



Response of Mung Bean (*Vigna radiata* L. Wilczek) Varieties to the Application Rates of Phosphorus in Ambasel District, North-eastern Ethiopian Lowlands

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Abstract: Phosphorus fertilizers have a great importance for mung bean (*Vigna radiata*). It not only increases the yield and yield components of the crop but also improve the quality of the produce. This experiment was designed to evaluate the performance of phosphorus application rates on different mung bean varieties. The experiment was conducted at Robbitkebele in Ambasel district on the land of fruit development and seedling nursery of Amhara Development Association (ADA). It was carried out under rain fed condition of 2016 main season. The effects of P application rate on yield and yield components of the crop were studied using three varieties (N26, NVL⁻¹ and Shewarobit). The varieties were received four levels of phosphorus (0, 23, 46 and 69 kg ha⁻¹ P₂O₅) with factorial randomized complete block design (RCBD) and the treatments replicated three times. The results showed that application of P significantly affected total mung bean yield. Main effects of crop varieties and phosphorus rate were showed significant influence on the days to flowering, days to maturity, plant height, number of pods per plant, number of seeds per pod, harvest index, biomass yield, and seed weight per plant. However, days to emergence, stand count at emergence, and stand count at harvest were not significantly affected by individual effects of crop variety and P rate. The maximum plant height, number of seeds per pod and 100 seeds weight were obtained due to planting mung bean N26 variety. The maximum weight of seeds per plant, number of pods per plant, biomass yield harvest index and grain yield were recorded by NVL 1 variety meanwhile the lowest grain yield obtained by Shewarobit variety. Mung bean N26 variety and 69 kg ha⁻¹ P₂O₅ treatment produce the highest yield. Application of phosphorus up to 46 kg ha⁻¹ P₂O₅ increased number of pods per plant, pod length, number of seeds per pod, seed yield, harvest index, biomass yield, yield and 100 seed weight in a rapid change but application of more dose of phosphorus increase the yield at low rate. Based on the economic analysis application of 46 kg ha⁻¹ P for variety NVL1, and 69 kg P for N26 and Shewarobit varieties were economically feasible.

Keywords: Ambasel, Mung Bean, N26, NVL1 Variety, Phosphorus

1. Introduction

Mung bean (*Vigna radiata* L. Wilczek) is an important legume crop with high nutritive values. It is an eco-friendly food grain leguminous crop for dry land agriculture [1]. According to the nutritionists, pulses are an excellent source of dietary proteins and can play an important role in fulfilling food requirements of rapidly increasing population [2]. Growth of human population from 6.1 billion in mid 2001 to

9.3 billion by 2050 should be in par with crop production to ensure food security [2]. Mung bean seed is more palatable, nutritive, digestible and non-flatulent than other pulses grown in country. It is also known as king of the pulses. Mung bean contains 1-3% fats, 50.4% Carbohydrates, 3.5-4.5% fibers and 5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively [3, 4 and 5]. Pulses

contain important amino acids known as lysine which is frequently available in mung bean crop but deficient in most of cereal grains and therefore known as poor man meat [5]. Besides, being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in furthering sustainable agriculture [6]. The crop is a short duration crop therefore has less water requirement as compared to summer crops. Moreover, it is drought resistant that can withstand adverse environmental conditions, and hence successfully be grown in rain fed areas [7].

Phosphorus effect on root establishment and development is well known [8]. Phosphorus is one of the three macronutrients that plants must obtain from the soil. It is a major component of compounds whose functions relate to growth, root development, flowering, and ripening [9]. Addition of N and P fertilizer enhances root development, which improves the supply of other nutrients and water to the growing parts of the plants, resulting in an increased photosynthetic area and thereby more dry matter accumulation [9].

Inadequate nutrient status of soil is a particular problem for small landholder farmers of the developing countries, where much grain-legume production couldn't apply that much [10]. Introduction of high yielding varieties and increased cropping intensity requires heavy applications of N and P fertilizers. As in [11] disclosed the yield of different crops have been noticed from the soil application of the deficient macronutrient, therefore the poor availability of phosphorus fertilizer is one of the major causes depressing the productivity of the crops. On the other hand, soil P fixation depends on method of application, P broadcasting expose for fixation than band application since broadcast application has create more contact ratio between the fertilizer and soil mean while and application narrowing the contact ratio between P and soil [12].

Farmers have a wrong notion that mung bean, being legume crop does not need any nutrient and usually grow it on the marginal lands without applying any fertilizer. This seems to be an important reason for low productivity in the country. In contrary many authors disclosed that, P application on leguminous crop improves yield components and yield of green gram straw yield, number of branches, number of pods plant⁻¹, number of seeds pod⁻¹ and 1000-grain weight considerably as compared with treatments given no phosphorus [13, 14]. As well as adequate amount of phosphorus in soils favors' rapid plant growth, early fruiting and maturity and improves the quality of the produce. However meager information on P application rate hinders the improvement of the crop yield in north Eastern Ethiopia in general and in the study area in particular.

Therefore, this study was designed with the following specific objectives

To investigate the effect of P application rates on phenological stages, growth and yield components of the crop.

To determine the optimum rate of P for different varieties of mung bean

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Robbitkebele in Ambasel district on the land of fruit development and seedling nursery of Amhara Development Association (ADA) (Figure 1). This site is located at 450 km north-east of Addis Ababa in south Wollo administrative zone of Amhara National Regional State. The area has been received an average rainfall of 800 mm in annual with mean average minimum and maximum temperatures of 15 and 20°C, respectively. This site is situated at an altitude of 1531 meters above sea level. The soil type of the site is sandy clay loam.

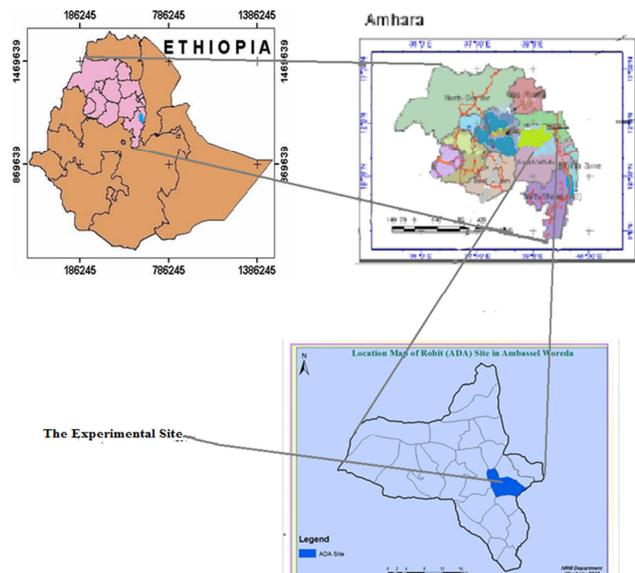


Figure 1. Location map of the experimental site.

2.2. Experimental Materials

Two mung bean varieties (N26 and NVL 1) were collected from Melkasa Agricultural Research Centre while Shewarobit variety collected from local area for this experiment. Nitrogen fertilizer as of urea and phosphorus fertilizer as of TSP were used in the study. Uniform rate of 11.5 kg/ha N fertilizer was applied for all experimental plots.

2.3. Treatments and Experimental Design

These experimental treatments were arranged through factorial combinations of three mung bean varieties (N26, NVL/1, and Shewarobit) and four levels of P (0, 23, 46 and 69 kg ha⁻¹ P₂O₅) (Table 1). The treatments were replicated three times and laid out in randomized complete block design (RCBD). Each experimental plot size was 2.5 m long and 2.0 m width (area of 5 m²), the crop planted on row by leaving 20 cm from both sides of gross plot size. The net area of each plot was considered by leaving one outermost row on both sides of inter row spacing while two outermost rows on both sides of intra row of the plot. Therefore, the net plot has an area of 1.6 x 2.1 m (3.36 m²). Each block was separated by a space of 1 m meanwhile each plots separated with a distance of 0.5 m.

Phosphorus fertilizer was applied in band just at time of planting while 11.5 kg/ha nitrogen applied as a starter. The crop was planted on row at 250,000 plants/ha seed rate with intra and enter row space of 10 and 40 cm, respectively. Furthermore, all recommended cultural practices that adopted for mung bean production properly implemented in this experiment for all plots, simultaneously.

2.4. Data Collection

Plant growth data such as plant height and number of pods per plant were recorded from randomly selected 10 plants on net plot area. Moreover, crop yield data such as grain, biomass and 100 seeds weights and harvest index were measured from the yield obtained on net plot area. Plant height was measured from the ground level to the top of the plant at flowering and at physiological maturity from 10 randomly selected plants from each plot. Number of pods per plant is determined as the total number of pods in each plant and it was recorded after pod formation and at physiological maturity (when pods matured and dried but before they start shattering). Number of seeds per pod was determined as the total number of seeds per pod on selected plant recorded at maturity. The dry weight was measured from 10 randomly taken mature plants seed from each plot after oven drying at 70°C until maintain constant weight. Harvest index was computed as the ratio of mature seed yield per plant to the total biomass.

One hundred seeds weight was measured by counting 100 seeds randomly collected from each treatments and measure by using a sensitive balance. All crop yields were converted into hectare basis. Biomass yield was determined during maturity the whole plant parts including stem leaves pods from the net plot area was measured after harvest and sun drying for three consecutive days.

2.5. Soil Sampling and Analysis

Ten soil samples were collected from the experimental field in zigzag fashion at plough depth (0-25 cm) before planting the crop. Then the samples thoroughly mixed and formed a composite sample to determine its physicochemical properties. After the crop harvest soil samples collected from each plot to determine the effect of treatment on selected chemical properties of the soil (organic carbon, total N and available P). The collected soil sample was air dried, grinded and sieved through a 2 mm sieve size to determine soil pH, available P, exchangeable potassium and electric conductivity of soil. While it was sieved in 0.5mm diameter size to determine the organic carbon and total N content of the soil. Soil pH was determined by diluting the soil in a 0.01 M CaCl₂ solution in the ratio of soil salt of 1: 2.5. Total nitrogen was determined by Kjeldahl method [15] while organic carbon estimated using the wet digestion method [16]. Available phosphorous content of the soil extracted with 0.5M NaHCO₃ [17] and measured by atomic absorption spectrophotometer following the procedure as outlined in [18]. Exchangeable potassium content of the soil was

measured using flame photometry [19].

2.6. Data Analysis

The data were subject to analysis of variance as in [20] procedure using the latest version of SAS software [21]. Significant difference among treatment means was delineated by LSD procedure at 5% level of significance.

Economic analysis was conducted through CIMMYT partial budget methodology [22]. The total variable cost included the cost of P fertilizer and grain seed in a hectare base. The net benefit was calculated as the difference between the gross field benefit (birr per ha). The economic analysis was carried out by considering estimated prices of P fertilizer and mung bean grain during the application and harvesting season, respectively. The price of each kg, P fertilizer and mung bean grain were 24.45 and 16.875 birr, respectively in local market area. While costs of weeding, harvesting (threshing and winnowing), packaging material and transporting were 1000 birr per ha, 80birr per 100 kg, 7 birr per 100 kg and 5 birr per 100 kg, respectively.

3. Results and Discussion

3.1. Selected Physicochemical Properties of the Experimental Soil

The pre planting soil was sandy clay loam in texture and with 6.8 soil pH; thus it was suitable for mung bean cultivation (Table 1). The experimental soil was found to be moderate in CEC (32.5 Cmolc₍₊₎ kg⁻¹), non saline or low in salt content (4 ds/m), high in exchangeable potassium (0.65 cmolc₍₊₎ kg⁻¹ soil), low in total nitrogen (0.18%) and also Available phosphorous of soil was high (13.4 mg kg⁻¹), according to Olsen P sufficiency test soil P is very low at < 3 ppm, low at 4 -7 ppm, medium 8⁻¹ ppm and high > 12 ppm [23]. As per [24] scaling the soil has high organic carbon content (4.5%) or 7.74% organic matter.

Table 1. The pre-planting properties of experimental soil.

Soil physicochemical properties	Unit	Value
Clay	%	41.5
Silt	%	28.9
Sand	%	30.5
Soil texture class	-	Sandy clay loam
Total nitrogen	%	0.18
Available phosphorus	mg kg ⁻¹	13.4
Exchangeable potassium	Cmol ₍₊₎ kg ⁻¹	0.65
Organic carbon	%	4.5
pH	-	6.8
EC	mm hos ⁻¹	4 ds/m
Cation Exchange Capacity (CEC)	Cmol ₍₊₎ kg ⁻¹	32.5

3.2. Effects of Residual Nutrients on Selected Chemical Properties of Soil

The post harvest soil samples were collected from each plot and then composited per treatment for the analysis of total N, available P and organic carbon. The analysis results indicated that maximum residual total N (0.2%) was obtained

on mung bean N26 variety planted and 69 kg ha⁻¹ P₂O₅ applied treatment. However, minimum residual total N was recorded on the local cultivar (Shewarobet) planted and P applied treatments (Table 2). Thus, improved variety removed lower N nutrient as compared to local variety, it might be due to more fixation capacity of an improved varieties as compare to local mung bean. Maximum residual organic matter content of post harvest soil (7.22%) was recorded on minimum P application rate across all crop varieties. Meanwhile, minimum residual organic matter (6.9%) observed on maximum P applied treatments. Thus an applied P nutrient increases decomposition of organic matter. Maximum residual P obtained on treatment that received more P fertilizers. Generally residual N and P nutrients were should positively related it might be due to synergetic effect of these nutrient (Table 2).

Table 2. Residual soil nutrient content of post harvest soil.

No	Treatments	Total N (%)	Avil. P(mg kg ⁻¹)	OC (%)	OM%
1	V1*0	0.189	12.8	4.2	7.24
2	V1*23	0.19	13.0	4.1	7.07
3	V1*46	0.192	13.2	4.1	7.07
4	V1*69	0.2	13.3	4.0	6.9
5	V2*0	0.19	12.9	4.1	7.07
6	V2*23	0.19	13.0	4.0	6.9
7	V2*46	0.196	13.2	4.0	6.9
8	V2*69	0.195	13.4	4.1	7.07
9	V3*0	0.185	13.0	4.2	7.24
10	V3*23	0.188	13.2	4.2	7.24
11	V3*46	0.19	13.2	4.1	7.07
12	V3*69	0.19	13.3	4.0	6.9
Mean		0.191	13.12	4.09	7.05

Whereas: V1, V2 and V3=N26, NVL 1 and Shewarobet (local), respectively.

3.3. Effects on Growth and Yield of the Crop

Crop growth and yield responses were significantly affected by genetic make-up of the crop and different environmental factors such as light, temperature, soil nutrient and management practices. In this experiment most parameters of the crop phenological stage, growth and yield were significantly influenced by individual effects of crop variety and P application rate. Maximum number of seeds per pod, weight of seed per plant, harvest index, biomass yield, plant height and 100 seeds weight were obtained at 69 kg ha⁻¹ P₂O₅ application rate. Grain yield of this P application rate increased by 1.63 t/ha over the control treatment. As in [25] report P application rates were significantly increased the growth of plants, number of nodules, dry matter production as well as mung bean grain yield as compared to the control plot. Phosphate fertilization has increasing influence in relation to growth and yield. Higher yields of mung bean have been obtained by application of 90 kg ha⁻¹ phosphorous under field conditions [26, 27]. Moreover, as in [28, 29] the effect of phosphorus rates on mung bean response indicated that application of 75 kg ha⁻¹ P gave the highest grain yield (1.83 t/ha). On the other hand, the combined use of P and Rhizobium inoculation gave maximum 100 seeds weight, grain yield and protein content seed [30]. Contrary to this

finding [31] report indicated that a factorial combination of three levels of nitrogen and three levels of phosphate fertilizer on mung bean and independent responses to phosphate was reported.

3.4. Growth Parameters

3.4.1. Stand count at Emergence (SCE) and Harvest (SCH)

The analysis of variance for stand count at emergence and harvest revealed that no significant variations due to the main effect of the variety, however slight differences of stand count were recorded among mung bean varieties. The maximum number of count (29.52 plant/m²) registered by N 26 variety. Meanwhile, the minimum number (26.8 plants per m²) was recorded by Shewarobet mung bean variety. Moreover, the stand count at harvest shows no significant result by the crop. Similarly, main effect of P application rate non-significantly influences stand count at the emergence and the harvest of the crop. The Combination effect of crop and phosphorus application rates showed no significant variation in respect of stand count at emergence and at harvest.

3.4.2. Plant Height

Plant height was influenced significantly by individual effect of crop variety but non-significantly affected by main effect of P and interaction effect of crop variety and P rate. N26 mung bean variety, gave the highest plant height (68.9 cm) at harvest time. The shortest plant height of 62.4cm was obtained in Shewarobet (local) variety. NVL1 variety also gave the medium plant height (64.5 cm). Probably the genetic makeup of the variety was responsible for the variation in plant height. Similar studies also revealed that plant height is increased by the age of plant and within the period of 40-50 DAS for different cultivars [32, 33, 34].

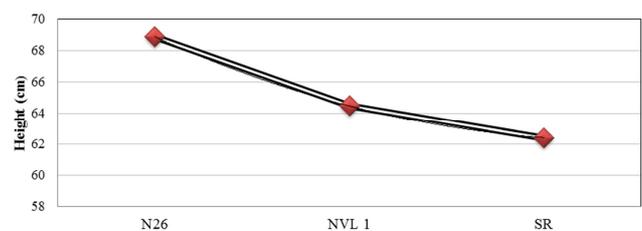


Figure 2. Main effect of crop variety on plant height of mung bean.

Phosphorus had a significant effect on plant height. The tallest plant height of (66.6cm) was recorded by the application of 69 kg ha⁻¹ P₂O₅ while the shortest plant height (63.6 cm) was found with control treatment (Figure 3). The increase in plant height under phosphorus treatment might be due to effect of phosphorus in metabolism of growing plants, in its growth yield, and yield parameters. The results are in agree with [35, 36] reports. As in [13] report phosphorus application showed significant influence on plant height with increasing levels of phosphorus application from 0 to 40 kg ha⁻¹ P₂O₅. In contrary to this, increasing p levels can decrease plant height [30].

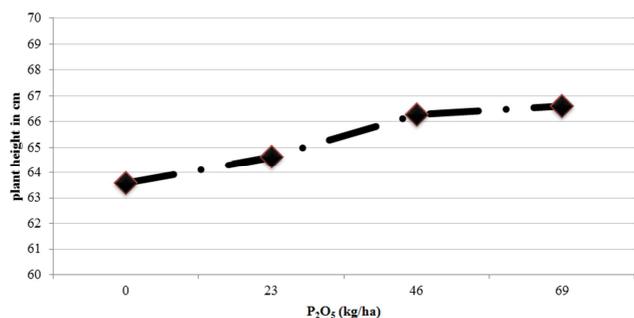


Figure 3. Effect of phosphorus rate on plant height.

3.5. Yield and Yield Related Parameters

3.5.1. Number of Pods Per Plant

Varieties were significant to the number of pods per plant. The highest number of pods per plant (33.1) was obtained by NVL1 variety. Meanwhile, the lowest number of pod per plant (31.2) recorded by Shewarobit variety (Figure 4). As in [37] report the variety has significant effect on number of pod per plant and number of pods of mung bean.

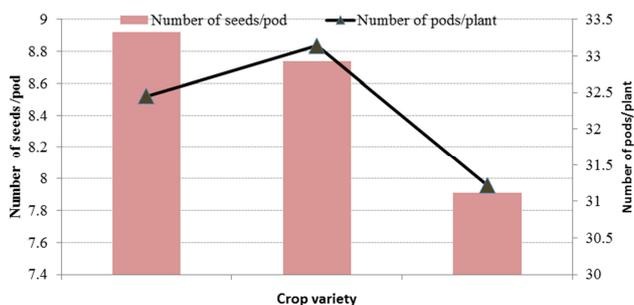


Figure 4. Effect of crop variety on number of pods per plant and number of seeds per pod.

Similarly, number of pods per plant was significantly affected by the application of phosphorus. However, the interaction effect of crop variety and P rate was not significantly affecting the number of pods per plant. The application of 46 kg ha⁻¹ P₂O₅ produced the highest number of pods per plant (33.7). The second highest number of pods per plant (33.6) was produced at 69 kg ha⁻¹ P₂O₅. The control treatment produced the lowest number of pods per plant (30.06). Increasing level of phosphorus up to 46 kg ha⁻¹ P₂O₅ increased the number of pods per plant and then it decreased with excess P rate (Figure 5). This result agrees with [38, 39] reports also. An application of 40 and 60 kg ha⁻¹ P₂O₅, respectively increased the number of pods of mung bean [40]. Besides, the greenhouse experiment on saline soil indicated that application of N and P increased pods number and grain yield of mung bean [41].

Number of seeds per pod

Main effect of crop variety showed significant influence on the number of seeds per pod. Hence; Individual effects of crop variety and P applications rate were showed significant influence on number of seeds per pod. The highest number of seeds per pod (8.9) was recorded by N26 variety, meanwhile

the lowest (7.9) number of seeds per pod was obtained by Shewarobit mung bean (Figure 4). In line with to this different mung bean varieties were responded various number of seeds per pod [42].

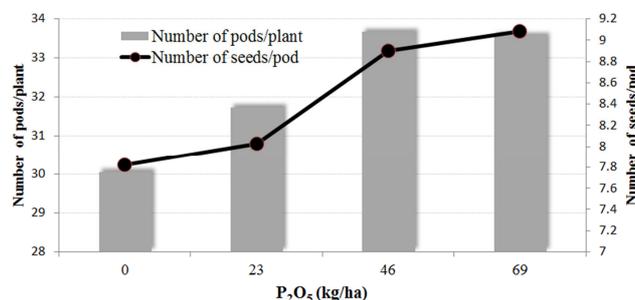


Figure 5. Effect of phosphorus rate on number of pods per plant and number of seeds per pod.

The treatments that received 69 kg ha⁻¹ P₂O₅ produced highest number of seeds per pod. Meanwhile, the lowest seeds per pod were recorded with zero P level treatment across all crop varieties (Figure 5). Thus, P application has enhances seed set up of the crop. As in [30, 43] reports mung bean seed inoculation with *Rhizobium* and 70 kg ha⁻¹ P₂O₅ applied treatment gave the highest (12) number of seeds per pod. Besides, field experiment conducted disclosed that an application of 40 kg ha⁻¹ phosphorus significantly increased the number of seeds per pod [44].

Weight of seeds per plant

Main effects of crop variety and P application rate significantly affect the weight of seeds but insignificantly affected by their interaction effect. The highest weight of each crop seeds (10.6 g) was recorded on NVL1 variety meanwhile the lowest weight of each crop's seeds (7.2 g) was obtained on Shewarobit variety (Figure 6). Similarly, six mung bean varieties were gave various weight grain yields from each plant [45].

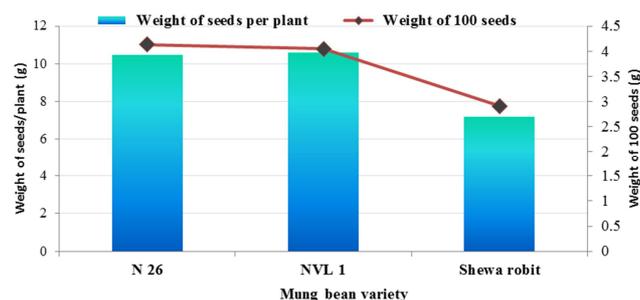


Figure 6. The influence of mung bean varieties on weight of seeds per plant and 100 seeds.

On the other hand, the treatment that received 69 kg ha⁻¹ P₂O₅ was produced the highest weight of seeds per plant (10.4 g). But zero P treatment of all crop varieties responded the lowest (7.9 g) weight of seeds per plant. Similarly, an application of 40 and 60 kg ha⁻¹ P₂O₅ were increased the weight of mung bean seeds over the control and low P application rate (20 kg ha⁻¹) [40].

The weight of hundred seeds

The weight of 100 seeds was influenced by individual effects of crop variety and P application rate but their interaction effect has no significance influence on 100 seeds weight. The highest weight of 100 seeds (4.1 g) was recorded by N26 variety meanwhile the lowest weight of seed (2.92 g) was registered from Shewarobit mung bean variety (Figure 6). This finding is also supported by [37] report.

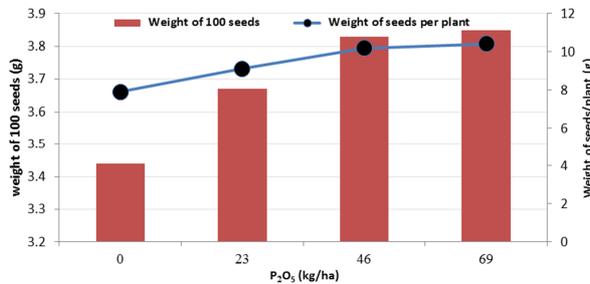


Figure 7. The effect of phosphorus rate on on weight of seeds per plant and 100 seeds.

Similarly, the highest weight of 100 seeds obtained by the application of 69 kg ha⁻¹ P₂O₅ (3.9 g). However, the lowest weight of 100 seeds registered due to zero P application rate (3.4 g) (Figure 7). These findings also correlated as in [30, 37] reports.

Grain yield

Individual effects of crop variety and P application rate were showed highly significant (p < 0.01) influence on crop grain yield, meanwhile their interaction effect significant at p < 0.05 level on the grain yield of mung bean. The highest grain yield (1.65 t/ha) and lowest yield (1.15 t/ha) were recorded due to the use NVL1 and Shewarobit mung bean variety, respectively (Figure 8). In the study conducted on four mung bean varieties viz., BINAmung-2, BINAmung-5, BARImung-2 and BARImung-5 for three years revealed that BINAmung-5 gave the highest grain yield than the other tested varieties because it produced greater number of pods per plant [46]. Moreover, improved mung bean varieties were gave more grain yield than the local variety [47].

The maximum grain yield of 1630 kg ha⁻¹ was obtained due to the application of 69 kg ha⁻¹ P₂O₅, meanwhile the minimum yield of 1280 kg ha⁻¹ recorded on control treatment (Figure 9). This result shows that seed yield increased by the application P fertilizer since more branches per plant, pods per plant, seeds per pod and higher pod length resulted through the availability of P nutrient.

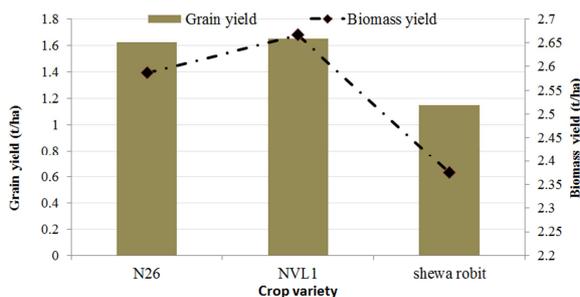


Figure 8. Grain and biomass yields were affected by the crop variety.

The present work findings are consistent as in [48, 49] reports also P application rates increased crop grain yield up to certain level. Moreover, P application enhance N uptake of mung bean [50, 51]. Besides, P application significantly increased the root biomass of mung bean [14]. Similarly, the experiment on the effects of P sources and rates on mung bean yield indicated that the crop showed more growth and yield responses due to the application of 60 kg ha⁻¹ P₂O₅ [49].

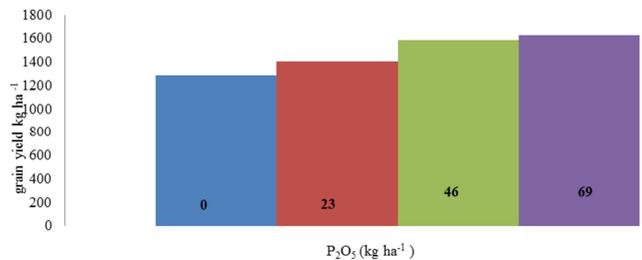


Figure 9. Grain yield of the crop influenced by the application of phosphorus.

On the other hand, the combined effect of crop variety and P rate had significant (p < 0.05) response on crop grain yield. The highest grain yield obtained due to the application of 69 kg ha⁻¹ P₂O₅ on NVL1 crop variety meanwhile the lowest grain yield was planting Shewarobit variety on zero P application. The result of the study might be due to different response of three varieties of mung bean to phosphorus fertilizer. Similarly, the highest grain yield (2.19 t ha⁻¹) was recorded from Binamoog-6 with application of 60 kg ha⁻¹ P₂O₅ followed by Binamoog-6 with 40 kg ha⁻¹ P₂O₅ and the lowest grain yield (0.81 t ha⁻¹) was recorded from BARI Mung-6 without application of phosphorus [52].

Table 3. Mean comparisons of seed yield due to interaction of crop variety and P application rate.

P ₂ O ₅ kg/ha	Mung bean variety		
	NVL1	N26	Shewarobit
0	1.51 ^{bc}	1.50 ^c	8.80 ^f
23	1.60 ^b	1.58 ^b	1.04 ^e
46	1.75 ^a	1.70 ^a	1.31 ^d
69	1.76 ^a	1.76 ^a	1.36 ^d

Means with the same letter are insignificant at p<0.05.

3.5.2. Biomass Yield

Mung bean biomass yield significantly influenced by main effects of the crop variety and P application rate but non-significantly to their interaction effect. The highest crop biomass of 7.93 t/ha was recorded on NVL 1 crop variety meanwhile the lowest 7.07 t/ha biomass obtained by Shewarobit crop variety (Figure 8). It might be due to the maximum plant height, higher number of branches per plant and number of pods per plant that contributed to higher straw yield. The straw yield varied due to variety conduct an experiment and SML 668 had the highest straw yield (4207 kg ha⁻¹) [37].

The highest biomass yield of 7.72 t/ha was registered on the highest P application rate since the crop growth and yield enhanced by the application of P nutrient (Figure 10). It was

markedly observed that increase in the rate of phosphorus increased biomass yield and reached the maximum further increase of phosphorus did not increase the seed yield. Similarly, 60 kg/ha P application increased crop straw and grain yield of mung bean. Meanwhile, the lowest biomass (7.12 t/ha) recorded on the control treatment [53].

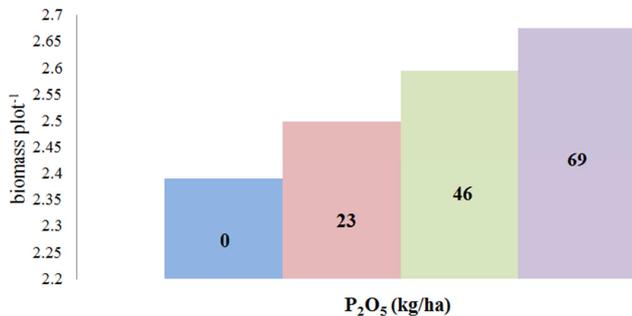


Figure 10. Biomass yield influenced by phosphorus rate.

3.5.3. Harvest Index

The individual effects of crop variety and P application rate have showed significant response to crop harvest index. However, the combined effect of crop variety and P application not significantly affect the harvest index of mung bean. The maximum harvest index of 26.6% was observed on NVL 1 mung bean while the minimum index of 21.7% was recorded due to Shewarobit variety (Figure 11). Thus, improved variety of mung bean gave more grain yield as compared to local cultivar. The improved variety has more number of branches per plant, more number of pods per plant and seeds per pod longer pods contributed to the difference between improved varieties with local one under present experimental situation. These findings are also supported by [37] report.

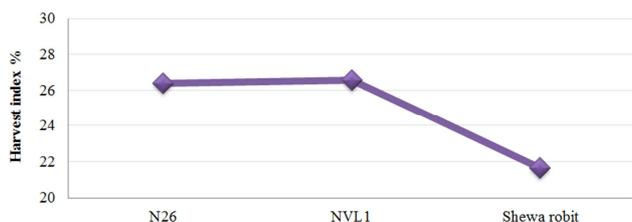


Figure 11. Individual effect of crop variety on harvest index.

Similarly, the maximum harvest index of (26.5%) was recorded with application of 69 kg ha⁻¹ P₂O₅ while the minimum index (23.1%) was obtained at the control treatment. The application of phosphorus rates (X) linearly increased the response harvest index of the crop (y) ($y=1.089x + 22.15$, at $R^2=0.99$) (Figure 12). In line with this, 40 kg ha⁻¹ P application increased number of seeds pod⁻¹, seed yield per plant and crop grain yield response [44].

Hence, therefore the above findings on mung bean growth and yield highly affected with genetic makeup of the crop (variety) and P application rate. Accordingly, planting of mung bean NVL1 and N26 varieties is more promising than Shewarobit (local) variety. Similarly, high application rate of

P fertilizer has great impact to improve the grain and biomass yield of the crop. Finally, the combined use of N26 variety and 69 kg ha⁻¹ P₂O₅ was found the most suitable management to increase mung bean yield in the study area.

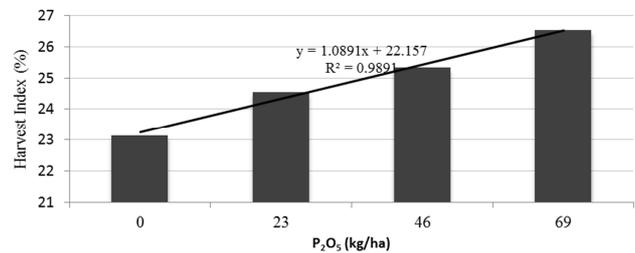


Figure 12. Effect of phosphorus application on harvest index of mung bean.

3.6. Correlation Analysis

The correlation analyses among the crop parameters were significant. However, plant height and stand count non-significantly related to most parameters of crop. Plant height significantly ($p < 0.05$) and positively ($r=0.38^*$) correlated with biomass yield. Grain yield has strong correlation with number of pod per plant ($r=0.75^{**}$), number of seed per pod ($r=0.78^{**}$) and seed weight ($r=0.91^{**}$). Number of pods per plant has highly significant correlation with number of seeds per pod ($r=0.78^{**}$), seeds weight ($r=0.54^{**}$), grain yield ($r=0.76^{**}$), biomass yield ($r=0.65^{**}$), and harvest index ($r=0.63^{**}$). The same to this number of seeds per pod has higher correlation with seed weight ($r=0.56^{**}$), grain yield ($r=0.78^{**}$), biomass yield ($r=0.80^{**}$), and harvest index ($r=0.79^{**}$). Seed weight strongly related to grain yield $r=0.8^{**}$ and harvest index 0.78^{**} but not correlated with plant height. As the result shows harvest index has strongly correlated with number of pod per plant ($r=0.62^{**}$), number of seed per pod ($r=0.79^{**}$), seed weight ($r=0.77^{**}$), yield ($r=0.85^{**}$) and biomass yield ($r=0.70^{**}$) but not correlate with stand count and plant height. Biomass yield has highly significant correlation with number of pod per plant, number of seed per pod, and grain yield but not correlate with stand count. Finally, most parameters of the crop significantly and positively correlated with harvest index and grain yield.

3.7. Economic Analysis

The economic analysis results showed that the maximum net benefit (23,623.95 birr ha⁻¹) with an acceptable MRR (224.2%) was obtained from phosphorus fertilizer application of 46 kg ha⁻¹ for mung bean NVL 1 variety. This treatment resulted in a net benefit advantage of Birr 2,524.28 ha⁻¹ over the control treatment. The second highest net benefit (Birr 23,244.68 ha⁻¹) with an acceptable MRR (127.9%) for NVL 1 variety was obtained from mineral phosphorus fertilizer application of 69 kg ha⁻¹ P₂O₅ this result is in par with the maximum result. In N26, variety the maximum net benefit (Birr 23,320.08 ha⁻¹) with an acceptable MRR was obtained from P fertilizer at 69 kg ha⁻¹ P₂O₅. This resulted in a net benefit advantage of 2,848.55 birr over the control treatments. The second highest net benefit (22,955.26 birr ha⁻¹) with an

acceptable MRR for N26 variety was obtained from mineral Phosphorus fertilizer application of 46 kg ha⁻¹ P₂O₅. For Shewarobit variety the maximum net benefit (17,283.42 birr ha⁻¹), with an acceptable MRR was obtained from the application of 69 kg ha⁻¹ P₂O₅. This has resulted in a net benefit advantage of 5,542.92 birr over the control fertilizer application. The second highest net benefit (17,109.6 birr ha⁻¹) with an acceptable MRR for Shewarobit variety was obtained from mineral Phosphorus fertilizer application of 46 kg ha⁻¹ P₂O₅ (Table 4).

Increase in output will raise profit as long as the marginal

rate of return is higher than the minimum rate of return [22]. The analysis data show application rates of 46 kg P ha⁻¹ for variety NVL1, and 69 kg P for N26 and Shewarobit varieties were economically feasible. The marginal rates of return at the phosphorus application rates of 23, 46, and 69 kg ha⁻¹ P were greater than 150% for all variety, probably it is economical to apply as much as 69 kg ha⁻¹ P for those varieties. Other treatments were eliminated by dominance analysis [22] since the net benefit obtained decreased as the cost increased.

Table 4. Economic analysis for effect of phosphorus fertilizer on three mung bean varieties.

Variety	Pkg ha ⁻¹	Average yield (kg ha ⁻¹)	Adjusted yield (kg ha ⁻¹)	Gross benefit (birr ha ⁻¹)	TVC (birr ha ⁻¹)	NB (birr ha ⁻¹)	MRR%
N26	0	1463.67	1317.31	22229.61	1758.076	20471.53	0
	23	1577.00	1419.3	23950.69	2320.316	21630.37	206.1117
	46	1701.33	1531.2	25839	2883.744	22955.26	220.6448
	69	1762.00	1585.8	26760.38	3440.296	23320.08	169.3328
NVL1	0	1505.33	1354.8	22862.25	1762.576	21099.67	0
	23	1597.67	1437.91	24264.73	2322.548	21942.18	150.4553
	46	1745.67	1571.11	26512.48	2888.532	23623.95	224.1893
	69	1757.00	1581.3	26684.44	3439.756	23244.68	127.8936
Shewarobit	0	884.67	796.21	13436.04	1695.544	11740.5	0
	23	1037.67	933.91	15759.73	2262.068	13497.66	310.1658
	46	1313.67	1182.31	19951.48	2841.876	17109.6	468.3726
	69	1361.67	1225.51	20680.48	3397.06	17283.42	325.7637

TVC=Total variable cost; NB=Net benefit; MRR=Marginal rate of return. Sale price of mung bean grain ETB 25 kg⁻¹; cost of weeding is 1000 ETB ha⁻¹; Cost of harvesting including threshing and winnowing ETB 80 per 100 kg; Packing and material cost Birr 7 per 100 kg and transportation Birr 5 per 100 kg.

Phosphorus fertilizer application for all the three varieties gave positive benefit over the control treatment. This means a very high increase in farmers' income with a simple improvement in crop nutrient management strategy. The same to this result, many studies reported that the income from fertilizer is much greater as compared to the yield from zero fertilizer rates. Finally, application of phosphorus at 46 kg ha⁻¹ rate gave economically optimum grain yields for variety NVL 1, whereas application of phosphorus at the rate of 69 kg P ha⁻¹ that led to the production of optimum grain yield for varieties N26 and Shewarobit (local).

4. Summary and Conclusion

The response of different mung bean varieties to P application rate study was conducted in Ambasel District in 2016 main season. The factorial combination of three mung bean varieties (N26, NVL1, and Shewarobit) and four P levels (0, 23, 46 and 69 kg/ha P₂O₅) treatments were replicated three times. The experiment was laid out in a randomized complete block design. The experimental plot size was 2.5 m x 2 m. The predetermined rate of phosphorus fertilizer as of TSP was applied in band during crop planting. Starter N fertilizer 11.5 kg/ha also applied for all plots at crop planting. The crops planted on intra and inter row spacing of 10 and 40 cm, respectively. All recommended cultural practices adopted for mung bean production were implemented in the experiment. Crop growth and yield data collected and their ANOVA and mean separation analyzed with SAS software.

Stand count at emergence and harvest revealed no significant variation due to the main effect of the variety. Plant height was significantly influenced by individual effects of P application rate and mung bean variety. The longest plant height were recorded by N 26 variety and 69kg ha⁻¹ P₂O₅ applied treatments meanwhile shortest height observed on Shewarobit variety and zero P rate treatments. Number of pods per plant was significantly increased by variety and phosphorus fertilization. The highest number of pods per plant was obtained from NVL1 while the lowest number of pods obtained by Shewarobit (local) variety. Similarly, highest number of pods per plant registered due to the application of 46 kg ha⁻¹ P₂O₅ meanwhile the lowest registered from the control treatment. The interaction of phosphorus and variety gave higher number of pods per plant, the highest pod per plant registered by mung bean NVL1 variety which grown on 46 and 69 kg ha⁻¹ P₂O₅ fertilizer 34.56 and 34.26, respectively. However, the lowest pod per plant registered from Shewarobit variety that grown on zero phosphorus rate.

Variety and phosphorus fertilizer significantly influenced the number of seeds pod⁻¹. Maximum number of seeds per pod (8.9) was obtained from N26 while the lowest of seeds per pod (7.9) was found on Shewarobit variety. Application of 69 kg ha⁻¹ P₂O₅ gave maximum number of seeds per pod (9.1) but zero P applied plot resulted minimum number of seeds per pod. Based on the interaction the maximum number of seeds per pod (9.35 and 9.20) was obtained from N26 variety grown at 69 and 46 kg ha⁻¹ P₂O₅, respectively. Maximum dry seeds weight per plant (10.6 g) was recorded

on mung bean N 26 variety but the minimum dry seeds weight per plant (7.2 g) occurred on Shewarobit variety. Similarly, maximum application rate of P fertilizer gave maximum dry seeds weight per plant (10.4 g) while zero P respended the minimum weight of dry seeds per plant (7.9 g).

Seed yield and biomass yield were significantly influenced by individual effects of crop variety and phosphorus fertilization. The maximum grain (1.7 t ha⁻¹) and biomass (7.93 t ha⁻¹) yields were obtained by planting mung bean NVL variety while minimum grain (1.1 t ha⁻¹) and biomass (7.07 t ha⁻¹) yields were recorded by Shewarobit mung bean. Similarly, maximum grain (1.6 t ha⁻¹) and biomass (7.72 t ha⁻¹) yields were found by application of 69 kg ha⁻¹ P₂O₅, meanwhile minimum grain (1.3 t ha⁻¹) and biomass (6.25 t ha⁻¹) yields were recorded on control P application. The minimum is from controlled Shewarobit variety. The maximum biomass yield (8.3 t ha⁻¹) was obtained from NVL1 grown at 69 kg ha⁻¹ P₂O₅ but the minimum biomass of 6.25 t ha⁻¹ was recorded by mung bean Shewarobit.

The highest (26.6%) and the lowest (21.7%) harvest index were obtained from NVL 1 and Shewarobit, respectively. Application of 69 kg ha⁻¹ P₂O₅ produced the highest harvest index (26.5%) and the lowest harvest index (23.1%) was found at control. It can be concluded that NVL1 performed better than N26, and Shewarobit (local) in respect of productivity. Application of phosphorus up to 46 kg P₂O₅ ha⁻¹ increased the seed yield very fast further higher dose of phosphorus increases seed yield slowly. N26 grown with 69 kg ha⁻¹ P₂O₅ emerged as the promising one to increase the yield of the crop as compared to other treatment combinations.

The post harvested soil analysis result indicated that the improved variety (N 26) recorded highest residual soil N (0.2%) but the post harvest soil of local cultivar (Shewarobit) with lower residual soil N (0.18). Thus, improved mung bean variety removed lower N nutrient as compared to local variety, it might be due to more fixation capacity of an improved varieties. Maximum residual organic matter was recorded on minimum P applied treatment, however minimum organic carbon observed on maximum P applied treatments. It might be due to the applied P enhance decomposition of organic matter.

This conclusion has been made based on the results of the study that was conducted in one season only. Therefore further empirical studies required to put forward comprehensive conclusion due to climatic and soil variations of the country.

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