Experimental Soil before Planting

Soil analysis before sowing indicated that the soil has medium level of total nitrogen, available phosphorus, and organic matter. The pH of the soil was 7.2 showing nearly neutral. FAO Reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range of productive soil [20]. The level of phosphorous content of the experimental soil was high (12.8ppm) (Table 1). The organic carbon content (1.69%) and total nitrogen (0.12%) of the soil were low. According to low organic carbon and nitrogen content in the study area indicates low fertility status of the soil which is a limiting factor for optimum crop growth [21]. This could be due to continuous cultivation, depletion nutrient and lack of incorporation of organic materials into the soil.

Soil Analysis after Harvesting

The analysis of variance showed that there was highly significant ($p<0.01$) difference among treatments in the total nitrogen content. According to the soil textural class determination triangle, the soil of the experimental site was found to be clay loam (Table 1). The texture indicated the degree of weathering, nutrient and water holding capacity of the soil. High clay content might indicate better water and nutrient holding capacity of the soil in the experimental site. The *Rhizobium* inoculation and the application phosphorous fertilizer did not influence the soil pH 7.2, showing nearly neutral. Thus, the pH of the experimental soil was within the range of productive soils (Table 2).

The application of different dose of phosphorus and *Rhizobium* on the soil after harvest, showed highly significant effect on available phosphorus.

Physical properties			**Chemical properties**					
Particle size	**Distribution (%)**	**Textural class**	**pH**	**OC (%)**	**OM (%)**	**Total N (%)**	**Avail P (ppm)**	**Avail K(ppm)**
Sand	10	Clay loam	7.2	1.69	2.6	0.12	18.8	21.95
Silt	34							
Clay	70							

Table 1: Physico- chemical characteristics of the experimental soil before planting.

According to Olsen SR, et al. phosphorus sufficiency test soil grouping, the level of phosphorus content of the experimental soil was high (66.4ppm) [22]. The organic carbon content was recorded (1.93%) and total N (0.19%) of the soil were low. As per the classification made by Wakene N, et al. the soil has low organic carbon and nitrogen content in the study area, indicates medium fertility status [23]. The comparison before and after the crop harvest showed that, there was an increase in organic carbon content, organic matter, total nitrogen, available phosphorus while there was no difference in available potassium [22,23].

Chemical properties					
pH	**OC (%)**	**OM (%)**	**Total N (%)**	**Available P (ppm)**	**Available K (ppm)**
7.25	1.935	3.3	0.19	66.4	21.94

Table 2: Selected physico - chemical properties of the experimental soil after harvesting.

The effect of Rhizobium and Phosphorous on Morphological and Phonological Traits

Both varieties, application of *Rhizobium* and phosphorous have showed significant effects ($p < 0.05$), on days to 50% flowering and 90% physiological maturity, plant height, nodules number and number of branches while their interaction was non- significant effect (Table 3). An increase in the rate of application of *Rhizobium* and phosphorous linearly increase the mean for plant height, nodules number, root length and number branch in both cultivar.

The lowest mean for plant height, root length, nodules number, and number branch was recorded with the control treatment. Treatment combination of 500g *Rhizobium* inoculants and P_20_5 46 kg ha^{-1} showed the longest mean values for 50% flowering and days to 90% physiological maturity. The highest mean values for plant height, and root length recorded for treatment combination of 500g *Rhizobium* inoculants and P_20_5 46 kg ha^{-1}, whereas treatment combination B500 and P_20_5 23 kg ha^{-1} showed the highest number of branches plant^{-1} (Table 3). Number of nodules significantly influenced at high rate (100 %) *Rhizobium* inoculants with 46 and 0 kg ha^{-1} phosphorus levels produced (35.5 and 30.5 plant^{-1}), respectively. This observation showed that, mungbean response positively for growth parameter at high rate (100 %) of *Rhizobium* inoculants and 23-46 kg P_20_5. The overall improvement in crop growth under the influence of Rhizobia plus P_2O_5 application could be attributed to better environment for growth and development that might be due to increased availability of nitrogen to the growing plants. Further, addition of phosphatic fertilizers in the soil increases the concentration of readily available phosphorus in the rhizosphere. The increased availability of phosphorus to plant, might have enhanced early root growth and cell multiplication leading to more absorption of other nutrients from deeper layers of soil ultimately resulting an increased in plant growth in terms of plant height, root length, number of nodules and number of branches. In agreement to this finding, reported that phosphorus application at the rate of 60 kg P_2O_5 ha^{-1} significantly increased nodulation [24].

The application of *Rhizobium* 500gm ha^{-1} and P_20_5 46 kg ha^{-1} increased plant height by 26.5 %, over the control (Table 3). An increment of plant height with the highest level of *Rhizobium* was probably due to the availability of nitrogen due to nitrogen fixation.

Treat. No.	Treatment	DF	DM	PH	RL	NN	NB
1	$P_20_5$0B0	50.5b	71.5b	52cd	22.17c	11.17d	4.33c
2	$P_20_5$0B400	52.33a	73.3a	58.83b	29.83b	22.17c	5c
3	$P_20_5$0B500	52ab	73a	64.33a	35.33ab	35.5a	5.17b
4	$P_20_5$23B0	50.17b	71.2bc	57.5b	26.5c	18.83c	4.67c
5	$P_20_5$23B400	52ab	73a	63ab	34ab	24.33b	6ab
6	$P_20_5$23B500	52.83a	73.8a	66.5a	35.83ab	30.17ab	6.67a
7	$P_20_5$46B0	49.5bc	70.5bc	53.67c	23.83c	12.83d	4.5c
8	$P_20_5$46B400	51.83ab	72.8a	64.17a	35.17ab	24.17b	5.5b
9	$P_20_5$46B500	52.83a	73.8a	65.83a	36.83a	30.5ab	6.5a
	LSD at 5% SP	1.55	1.55	3.97	5.2	6.15	0.89
1	Shewa Robit	50.5b	71.5b	58.7a	27.7a	19.93b	5.41a
2	N-26	52.5a	73.6a	62.6a	34.4a	26.67a	5.33a
	LSD at 5% MP	0.422	0.422	9.188	10.62	6.56	1.389
	Grand mean	51.56	72.56	60.65	31.06	23.3	5.37
	CV%	2.6	1.8	5.6	13.9	22.4	14

DF=Days to flowering, DM=Days to maturity, PH=plant height, RL=root length, NN=number of nodules NB=number of branches plant^{-1}

Table 3: Effect of Rhizobium, phosphorous rate and variety on morphological and phonological traits of Mungbean.

This result was in line with who reported that an increasing nitrogen rates increased the plant height. Reported the highest plant height was recorded on plot receiving 35 kg P_2O_5ha^{-1} with *Rhizobium* inoculums on mungbean [25,26]. Statistical analysis revealed that, the effect of with phosphorous and *Rhizobium* alone, were highly significant on root length. Similar results were also reported by Solaiman ARM, where *Rhizobium* inoculants alone gave 30% higher root length over uninoculated control [27].

Seed inoculation with *Rhizobium* alone (500g) and 500g plus P_2O_5 46 kg ha^{-1}significantly increased nodule number plant^{-1} (218%) and (173%) compared to the uninoculated seeds of mungbean, respectively (Table 3). In agreement with this found that 50 kg P_2O_5 ha^{-1} with other fertilizers increased nodule number over the control by 245% on mungbean. In line with this reported that, seed inoculation with *Rhizobium* and application of 40 kg P_2O_5 ha^{-1} in chickpea (*Cicer arietinum*) either alone or in combination enhanced nodulation over uninoculated control [24,28]. Khanam D also reported similar results with lentil [29].

Seed inoculation at the higher rate of *Rhizobium* (500 g) in combination of (P_2O_5 23 and P_2O_5 46 kg ha^{-1}) produced significantly higher number of branches plant^{-1} than all other treatments (Table 5). In line with the present study, Muhammad D, reported that the number of branches plant^{-1} was significantly influenced by both higher level of *Rhizobium* inoculums and phosphorous application [26]. Also found an increased dry matter accumulation of mungbean with application of 20 kg N and 60 kg P_2O_5ha^{-1} over the control [30]. Similarly increases in various growth attributes in different pulses have been reported by Borse PA, et al. [31-33].

Effect of Rhizobium, Phosphorous and Cultivar on Yield and Yield Components of Mungbean

The effect of *Rhizobium* and phosphorous was significant on number of pods plant^{-1} (Table 4). Treatment containing 500 g *Rhizobium* with $P_2O_5$46 kg ha^{-1} produced 127% higher number of pods plant^{-1} than the control. Malik MA and Muhammad D reported similar observation on mungbean. Combination of *Rhizobium* inoculation and phosphorous application had a significant effect on leaf biomass plant^{-1}, biomass plot^{-1} (g), seed yield in kg^{-1}, and harvest index (Table 4) [9,26]. An increase at the rate of *Rhizobium* and phosphorous linearly increase number of pods plant^{-1}, 1000-seed weight (g), leaf biomass plant^{-1}, biomass in g plot^{-1}, seed yield in kg^{-1}, and harvest index (Table 4). Malik MA, Reported that seed inoculation with *Rhizobium* significantly increased 100 seed weight of mungbean [34]. The highest biomass (7.7 tones ha^{-1}) was found with treatment combination of 500 g *Rhizobium* plus $P_2O_5$46 kg ha^{-1} and the lowest biomass (3.2 tones ha^{-1}) was obtained with uninoculated treatment (Table 4). Besides the analysis result showed that cultivars vary significantly at ($P > 0.05$) for leaf biomass plant^{-1}, total biomass plot^{-1}, seed yield in kg^{-1}, and harvest index performance.

Seed yield of mungbean was significantly influenced by the different levels of phosphorus and *Rhizobium* inoculants. Treatment combination of 500 g *Rhizobium* plus $P_2O_5$46 kg ha^{-1} produced the highest seed yield (1846 kg ha^{-1}), 58% yield advantage over the uninoculated control (Table 4). The application of *Rhizobium* 500g plus 46kg ha^{-1}phosphorous significantly increased number of pods plant^{-1}, number of seeds pod^{-1}, and biological yield, and net returns of mungbean over the control (Table 4). The combined application of *Rhizobium* and phosphorous to mungbean might be increased the availability of major nutrients to the plant due to enhanced early root growth and cell multiplication leading to more absorption of other nutrients from deeper layers of soil ultimately resulting in increased crop growth rate and finally increased crop yield. Besides the increased yield attributes and yield might be due the increased supply of the major nutrients (NPK) by translocation of the photosynthates accumulated under the influence of the sources of inorganic nutrients. Further, the translocation and accumulation of photosynthates in the economic sinks, resulted an increased seed yield, leaf and biological yields. Malik MA, observed that phosphorous at 50 and 100 kg ha^{-1} increased mungbean seed yield over the control [34]. In addition to these, increased yield attributes and yield by various workers have been reported in different pulses [30].

Harvest index was significantly influenced by the application of phosphorous and *Rhizobium* inoculant (Table 4). The highest harvest index was recorded when *Rhizobium* inoculated with 500g alone, whereas the lowest harvest index was recorded for the control on both the test cultivars. Herridge DF observed that phosphorous at 50 and 100 kg ha^{-1} and *Rhizobium* 500g ha^{-1} increased mungbean harvest index than the control [7].

Effects of *Rhizobium* and Phosphorous on the Nutrient Uptake of Mungbean

Seed, leaf nitrogen content and uptake significantly influenced by the application of *Rhizobium* and phosphorus rates and the interaction. While non-significant variations were observed between cultivars for nitrogen content. The results showed that, higher nitrogen content was found in the leaf as compared to the seed at all levels of *Rhizobium* and phosphorus application. The highest nitrogen content was recorded in the leaf at the rate of *Rhizobium* (500g) plus phosphorous at 46kg P_2O_5 ha^{-1} (Table 5). Seed inoculation at higher dose of *Rhizobium*, and phosphorus significantly enhanced nitrogen and phosphorus content and their uptake and nitrogen content in seed over untreated control. This may be due to more nitrogen fixation by the bacteria which in turn helped in better absorption and utilization of all the plant nutrients, thus resulting in more nitrogen and phosphorus content in seed and leaf. The same conclusion was made by Awomi TA, nitrogen uptake was significantly higher with higher dose of *Rhizobium* and phosphorus, while lower with lower dose of *Rhizobium* [35]. Besides, these results are also confirmed by Walley FL, a significant increase in N uptake or their contents in the leaves or biomass due to *Rhizobium* and phosphorus application in chickpea [36].

Significant differences were also observed among *Rhizobium* and phosphorus rates for seed and leaf phosphorous uptake and its interaction with varieties. Phosphorus content in leaf was found significantly the highest with the *Rhizobium* 500 g in combination with phosphorous 23 P_2O_5 ha^{-1} in the Shewarobit cultivar and *Rhizobium* 500 g in combination with Phosphorous 46 P_2O_5 ha^{-1} in N-26 cultivar (Table 5).

No.	Treatment	NP	NS	SWT	LB	BM	SY	HI
1	$P_20_5$0B0	31.0d	8.8a	6.2a	3233.8	5254.1	1157.0c	21.9b
2	$P_20_5$0B400	55.5b	10.0a	6.5a	4101	6677.9	1588.0b	24.2a
3	$P_20_5$0B500	60.3b	10.5a	6.3a	4541.6	7366.1	1682.0b	23.0ab
4	$P_20_5$23B0	35.3cd	9.8a	4.6a	3586.3	5813.8	1292.0c	22.1b
5	$P_20_5$23B400	57.7b	10.3a	5.8a	4386.9	7120.5	1620.0b	22.9a
6	$P_20_5$23B500	62.0ab	9.8a	6.8a	4602.4	7459.1	1712.0ab	23.1ab
7	$P_20_5$46B0	42.3c	9.7a	5.9a	3469.1	5614.4	1266.0c	22.6b
8	$P_20_5$46B400	63.2ab	10.2a	7.0a	4528.3	7351.2	1745.0ab	24.0a
9	$P_20_5$46B500	70.3a	10.3a	7.3a	4766	7738.2	1846.0a	24.2a
	LSD at 5% SP	9.21	0.9	2.5	350.5	570.3	174	1.71
1	Shewa Robit	53.1a	10.0a	6.5a	3849.5b	5928.2b	1478.0b	24.9a
2	N-26	53.0a	9.9a	6.1a	4420.6a	7492.9a	1612.0a	21.5b
	LSD at 5% MP	11.19	2.09	0.844	529.334	842.605	129.7	1.17
	Grand mean	53.1	9.94	3.626	4135.06	6710.59	1545	23.13
	CV%	14.8	7.9	11.5	7.2	7.2	9.6	6.3

NP=number of pods plant^{-1}, NS= number of seeds pod, SW=100-seed weight (g), LB=leaf biomass in gm, BI= biomass in gplot^{-1}, SY=seed yield in kg ha^{-1}, HI=harvest index %, SP= Sub-plot, MP= main plot

Table 4: Effect of Rhizobium, phosphorous and varieties on yield and yield component traits of Mungbean.

The application of phosphorus might have improved the nutritional environment in rhizosphere as well as in plant system leading to the increased uptake and translocation of nutrients especially of nitrogen, and phosphorus in reproductive structures which led to higher content and uptake. Since, uptake of nitrogen and phosphorus were the function of seed and biomass yields and their concentration. Thus the significant increase in concentration of these nutrients coupled with increased seed and biomass yield enhanced the total uptake of thus nutrient.

Rhizobium inoculants alone led to 239 % higher phosphorus uptake over the control in N-26 cultivar. In line with this study, Chowdhury MI, reported that phosphorus content and uptake increased in both seed and leaf due to inoculation with *Rhizobium* in cowpea [37]. Besides Prajapati JP also reported similar findings; phosphorus content in the leaf biomass was significantly affected at higher level of *Rhizobium* inoculants and phosphorus rate [38]. In agreement with the present study, Prajapati JP reported the judicious application of phosphorous with *Rhizobium* was significantly increase the nutrient uptake [39].

Treatment	TN in leaf		TN in seed		AvP in leaf		AvP in seed (ppm)	
	Shewarobit	N-26	Shewarobit	N-26	Shewarobit	N-26	Shewarobit	N-26
P0B0	1.25cd	1.20a	0.82d	0.80c	0.64d	0.64c	0.12ab	0.08a
P0B400	1.30b	1.36b	0.83c	0.79d	0.60d	0.80bc	0.12ab	0.64a
P0B500	1.33b	1.15c	0.79e	0.88a	0.92b	0.98bc	0.28a	0.20a
P23B0	1.28c	1.16c	0.90b	0.74g	0.80c	0.96bc	0.44a	0.92a
P23B400	1.26c	1.20d	0.78e	0.77f	0.82c	1.06bc	0.28a	0.76a
P23B500	1.54a	1.37be	0.95a	0.85b	1.38a	1.00bc	0.12ab	0.16a
P46B0	1.15e	1.22f	0.85c	0.78df	0.82c	2.53a	0.44a	0.84a
P46B400	1.22f	1.43g	0.85c	0.81c	0.70cd	1.24b	0.48a	0.76a
P46B500	1.34b	1.37h	0.81de	0.88a	0.94a	1.56b	0.40a	0.64a
LSD (5%)	0.02	0.02	0.01	0.01	0.2	0.55	NS	NS

Table 5: Effects of Rhizobium and phosphorous treatments on nitrogen (N) and phosphorus (P) uptake of mungbean.

Economics of *Rhizobium*, Phosphorous and Variety of Mungbean

The economic parameters such as cost of cultivation, gross return, net return were found maximum with the higher dose of phosphorus (23 or 46 P_2O_5 ha^{-1}) together with full higher dose of *Rhizobium* inoculation (500g) at N-26 cultivar (Table 7). The lowest economic parameters were recorded with yield obtained from the control treatment. Application of a combination of 23 P_2O_5 ha^{-1} with 500g *Rhizobium* gave the maximum gross return (36576 ETB ha^{-1}) and net return (34661 ETB ha^{-1}) in *Shewarobit*. The best economic return was obtained from the combination of treatment of P_2O_5 $kgha^{-1}$ plus 500g *Rhizobium* with gross return of (40010 ETB ha^{-1}) and net return of (39294 ETB ha^{-1}) in N-26 variety.

Treat. No.	Treatments (*Rhizobium* x P)		Yield kg/ha	Adjusted yield (kg/ha)	Gross return (ETB/ha)	Total variable cost (ETB/ha)	Net return (ETB/ha)
Shewarobit Cultivar							
1	P0	B0	1039	935.1	27074	675	26399.3
2	P0	B400	1459	1313	31037	715	30321.5
3	P0	B500	1604	1444	34889	715	34173.5
4	P23	B0	1242	1118	33388	1875	31512.8
5	P23	B400	1536	1382	32513	1915	30597.5
6	P23	B500	1696	1526	36576	1915	34661
7	P46	B0	1272	1145	29324	1875	27449.3
8	P46	B400	1681	1513	29626	1915	27710.8
9	P46	B500	1776	1598	36324	1915	34409
N-26 Cultivar							
1	P0	B0	1276	1148	28512	675	27837
2	P0	B400	1727	1554	30253	715	29538
3	P0	B500	1717	1545	40010	715	39295
4	P23	B0	1915	1724	31512	1875	29637.2
5	P23	B400	1260	1134	33072	1915	31156.8
6	P23	B500	1761	1585	39213	1915	37298
7	P46	B0	1808	1627	35772	1875	33896.8
8	P46	B400	1704	1534	35683	1915	33768.2
9	P46	B500	1342	1208	36096	1915	34180.8

Mungbean market price ETB 25/kg and 24 ETB/kg in Shewarobit and N-26 respectively.
Combination of treatment of P_2O_5 $kgha^{-1}$ plus 500g *Rhizobium* with gross return of (40010 ETB ha^{-1}) and net return of (39294 ETB ha^{-1}) in N-26 variety.
Table 7: Effect of Rhizobium rate, variety and phosphorous rate on economics of mungbean.

Conclusion and Recommendation

It is well established fact that seed yield of mungbean is function of yield attributes such as number of pods per plant, seeds per pod and leaf biomass, 100 Seed weight, uptake of major nutrient and other agronomic traits. Increase in these yield attributes due to fertilization might have increased grain yield of mungbean. The significant increase in biomass yield due to application of *Rhizobium* and phosphorous could be attributed to the increased vegetative growth possibly as a result of effective utilization of nutrients absorbed through extensive root system and prolific branch development on account of improved nourishment through macro nutrient and bio fertilizer. Since, uptake of nitrogen, and phosphorous is the function of seed and biomass yields and their concentration, the significant increase in concentration of these nutrients coupled with the total uptake of nitrogen and phosphorous increased seed and biomass yield.

The combined application of *Rhizobium* inoculation and phosphorous fertilizer had profound effect on nodulation of mungbean varieties. The *Rhizobium* inoculation alone and along with application of phosphorus fertilizer significantly increased all the parameters measured. Application of mungbean with *Rhizobium* 500g plusP_2O_5 46 kg ha^{-1}, *Rhizobium* 500g plus P 23 kg P_2O_5 ha^{-1} combinations and *Rhizobium* 500g alone, increased yield and yield component trait compared with other treatment combination. However, phosphorus fertilizer application at 23 kg P_2O_5 ha^{-1} was found more effective and economical than 46 kg P_2O_5ha^{-1}. The study revealed that *Rhizobium* inoculation at 500g along with 23 kg P_2O_5ha^{-1} application increased growth and yield of mungbean. It is therefore recommended that farmers should adopt *Rhizobium* inoculants at 500g alone or *Rhizobium* inoculants 500g along with phosphorus application at the rate of 23 kg P_2O_5 ha^{-1} to increase mungbean productivity in North Eastern Region of Amhara, Ethiopia. Despite significant increases observed in yield, nutrient uptake, economic response to the recommended rates of bio fertilizer, future studies should focus on multi-locations and seasons to arrive at conclusive results.

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