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Response of Mung Bean (*Vignaradiata* L.) Varieties to Phosphorus Fertilizer Rates Under Irrigation Condition

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Abstract: The field experiment was conducted during 2018/19 cropping season at Gewane Afar region of Ethiopia to identify well adapted and high yielding varieties, determine optimum and assess cost-benefit of phosphorus fertilizer rates for production of mung bean. Treatments studied consisted of factorial combinations of three improved mung bean varieties and one local varieties (Boreda, NVL-I, Rasa and Showa robit respectively) and four phosphorus rates (10, 20, 30 and 40 kg P ha^{-1}) laid out in Randomized Complete Block Design with three replications. The results showed that the highest effect of 40 kg P ha^{-1} on plant height (45.03 cm), primary branch (5.64), secondary branch (6.5), total number of nodules (8.0), hundred seed weight (4.77g) and aboveground dry biomass (5.08 t). The interaction effect of varieties and phosphorus rate also significantly influenced 50% flowering, 90% physiological maturity, number of pod plant^{-1}, number of seed pod-^{1} and grain yield. The highest days to flowering (45 days) and days to maturity (74.15 days) were recorded from variety Rasa with 10 kg P ha^{-1} whereas, the highest numbers of pods plant^{-1} (28.5), number of seed pods^{-1}(10.8) and grain yield (1.54 t) were recorded from the combination of variety Boreda with 30 kg P ha^{-1}, which was statistically at par with that from variety Boreda with 40 kgP ha^{-1}. Whereas the lowest grain yield (0.72 t ha^{-1}) was obtained from the application of 10 kg P ha^{-1} with variety NVL-1. The results of partial budget analysis showed that application of 30 kg Pha^{-1} with variety Boreda gave marginal rate of return above the minimum acceptable values with additional investment advantage for the future. Among the combinations of varieties with P fertilizer rates, variety Boreda with 30 kg P ha^{-1} had showed acceptable marginal rate of returns (262%) and generated the highest net benefit (31,493 birr). Hence it can be concluded that use of 30 kg P ha^{-1}with variety Boreda can be used to enhance the yield and profitability of mung bean production at Gewane and areas with similar agro-ecology. However, the results need to be evaluated and cheeked under different agro climatic conditions and season.

Keywords: Cash Crop, Grain Yield, Nodules, Pulse Crop, Rhizobium Bacteria

1. Introduction

Mung bean (*Vigna radiate* L.) is one of the most essential legume crops, grown in the tropical and subtropical areas of the world [24]. It is an important widespread, herbaceous and annual legume crop cultivated mostly by traditional farmers [4]. The crop is grown widely for use as a human food (as dry bean fresh sprouts), and can be used as a green manure crop and as forage for livestock [49]. The seeds of mung bean contain an average of 26%protein, 63%carbohydrates, 1.4% fat, 4.2% fibers, vitamins, minerals, calcium (Ca) and phosphorus (P). As they are easily digested, they replace scarce animal protein in human diets in tropical areas of the world [5]. Its seed is also more palatable, nutritive, digestible and non-flatulent than other pulses [6]. Besides its high nutritional values, mung bean has also a capacity of improving the fertility status of a soil by fixing atmospheric nitrogen (N) through the process of biological nitrogen fixation [38]. Mung bean has been domesticated in India and it is one of the most essential short-season pulse crops belonging to the family Fabaceae, and subgenus *Ceratotropis* in the genus *Vigna*. Nearly all 90%, of the world's mung bean production comes from Asia. India is the world's largest producer of the crop [47]. It has been grown in the conventional farming system of tropical and temperate regions. Mung bean has green skin and is also called green beans or golden gram. It is sweet in flavor and cold [18]. It can be grown on different soil and climatic conditions [29]. The crop is characterized by fast growth under warm conditions, low water consumer, and excellent soil N-fixer [62].

Mung bean is a short duration (65–90 days) warm season grain legume having wide adaptability and low input requirements [39]. In Ethiopia, it is commonly grown in DebreSina, North Showa Zone, and Qallu, in the South Wollo Zone. However, the crop becomes increasingly important in other dry land areas of the country because of its high market and nutritional values and early maturity [17]. For instance, the production area was increased from 27,085.92 to 37,774.3 ha with bulk production from 27,158.98 to 42,915.55 tones and with average seed yield increase from 1.0 to 1.14, t ha^{-1} [14]. According to Asrat *et al.* [8] mung bean is mostly grown by smallholder farmers under drier marginal environmental conditions and its productivity is lower than other pulse crops. The crop has a great demand in the international market, but there is a huge supply gap due to the existence of limited production in the country [16]. The average yield of mung bean on the farmers' field is far below the level of its potential yield. According to Gewane Woreda office of Agriculture report in 2015, the yield of mung bean recorded from farmers' field ranged from 0.6–0.9 tha^{-1} under irrigation (unpublished data) which is low as compared to the national yield (1.14 t ha^{-1}) and attainable yield which can reach up to 2.0 t ha^{-1} [31]. The low yield of mung bean at Gewane is attributed to various constraints related to lack of well adapted and high yielding improved varieties, poor cultural practices including inadequate use of fertilizer, prevalence of disease and pests.

Phosphorus (P) is a major component of compounds whose functions relate to growth, root development, flowering, and fruit ripening [48]. According to Sign *et al.* [46] reported that growth parameters such as branches plant^{-1}, leaves plant^{-1}, leaf area index, plant dry matter accumulation, and yield components such as pods length, pods plant^{-1}, grains pod^{-1} and 1000-grain weight were significantly affected by supplied P rates. The grain yield of mung bean is also significantly improved due to successive increase in P levels up to 40 kg ha^{-1} [27]. Similar finding has also shown that application of P fertilizers commonly has great influence on crop yields because its inadequacy limits the response of plants to other nutrients [3]. Currently in Ethiopia, 100 kg DAP (46 kg P_2O_5 and 18 kg N) is commonly recommended and applied for mung bean production [32]. Identifying an appropriate crop variety is also one of the most important factors, which greatly affects the yield of mung beans. Taji *et al.* [51] reported that varieties had a significant effect on growth and yield of mung bean. Similarly, Sarkar *et al.* [44] also described that yield of mung bean was significantly influenced by varieties. Wedajo [61] also observed that there is a difference of mung bean yield due to varieties. Moreover, appropriate field management practices, optimum P fertilizer rate and growing high yielding varieties can increase the seed yield to a great extent since higher productivity in any crop can be achieved through a combination of an ideal cultivar grown in suitable environment and with appropriate agronomic practices. Therefore, this study was conducted with the following objectives:

1. To determine optimum phosphorus fertilizer rate and identify well adapted and high yielding variety for mung bean production under irrigation in Afar region.
2. To determine the possible interaction effects of P fertilizer rates and varieties on growth, yield and yield components of mung bean and to assess the economic feasibility of the different P rates for mung bean production at Afar region.

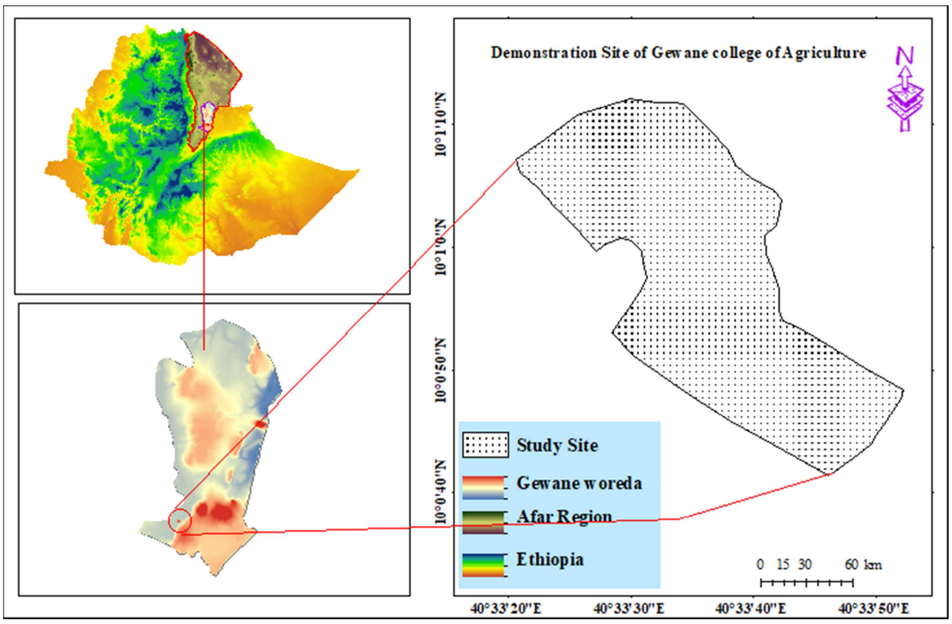

Figure 1. *Map of the study site (Gewane).*

2. Materials and Methods

2.1. Description of the Experimental Site

The experiment was conducted at Gewane Agricultural Technical and Vocational Education and Training (ATVET) College demonstration site in Afar Regional State during 2018/19 cropping season under irrigation. The site is located in Gewane Woreda at 10°10' N latitude, 40°32' E longitude, and 356 km North East from Addis Ababa (Figure 1). The altitude of the site is about 626 meters above sea levels (m.a.s.l) [19]. The experimental site is characterized as a semi-arid climatic zone with an average annual rainfall of about 400 mm. The rainfall is erratic and unreliable in nature and mostly it is not suitable for regular crop production under rain-fed condition. The mean annual minimum and maximum temperatures of the experimental site are 22.5 and 39°C, respectively [17].

The main soil type of the experimental area is alluvial which resulted from the Awash River basin [63]. The major land uses of the area are pastoral and agro-pastoral farming systems. Agricultural crops such as cotton, sesame, maize, broom corn, onion, tomato, pepper, date palm, citrus and mango are the main cultivated crops in Gewane.

2.2. Experimental Materials

Phosphorus fertilizer in the form of (TSP), and three nationally released mung bean verities and one local variety namely Boreda, Rasa, NVL-1 and Shewa robit respectively were used as experimental materials.

Table 1. *Mung bean varieties with their some characteristics.*

Characteristics	Varieties			
	Boreda	**Rasa**	**Showa robit**	**NVL-1**
Growth habit	Indeterminate	Determinate	Indeterminate	Indeterminate
Maturity group	Medium	Medium	Medium	Medium
Flower color	White	Yellow	White	Yellow
Yield in research field (kg ha^{-1})	1350	800-1500	800-1500	800-1500
Yield in farmer field (kg ha^{-1})	1000	500-1000	500-1000	500-1000

Source: MoARD (2008); MoARD (2011)

2.3. Treatments and Experimental Design

The treatment combinations include three improved (Boreda, Rasa and NVL-1) and one local (Showa robit) mung bean varieties and four P rates (10, 20, 30 and 40 kg P ha^{-1}) (Table 2). The experiment was laid out in a randomized complete block design in factorial arrangement with three replications having 1.5 and 0.75 m distance between blocks and plots, respectively. The plot size for each treatment was 2 m x 1.5 m (3 m^2). The spacing between plants and rows were 10 and 30 cm, respectively.

Table 2. *Factorial combination of varieties and P fertilizer rates.*

Varieties	Prates (kg ha^{-1})			
	10	**20**	**30**	**40**
Boreda	Bored +10	Boreda+20	Boreda+30	Boreda+40
Rasa	Rasa+10	Rasa +20	Rasa +30	Rasa +40
Showa robit	Showa robit +10	Showa robit +20	Showa robit +30	Showa robit +40
NVL-1	NVL-1 +10	NVL-1 +20	NVL-1 +30	NVL-1 +40

2.4. Experimental Procedure and Field Management

The experimental field was plowed with a tractor to a depth of 25 – 30 cm and leveled to form uniform seed bed for uniform water flow in ridges. After preparing a field layout on the ground, ridges with 30 cm depth and 20 cm width at the bottom of the furrows were prepared manually. Pre-planting furrow irrigation was done to stabilize the soil and after three days rows with 10 cm depth was prepared on the right side of the furrow just about 10 cm above the bottom and fertilized with the specified treatment mixtures of P and 50 kg ha^{-1} urea fertilizers. The applied fertilizer was incorporated in to the soil of each row just before sowing to reduce direct contact of seeds with fertilizer.

Two seeds from seed lot tested for its germination percentage were planted in hill at a depth of about 2.5 cm in rows. One of the seedlings which had poor growth performance was thinned out from each hill two weeks after emergence. The furrow irrigation frequency was determined based on the experience of mung bean producers in Gewane area. The first irrigation was made before sowing and the last irrigation was made10 days before harvesting. Seven days' irrigation intervals were maintained up to the crop flowering stage. Then after, the irrigation interval was reduced to five days for the purpose of satisfying the increased moisture demand of mung bean. During the irrigation a care was given to avoid water logging. All other recommended practices including weeding and pest control were done as required. Harvesting was done after the bottom of the mung bean pods started to dry and the green pod color changed in to black color [15].

2.5. Data Collection and Analysis

2.5.1. Soil Sampling and Analysis

Before sowing of the seed, soil sample were taken from ten spots at a depth of 0 – 30 cm and one composite sample formed. From composite sample, soil physical and chemical properties were determined at Werer Agricultural Research Centre and available P, sulfure (S) and N were analysed at Holeta Agricultural Research Centre. Organic carbon (OC) was determined following the modified method of Walkley and Black [60]. Total N in the soil was determined by the Kjeldahal method. Available soil P was determined using the Olsen extraction method as described by Olsen *et al.* [40]. The Bouyoucas hydrometer method was used to determine soil texture. Soil pH was determined by taking 1: 2.5 (soils: water) ratio with the help of digital pH meter. Electro-conductivity was determined by using digital EC meter. Soil cation exchange capacity (CEC) was determined by Landon [28].

2.5.2. Phenological Parameters

Date to 50% emergence: it was recorded when 50% seedlings in each plot are emerged, and number of days to seedling emergence was calculated from the date of sowing to the date of seedling emergence.

Date to 50% flowering: it was recorded when 50% of plants in each plot produced the first flower, and its number was counted from date of seedling emergence to the date of flowering.

Date to 90% physiological maturity: it was recorded when90% of the plants in each plot were physiologically matured indicated by senescence of leaves and drying of pods, and days to maturity was counted from the date of emergence to the date of maturity.

2.5.3. Growth Parameters

Plant height (cm): it was measured at physiological maturity from the base to the tip of five plants in harvestable rows using meter tape and averaged on a plant basis.

Number of primary branches plant^{-1}: it was determined by counting the total number of branches on five randomly tagged plants in the net plot at physiological maturity and averaged on plant-^{1} basis.

Number of secondary branches plant^{-1}: The numbers of branches arising from the primary branches was counted at the time of maturity for five randomly taken plants and the average was recorded on plant^{-1} basis.

Number of total and effective nodules plant^{-1}: Five plants were randomly selected from destructive rows of both sides at mid flowering stage. Roots were uprooted carefully with the bulk of root mass and nodules. The nodules were separated from the soil by washing on metal sieve and the total numbers of nodules were determined by counting and then the averages of the five plants were taken as a number of nodule plant^{-1}. For determination of effective number of nodules, the inside color of nodules was observed by cutting each with the help of sharp blade and the pink colored nodules were considered as an effective nodule, while green colored nodules were considered as non-effective. Then the counted effective nodules were taken as effective nodules plant^{-1}.

2.5.4. Yield and Yield Components

Number of pods plant^{-1}: Pods from five randomly selected and taken plants were counted in each net plot area at harvest and the average was taken as a number of pods plant-^{1}.

Number of seeds pod^{-1}: the total number of pods and seeds of the five plants was counted and divided by a total number of pods to find the number of seeds pod-^{1}.

Hundred seed weight (g): it was determined by counting unbroken 100 seeds of each plot indiscriminate and weighted with sensitive balance and the weight was adjustedto10%moisturelevel based on the actual moisture content of the seed harvested from each plot.

Grain yield (kgha^{-1}): The sun-dried seeds harvested from three central rows were cleaned and weighed. Immediately after weighing the actual moisture content was measured and the plot yield was adjusted to the standard moisture content and converted to t ha^{-1} using the formula adjusted yield t ha^{-1} = plot yield(kg) x (100-actual moisture content) x 10000 m^{2}/ (100-10) x plot size x 1000kg.

2.6. Analysis of Variance

Analysis of variance (ANOVA) was done on collected data using the general linear model of $Y_{ijk} = \mu + V_i + P_j + (VP)_{ij} + B_k + E_{ijk}$, where Y_{ijk} the effect of genotype I at j phosphorous level and k block; μ is grand mean, Vi is effect of genotype I; Pj is effect phosphorus level j;(VP) ig the effect of the interaction of V and P; Bk is block effect and Eijk is error term. Per the procedure describe by using appropriate statistical software. Least significant difference (LSD) test at5%level of probability was used to determine significant differences between means using SAS version 9.3.

2.7. Partial Budget Analysis

The partial budget analysis was done as described by CIMMYT [13]. The cost of TSP and seed cost involved for the planting of mung bean are recorded and used for this analysis. The net returns (benefits) and other economic analysis was done based on the formula developed by CIMMYT [13] and given as follows:

Unadjusted grain yield (UGY) (kg ha^{-1}): is an average yield of each treatment.

Adjusted grain yield (AGY) (kg ha^{-1}): is the average yield was adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers.

Gross field benefit (GFB) (ETB ha^{-1}): it was computed by multiplying field/farm gate price that farmers receive for the crop when they sell it as adjusted yield. GFB = AGY × field/farm gate price for the crop.

Total variable cost (TVC) (ETB ha^{-1}): it was calculated by summing up the costs that vary, including the cost of TSP fertilizer (14.00 ETB kg^{-1}) and the cost of planting materials mung bean varieties (Boreda, Rasa, Showa robit and NVL-1). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding and, harvesting and threshing was considered the same for all treatments or plots.

Net benefit (NB) (ETB ha^{-1}): was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment. NB = GFB – TVC

Dominance analysis: was carried out by first listing all the treatments in their order of increasing costs that vary (TVC) and their net benefits (NB) are then put aside. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D").

Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC) then multiplied by 100.

3. Results and Discussion

3.1. Physico-Chemical Properties of Experimental site

A composite soil (0 –30 cm depth) samples collected from an experimental site before planting was analyzed for some selected physico-chemical properties. The results of the soil analysis are presented in (Table 3). The soil reaction of the experimental site was alkaline with a pH value of (8.07). This pH value is ideal for the production for mung beans and other legumes [35]. The site of the experiment has clay soil textures. Mung bean grows on a wide range of soils but prefers well-drained clay loams or sandy loams. The electrical conductivity (EC in mS/cm) of a soil is 1.22dS/m, which was slightly saline according to Tekalign *et al.* [56]. The authors also classified soil total N availability of < 0.05% as very low, 0.05-0.12% as poor, 0.12 - 0.25% as moderate and > 0.25% as high. According to this classification, the total nitrogen of the study site (0.11%) was poor requiring application of nitrogenous fertilizer for pulse production as a starter. According to Olsen *et al*. [52] rating of available P in the soil test as >25, 18-25, 10-17, 5-9, <5 ppm was classified as very high, high, medium, low and very low, respectively. Thus, the soils of the study site fall under the medium category in its available P (12.4 ppm).

In general, soils high in CEC are considered as agriculturally fertile. According to Landon [28] top soils having CEC greater than 40 Cmol (+) kg^{-1} are rated as very high and 25-40 Cmol (+) kg^{-1} as high, 15-25 as medium, 5-15 low and < 5 Cmol (+) kg^{-1} of soil as very low in CEC. According to this classification, the soils of the site had high CEC of 36.5 Cmol (+) kg^{-1}, which indicates that the soil has the capacity to hold nutrient cations and supply to the crop. According to Tekalign [56] rating, organic matter content of soil is very low (< 0.86%), low (0.86 to 2.59), medium (2.59 to 5.17) and high (> 5.17), thus the organic matter content of the soil (1.7%) is in the low range. According to Horneck *et al*. [23] available sulfur (9.82 mg kg^{-1}) is in the medium range. Thus, considering the soil parameters at the experimental site of the soil is suitable for mung bean production.

Table 3. *Soil physical and chemical properties at Gewane in 2018/19.*

Soil properties	Results	Rating
Soil particle size Clay (%)	50	
Silt (%)	28	
Sand (%)	22	
Textural class	clay	
Soil pH (1:2.5 H_2O)	8.07	Alkaline
Electro-conductivity (mS/cm)	1.22	Medium
Organic matter (%)	1.7	Low
Total nitrogen (%)	0.11	Low
Available phosphorus (ppm)	12.4	Medium
SO_4-S (mg kg^{-1})	9.82	Medium
Cat-ion exchange capacity (CEC) ($Cmol^+kg^{-1}$)	36.5	high

3.2. Phenological Parameters

3.2.1. Days to 50% Emergence

The analysis of variance revealed that days to 50% emergence was significantly affected by applied P fertilizer rates. However, the response of test varieties and their interaction was not significant. The longest days to 50% emergence (4.4 days) was recorded from 10 kg P ha^{-1}, while the shortest days to 50% emergence (4.0 days) was recorded from 40 kg P ha^{-1}. The probable reason might be that applied P played an essential role in plant emergence. This is due to the reason of it plays a vital role in hasting of root formation and growth. In line with these result Daniel *et al*. [14] reported that the maximum days to 50% emergence on field pea emergence were (8.1, 8.0 and 7.6 days) at the P fertilizer rate of 10, 20 and 30 kg ha^{-1}, respectively. Similarly, Takele *et al*. [52] also found that the longest days to 50% seedling emergence on lentil was (5 days) at 0 kg P ha^{-1}, while the shortest days to 50% seedling emergence (4.42 days) was recorded at 13 kg P ha^{-1}.

Table 4. *Effects of varieties and phosphorus fertilizer rates on 50% seedling emergence of mung bean at Gewane in 2018/19.*

Treatment Varieties	50%Seedling Emergence	Treatment P(kg ha^{-1})	50% Seedling Emergence
Boreda	4.08^a	10	4.4^a
Rasa	4.16^a	20	4.0^b
Shewa robit	4.08^a	30	4.0^b
NVL – 1	4.0^a	40	4.0^b
LSD (0.05)	NS		0.18
CV (%)	5.34		

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

3.2.2. Days to 50% Flowering

The analysis of variance revealed that the effects of variety and P rates had highly significant ($P < 0.01$) effects on days to 50% flowering. Likewise, the interaction effect of variety and P rates also showed highly significant ($P < 0.01$) effects on days to 50% flowering. Variety Rasa with fertilizer rate of 10 kg Pha^{-1} took the longest days to reach 50% flowering (43.23 days), while the variety Boreda with fertilizer rate of 40 kg P ha^{-1} was flowered earliest (39.1 days) (Figure 2). The effects of other varieties and fertilizer rates were intermediate on number of days to reach 50% flowering. This might be due to the genetic differences of test varieties or the effect of applied P. Generally, the flowering days showed decreasing trend as P rates increase up to 40 kg P ha^{-1}. On the other hands, mung bean varieties had their own distinct characters with respect to flowering days [61, 55]. Furthermore, application of P to soils low in available P promotes root growth and often hastens maturity which eventually shortens the time of flowering. In line with this result Imran *et al*. [24] reported that higher P rates had a significant effect on days to first flowering and early flowering in all mung bean varieties. Similarly, Acharya *et al*. [1] reported that application of optimum P is important for flowering and seed formation and fastening crop maturity.

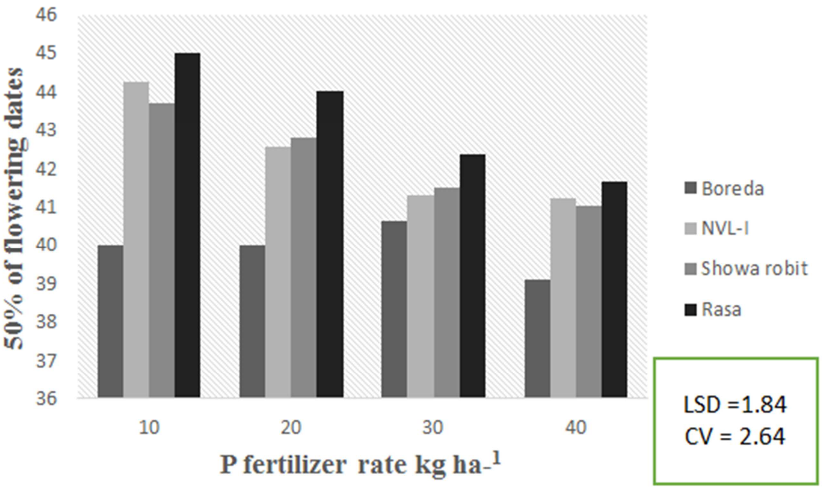

Figure 2. *Interaction effects of varieties and phosphorus fertilizer rates on days to 50% flowering of mung bean at Gewane in 2018/19.*

3.2.3. Days to 90% Physiological Maturity

The effects of varieties and P rates as well as their interaction on days to 90% physiological maturity were highly significant ($p < 0.01$). Variety Rasa with 10 kg P ha^{-1} took maximum days (74.15 days) to reach 90% physiological maturity, while variety Boreda with 40 kg P ha^{-1} was earliest to reach 90% physiological maturity (63.94 days) (Figure 3). The observed difference in days to physiological maturity among the four mung bean varieties might be attributed to inherent genotypic difference, since each varieties have different growing habit, flowering and maturity date. Hence, variability among the varieties revealed that the possibility of selecting genotypes that mature earlier and adapt well in moisture deficit environments. The result of this study is in line with the previous reports of MoARD [33, 34], which showed that variety Boreda is significantly earlier than variety Rasa and others. Similarly, Wedajo [61] reported that variety Boreda was earliest in days to maturity (58.8 days) than other mung bean varieties Rasa (59.2 days) and Showa robit (60.2 days).

On the other hands, the result clearly indicated that days to maturity were early due to the effect of the increased levels of P fertilizer rate. This might be due to the role of P in promoting early maturing and seed formation of the crop [11]. Havlin *et al*. [22] also showed that enough P nutrition could reduce the time required for grain ripening. Moreover, Marschner [30] reported that P could reduce the days to physiological maturity by controlling some key enzyme reactions that involve in hastening crop maturity.

Figure 3. *Interaction effect of varieties and phosphorus fertilizer rates on 90% physiological maturity of mung bean at Gewane in 2018/19.*

3.3. Growth Parameters

3.3.1. Number of Total and Effective Nodules

The effect of P rates was highly significant ($p < 0.01$) on a total of nodules plant^{-1}, while the effects of varieties and the interaction were non-significant. Significantly the highest number of total nodules plant^{-1} were recorded from the application of 40 kg P ha^{-1} (8.0), while the lowest number of total nodules were recorded from 10 kg P ha^{-1} (3.4) (Table 5). The increase in total number of nodules might be due to application of P fertilizer, which needed to promote the development of extensive root systems and good nodule development which resulted in increment of yield of pulses including mung bean. In line with the present study, Murat *et al.* [37] found that P application (85 kg ha^{-1}) to filed pea had significant effect on number of nodules. Similarly, Tang *et al.* [53] indicated that nodule number and nitrogenous activities were increased with higher P rates of 30 kgha^{-1}. Number of effective nodules plant^{-1}was not significantly ($P > 0.05$) affected by P fertilizer rates. Lack of significant effects of varieties and P fertilizer might be attributed due to the presence of salinity and high soil temperature at an experimental site that affected the function of *Rhizobium* bacteria. In harmony with this study, Mudgal *et al.* [36] found that soil salinity inhibit initiation, decrease number and weight of nodules as well as N-fixing effectiveness of nodules and effective nodules in some selected legumes, causing significant reduction in leghemoglobin content, which decreased with aging of nodules by irreversible oxidation.

Table 5. *Effects of varieties and phosphorus fertilizer rates on number of total and effective nodules plant-^{1} of mung bean at Gewane in 2018/19.*

Treatment P rate (kg ha^{-1})	No of total nodules	No of effective nodules	50% of emergence
10	3.4^{d}	3.44^{a}	4.4^{a}
20	4.2^{c}	3.72^{a}	4.0^{b}
30	7.1^{b}	3.8^{a}	4.0^{b}
40	8.0^{a}	3.9^{a}	4.0^{b}
LSD (0.05)	0.65	NS	0.18
Varieties			
Boreda	5.75^{a}	3.67^{a}	4.08^{a}
Rasa	5.45^{a}	3.8^{a}	4.16^{a}
Shewa robit	5.84^{a}	3.85^{a}	4.08^{a}
NVL-1	5.81^{a}	3.57^{a}	4.0^{a}
LSD (0.05)	NS	NS	NS
CV (%)	13.6	11.76	5.34

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

3.3.2. Plant Height

The analysis of variance revealed that plant height was significantly affected by P rates. However, the effect of variety and their interactions were not significant on the plant height of mung bean. The tallest plant height (45.03 cm) was recorded from 40 kg Pha^{-1} fertilizer rate which was statistically at par with 30 kg Pha^{-1} fertilizer rate (44.97 cm), while the shortest plant height (40.24 cm) was found from the 10 kg Pha^{-1} fertilizer rate (Table 6). The increase of plant height with the increment of P rates might be due to the fact that P fertilizer is involved in vital plant functions and contribute to enhanced growth in the height of the crop. Moreover, the increase in plant height with the increased P rates might be attributed due to its pivotal role in early root proliferation that might increase the nutrient uptake of the plant and which it turns resulted in increased vegetative growth. Increased in plant height with the increase in rate of P might be due to phosphorus fertilizer contribution to availability of soil nutrients which increases their uptake by plants. This result is in line with the finding of Kahn *et al.* [25] who reported that increasing in P rates from 0 – 30 kg P ha^{-1} increased plant height of mung bean. Similarly, Farhan *et al.* [20] reported that an increase in plant height of mung bean in response to P application (8.75 kg P ha^{-1}) recorded taller plant height (50.00 cm) followed by 47.83 cm with (4.37 kg P ha^{-1}) and (0 kg P ha^{-1}) recorded the shortest (43.11 cm). Kubure *et al.* [26] also found that P application that facilitated better absorption of soil moisture and nutrients resulting in taller plant height of faba bean in comparison with no P application. Increased plant height might have been due to the adequate availability of plant nutrient through optimum P supply required for its growth and development. Optimum P supply also had indirectly roles for providing N to the plants and its availability help the plants to attain more vigor in terms of plant height.

Table 6. *Effects of varieties and phosphorus fertilizer rates on plant height, primary and secondary branches per plant of mung bean at Gewane 2018/19.*

Treatment P rate (kg ha^{-1})	Plant height (cm)	Primary branches	Secondary branches
10	40.33^{c}	4.5^{b}	5.5^{b}
20	42.02^{b}	4.6^{b}	5.6^{b}
30	44.97^{a}	5.64^{a}	6.5^{a}
40	45.03^{a}	5.57^{a}	6.4^{a}
LSD (0.05)	1.42	0.33	0.35
Varieties			
Boreda	43.60^{a}	5.17^{a}	6.2^{a}
Rasa	42.0^{a}	5.07^{a}	5.9^{a}
Shewa robit	43.24^{a}	5.09^{a}	5.9^{a}
NVL-1	43.5^{a}	5.05^{a}	6.0^{a}
LSD (0.05)	NS	NS	NS
CV (%)	3.96	7.96	7.01

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the columns followed by the same letters are not significantly different at 5% level of significance.

3.3.3. Number of Primary and Secondary Branches

The result of analysis of variance revealed that highly significant ($P < 0.01$) effect of P rates on number of primary and secondary branches plant^{-1}, but the effect of variety and their interactions were not significant on the same parameters (Table 6). Number of primary and secondary branches plant^{-1} is essential parameters of plants and play an important role to achieve higher grain yield. The highest number of primary and secondary branches plant^{-1} were recorded from 40 kg P ha^{-1} and it was statistically at par with 30 kg P ha^{-1}, whereas the lowest number of primary and secondary branches plant^{-1} were recorded from 10 kg Pha^{-1} (Table 6). The increasing of number of primary and secondary branches plant^{-1} with the increment of P rates might be attributed due to the availability of P which in turn involved in vital plant functions and contributed to enhanced growth in the height of the crop along with increase of branch numbers.

Moreover, P plays a pivotal role in early root proliferation that might increase the nutrient up take of the plant which in turn resulted in increased vegetative growth. The result of this finding agrees with the previous work by Akter *et al.* [3] who reported that significantly higher number of secondary branches with 22 kg Pha^{-1} over the control on soybean. Similarly, Shubhashree [45] reported significantly higher number of secondary branches plant-^{1} with 33 kg Pha^{-1} as compared to the control treatments on common bean. Moreover, Kahn *et al*. [25] also reported that the maximum number of primary branch plant^{-1} was recorded from treatment 20 kg P ha^{-1} followed by 13 kg P ha^{-1} and the minimum branches plant^{-1} was obtained from the control. Higher number of branches plant^{-1} might have been possible due to more vigor and strength attained by the plants as a result of better photosynthetic activities with sufficient availability of nutrients in balanced quantity to the plants during the growing stages.

3.4. Yield and Yield Components

3.4.1. Number of Pods Per Plant

The analysis of variance revealed that the main effects of variety and P rates had highly significant effect ($P < 0.01$) on number of pods plant^{-1}. Similarly, the interaction effect of variety and P rates revealed significant ($P < 0.05$) differences on number of pods plant^{-1}. Variety Boreda with 30 kg Pha^{-1} produced significantly highest number of pods plant^{-1} (28.5), which was statistically at par with the application of 40 kg P ha^{-1} with the same variety (28.33) (Figure 4). In contrast, variety NVL-1 with 10 kg P ha^{-1} rate gave the lowest number of pods plant-^{1} (16.6). The highest number of pods plant^{-1} for variety Boreda might be due to genotypic differences as individual varieties have different genetic makeup and nutrient absorption. Moreover, the supply of adequate nutrients might have facilitated the production of primary branches, secondary branches and plant height which might in turn have contributed for the production of higher number of pods plant^{-1}. The variety Boreda gave highest number of pods plant^{-1} over Rasa, Showa robit, and NVL-1 varieties regardless of all the P rates.

The highest number of pods at the higher rates of 30 kg P ha^{-1} might be attributed due to the fact that P enhance establishment of beans, promote the formation of nodes, canopy development and pod setting. Moreover, the increase in number of pods with these levels might be due to activation of various enzymatic activities which controlled flowering and pod formation due to supplied P. The present finding agrees with the results of [2, 61] and Rasul, *et al*. [43] stated that mung bean cultivars had significant effect on number of pods plant^{-1}. Shubhashree [45] also reported significant increase in number of pods plant^{-1} on common bean due to increased P fertilization up to 30 kg P ha^{-1}. Similarly, Veeresh [59] observed significantly a greater number of pods plant^{-1}(28.08) at application rate of 33 kg P ha^{-1} on mung bean. Kahn *et al.* [25] reported that the maximum number of pods plant^{-1} (27.12) was recorded from 20 kg P ha^{-1} application followed by (25.27) with 13 kg P ha^{-1} and the minimum pods plant-^{1} was (21.66) recorded in the control treatment.

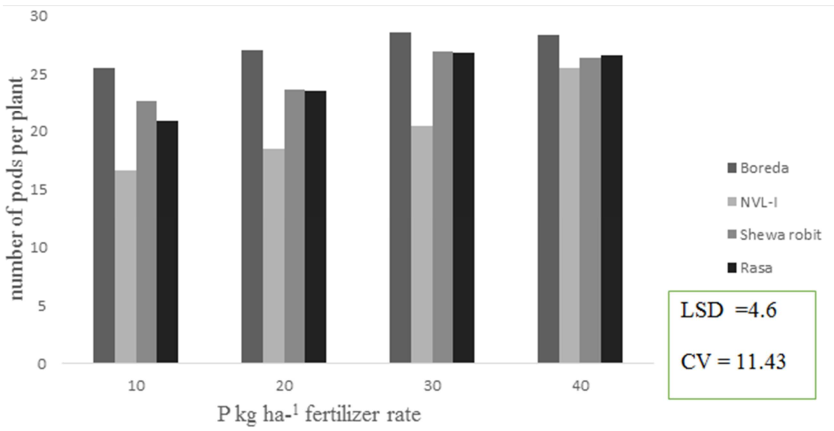

Figure 4. *Interaction effects of varieties and phosphorus fertilizer rates on numbers of pods per plant of mung bean at Gewane in 2018/19.*

3.4.2. Number of Seeds Per Pod

Both the effects of variety and P rates had highly significant ($p < 0.01$) effect on number of seeds pod^{-1}. Interaction between variety and P rates was also significant ($P < 0.05$). Variety Boreda with 40 kg P ha^{-1} produced significantly highest number of seeds pod^{-1} (11.87), which was statistically at par with the application of 30 kg P ha^{-1} with the same variety (Table 7). On the other hand, variety Showa robit with 10 kg P ha^{-1} gave the lowest number of seeds pod^{-1} (4.66). The observed differences in number of seeds pod^{-1} among the mung bean varieties might be attributed due to inherent genetic difference of the test varieties for seed production pod-^{1}. The variety Boreda gave highest number of seed pod^{-1} over Rasa, Shewa robit and

NVL-1 varieties. These results are in line with those of [2, 43] and Uddin, *et al*. [58] that different mung bean varieties have different genetic makeup as such they have different number of seeds. Similarly, Wedajo [61] reported that variety Boreda gave highest number of seeds pod-^{1} over Rasa varieties and Shewa robit.

The increment in number of seeds pod^{-1} with increasing rate of P fertilizer might be due to the fact that P is essential component in seed formation. Similarly, P plays key role in protein synthesis, phospholipids and phytin all of which are important in the growth of the plant [10]. The result of the present study agrees with the finding of Shubhashree [45] who reported that the number of seeds pod^{-1} of common bean was increased significantly with increased levels of P up to 40 kg P ha^{-1}.

Table 7. *Interaction effects of varieties and phosphorous rates on number of seeds pod-^{1} of mung bean at Gewane in 2018/19.*

Varieties	Prates (kg ha^{-1})			
	10	20	30	40
Boreda	6.55^{hg}	7.7^{fegd}	10.82^{ba}	11.87^{a}
NVL-I	5^{hi}	6.97^{fg}	9.07^{becd}	8.47^{fecd}
Shewa robit	4.66^{i}	7.6^{fegd}	9.21^{bcd}	9.94^{bc}
Rasa	7.3^{feg}	7.9^{fegd}	8.74^{fecd}	8.85^{ecd}
LSD (0.05)	1.85			
CV (%)	13.6			

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance.

3.4.3. Hundred Seed Weight

The analysis of variance indicated that both variety and P rates had highly significant (P <0.01) effect on hundred seed weight. However, their interaction effect was not significant on hundred seed weight. Among the tested varieties the heaver seed weight (5.12 g) was produced from the variety Boreda followed by variety Rasa (4.34 g). While, the lowest hundred seed weight was produced by NVL-1 (3.94g) variety (Table 9). The superior seed weight of Boreda and Rasa over other varieties might be attributed due to genetic makeup of these varieties which might lead to an increased photosynthesis and accumulations of carbohydrate in seed to produce heavy seeds and consequently increased seed weight pod^{-1}. These results were in line with Teame *et al* [55] and Wedajo [61] who reported that differences on seed weight among the test varieties of mung bean. Likewise, Ahmad, *et al*. [2] showed that differences among the 100 grains weight in these cultivars might be due to hereditary growth rate, crop potential of yield, higher nutrients translocation, assimilation and dry matter partitioning.

On the other hand, the highest hundred seeds weight (4.77 g) was produced when P was applied at the rate of 40 kg ha^{-1}, which was statistically at par with the application of 30 kg ha^{-1} (4.73 g), while the minimum hundred seeds weight (3.95 g) was recorded from 10 kg Pha^{-1} (Table 10). As the level of P increased the hundred seed weight was increased proportionally. This might be because of nutrient use efficiency by crop enhanced at optimum level of P since grain weight indicates the amount of resource utilized during critical growth periods. The heaver seed weight due to adequate P fertilization could be due to increased translocation and partitioning of assimilates from source to grain [57]. These results are in line with the result of Tariq et al. [54] who reported that P application significantly increased dry matter production and resulted in greater partitioning of dry matter to pods and leads to seed quantity. Similarly, Tairo and Ndakidemi [50] also reported that 100 seed weight was increased with P application rate on soya bean and common bean, respectively.

3.4.4. Grain Yield

The effects of variety and P rates had highly significant effect (P < 0.01) on grain yield. Likewise, the interaction effect of variety and P rates revealed significant (P < 0.05) differences on number of pods plant^{-1}. Variety Boreda with 30 kg P ha^{-1} produced significantly highest grain yield (1.54 t ha^{-1}), which was statistically at par with the application of 40 kg P ha^{-1} with variety Boreda (1.52 t ha^{-1}), while variety NVL-1 with 10 kg P ha^{-1} rate gave the lowest grain yield (0.72 t ha^{-1}) (Table 8). The variety Boreda gave highest grain yield over Rasa, Shewa robit and NVL-1 varieties regardless of applied P rates. The increase in grain yield with P application might be due to increase branching, fruiting, and number of pods plant^{-1}, number of seeds pod^{-1} and hundred seed weight. Such increase in yield could also be due to improved root development, translocation of photosynthesis towards the sink development [41]. Similar results were reported by Singh *et al*. [46] P application at the rate of 45 kg P_2O_5 ha^{-1} gave higher yield as compared to 30 kg P_2O_5 ha^{-1}, 15 kg P_2O_5 ha^{-1}and control plots in mung bean. Grain yield was also, highly dependent upon plant height, number of secondary branches and pods plant^{-1} both under drought and normal field conditions [42], and it might be that P play key role on these traits, in fact that, phosphorus is an essential nutrient for plant growth and development, which stimulates blooming and seed formation. This result is in line with the finding of Wedajo [61] reported that variety Boreda gave highest grain yield over varieties Rasa and Showa robit.

Table 8. *Interaction effects of varieties and phosphorous fertilizer rates on grain yield (t ha^{-1}) of mung bean at Gewane in 2018/19.*

Varieties	P (kg ha^{-1})			
	10	20	30	40
Boreda	1.26^{edc}	1.42^{bac}	1.54^{a}	1.52^{a}
Rasa	1.29^{bde}	1.30^{bde}	1.44^{ba}	1.42^{bac}
Shewa robit	1.14^{ed}	1.27^{bedc}	1.34^{bc}	1.32^{bc}
NVL-1	0.72^{f}	1.11^{e}	1.27^{bedc}	1.33^{bc}
LSD	0.176			
CV	8.16			

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.

3.4.5. Aboveground Biomass Yield

The result indicated significant (p <0.05) effect of P rates on the above ground dry biomass yield of the crop. However, the effects of varieties and their interaction did not show significant effect on the above ground biomass yield of mung bean. The highest dry biomass yield (5.08 t ha^{-1}) was produced at the rate of 40 kg P ha^{-1} which was statistically at par with the application of 30 kg of P ha^{-1} (5.05 t ha^{-1}), while the lowest dry biomass yield (4.6 t ha^{-1}) was obtained at 10 kg P ha^{-1}(Table 9). Such improvement might be due to enhanced shoots biomass and grain production in the mung bean crops due to supplied P fertilizer which in turn increased above ground total biomass yield. Furthermore, this increment in the above ground dry biomass yields due to added P might be attributed due to the fact that P plays essential roles in most metabolic processes to produce biomass. These processes include: energy generation, nucleic acid synthesis, photosynthesis, respiration, glycolysis, membrane synthesis and integrity, enzymatic activation or inactivation, redox reactions, signaling and carbohydrate metabolism leading to the enhancement of dry biomass yield. Therefore, higher biological yield was obtained due to vigor stands, good canopy development and dry matter production in response to P fertilization. Increase in dry matter production with increasing levels of Pup to 26-35 kg ha^{-1} has been also reported by Bhattacharya and Pal [9]. Similarly, Girma [21] found a significant increment in biological yield of common bean with increased rates of P fertilizers from 0 kg P to 30 kg P kg ha^{-1} (150 kg DAP).

Table 9. *Effects of varieties and phosphorus fertilizer rates on hundred seed weight, harvest index and above ground dry bio mass of mung bean at Gewane in 2018/19.*

Treatment P rate (kg ha^{-1})	Hundred seed weight(g)	Aboveground biomass (t ha^{-1})	Harvest index
10	3.95^{b}	4.6^{b}	24.13^{b}
20	4.03^{b}	4.8^{ba}	27.16^{a}
30	4.73^{a}	5.05^{a}	27.76^{a}
40	4.77^{a}	5.08^{a}	27.54^{a}
LSD (0.05)	0.3	0.30	2.65
Varieties			
Boreda	5.12^{a}	4.7^{a}	30.22^{a}
Rasa	4.34^{b}	4.9^{a}	27.87^{ba}
Shewa robit	4.07^{cb}	4.9^{a}	26.12^{b}
NVL-1	3.94^{c}	4.9^{a}	22.73^{c}
LSD (0.05)	0.3	NS	2.65
CV (%)	8.28	7.52	11.72

LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.

3.4.6. Harvest Index

The effects of varieties highly significant ($p < 0.01$) and phosphorus fertilizer rates on harvest index was significant ($p < 0.05$) but the interaction did not show significant effect on the harvest index of mung bean. There was an increase in harvest index with an increase phosphorus fertilizer rate from 10 to 30 kg P ha^{-1} where the highest harvest index (30.22%) was recorded from variety Boreda, while the lowest harvest index (22.7%) was recorded for variety NVL-1 (Table 9). The highest harvest index (27.76%) was obtained from 30 kg P ha^{-1}, which was statistically at par with 40 kg P ha^{-1} (27.54%), while the lowest harvest index (24.17%) was recorded from plots with 10 kg P ha^{-1} (Table 9). The reason for low harvest index is due to the enhancement of the biomass yield more than seed yield. Increase in harvest index with phosphorus application is the indication of better translocation of assimilates from source to sink. The present study is in line with the findings of Singh *et al*. [46] who indicated that harvest index of mung bean increases in response to P application. Similarly, Chiezey *et al.* [12] reported that lowest value of harvest index (27%) was recorded at low level of phosphorus application (85 kg ha^{-1}) resulted in poor development of plants to different growth stages of mung bean.

3.5. Partial Budget Analysis

Partial budget analysis is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. From the result of this study, the mean yield of 16 treatments tested was obtained. According to CIMMYT [13], the average yield was adjusted downward by 10%. This is the reason that to compensate for better management in the experiment because of small plots compared to farmer's field. According to the economic analysis data (table 10) all marginal rates were above 100% that is in a range of acceptance [13]. Net benefit was calculated by subtracting from the total benefits with total variable costs such as current fertilizer (TSP) cost of 14.00 ETB kg ha^{-1}, cost of a kilo of mung bean seed during planting season Boreda, NVL-1, Rasa and Showa robit were (37, 34, 32 and 30 Birr) respectively and the other costs were kept constant for all treatments. Although variety Boreda with 10 kg P ha^{-1} ranked among the treatments with the highest marginal rate of return in percent, the fact that the net benefits lower than Boreda with 30 kg p ha^{-1} application. From the partial budget summary of economic analysis, the highest net return ((31,493.75 Birr ha^{-1}) with acceptable MRR of (262%) was obtained from variety Boreda with 30 kg P ha^{-1} application. This implies that the grower on the study area can get additional benefits 2.62 ETB for every 1 ETB expense by this treatment. Whereas the lowest net economic return was recorded in the variety NVL-1 with 10 kg P ha^{-1} (13,520.23 Birr ha^{-1}) (table 10). Therefore, use of variety Boreda with 30 kg P ha^{-1} application found to be economically feasible at Gewane soil Afar regional state of Ethiopia andother areas with similar agro-ecological conditions.

Table 10. *Summary of partial budget analysis of the response of mung bean varieties to the applied phosphorous fertilizer rates at Gewane in 2018/19.*

Treatment	AGY	T R	TVC	N. B	MRR%
NVL-1*10	651.01	14973.23	1450	13523.23	
Shewa*10	1032.37	23744.51	1660	22084.51	4076%
Rasa*10	1163.45	26759.35	1788	24971.35	2255%

Treatment	AGY	T R	TVC	N. B	MRR%
Boreda*10	1141.34	28533.5	1810	26723.5	7964%
NVL-I*20	1000.03	23000.69	2150	20850.69	D
Shewa*20	1145.1	26337.3	2360	23977.3	D
Rasa*20	1171.17	26936.91	2488	24448.91	D
Boreda*20	1286.57	32164.25	2510	29654.25	418%
NVL-I*30	1147.85	26400.55	2850	23550.55	D
Shewa*30	1206.33	27745.59	3060	24685.59	D
Rasa*30	1302.91	29966.93	3188	26778.93	D
Boreda*30	1388.15	34703.75	3210	31493.75	262%
NVL-I*40	1200.21	27604.83	3550	24054.83	D
Shewa*40	1194.11	27464.53	3760	23704.53	D
Rasa*40	1281.19	29467.37	3888	25579.37	D
Boreda*40	1374.88	34372.25	3910	30462	D

MRR (%) = Marginal Rate of Return; TSP fertilizer price =14.00 Birr kg^{-1};
Mung bean grain local selling price = 23 and 25 depends on varieties Birr kg^{-1};
TVC = Total variable cost; D= Dominated Treatment

4. Conclusion and Recommendation

Mung bean is an early maturing, self-pollinated diploid legume crop with high nutritive values and N2-fixing ability. It is an eco-friendly food grain leguminous crop of dry land agriculture with rich source of proteins, vitamins, and minerals. It is becoming an important pulse crop in dry land area of Ethiopia because it is mainly used as sources of food and cash for farmers and private investors. Although the crop has all these advantages, its yield in farmers' field is low compared to other pulse crops. Such low yields are partly attributed to the lack of well adapted and high yielding varieties, and low soil fertility and low P contents. Furthermore, appropriate management practices that combine high yielding varieties with optimum fertilizer rate were not identified for sustainable production of legumes in study area. Thus, filed experiment was conducted during 2018/19 cropping season at Gewane Afar region of Ethiopia to identify well adapted and high yielding varieties, to determine optimum P fertilizer rate and to assess the cost-benefit of different P fertilizer ratesfor production of mung bean. Treatments studied consisted of factorial combinations of three improved mung bean varieties (Boreda, NVL-I, Rasa) and one local varieties (Showa robit) with four P rates (10, 20, 30 and 40 kg P ha^{-1}) laid out in Randomized Complete Block Design (RCBD) with three replications.

The experiment results showed that the effect's P rates significantly influenced days to 50% of emergence, plant height, primary and secondary branches, total number of nodules, hundred seed weight and aboveground dry biomass. The longest days to 50 % of emergence (4.4 days) was recorded from 10 kg P ha^{-1}, whereas the highest plant height (45.03 cm), total nodules (8.0), a hundred seed weight (4.77) and above ground biomass (5.08 t ha^{-1}) was recorded from 40 $kgha^{-1}$, whereas the highest primary branches (5.64) and secondary branches (6.5), was recorded from 30 kg P ha^{-1} which is statistically at par with 40 kg ha^{-1}. The interaction effect of a variety by P rates also significantly influenced days to 50% flowering, days to 90% physiological maturity, number of pod $plant^{-1}$, number of seed pod^{-1} and grain yield. The longest days to flowering (45 days) and the longest days to reach physiological maturity (74.15 days) was recorded from variety Rasa with 10 kg P ha^{-1} fertilizer rate. The highest number of pods per plant (28.5), the highest number of seeds per pod (10.8), the highest seed yield (1.54 t ha^{-1}) was recorded from the combination of variety Boreda with 30 kg P fertilizer ha^{-1}, which is statistically at par with Boreda variety with 40 kg P fertilizer rate ha^{-1}. The result clearly indicated that days to maturity were hastened by the increased levels of P fertilizer rate and varietal characteristics, which is genetically controlled and individual varieties have different flowering and maturity days. This might be attributed to the role that P plays in promoting flowering and maturation period. The partial budget analysis revealed that the highest net benefits (31,493 ETB ha^{-1}) with MRR of 262% was obtained from the combination of variety Boreda with 30 kg P ha^{-1} fertilizer rate. Whereas the lowest net economic return was obtained from the combination of variety NVL-1 with 10 kg P ha^{-1} (13, 520.23 Birr ETB ha^{-1}). The analysis of the marginal rate of return (MRR) at the study area Gewane revealed that the combinations of variety Boreda with 30, 20 and 10 kg P ha^{-1}, variety Rasa with 10 kg P ha^{-1} and variety Showa robit with 10 kg P ha^{-1} had given a marginal rate of return above the minimum acceptable rate (100%). In general, the combination of variety Boreda with 30kg P ha^{-1} had given higher grain yield than other treatment combinations.

Generally, the present study entails the presence of significant variations among mung bean varieties on grain yield. Among the varieties Boreda (1.54 t ha^{-1}) showed best performs followed by Rasa (1.44 t ha^{-1}), Showa robit (1.2 t ha^{-1}) and NVL-1 (0.72 t ha^{-1}). The study area was characterized by high temperature and erratic rainfall, thus well adaptated and high yielding is best criteria for selection and recommendation of varieties in such areas. Therefore, it could be concluded that varieties of Boreda with use of 30 kg P fertilizer ha^{-1} might be recommended for farmers and growers of mung bean in the study area and areas with similar agro-ecology. Since this study was undertaken in single location and season, it is important to repeat the study over different location and seasons to come up with a conclusive recommendation.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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