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Research Article

RESPONSE OF MUNG BEAN [*Vigna radiata* (L.) WILCZEK] VARIETIES TO BLENDED NPS FERTILIZER IN SOUTHERN ETHIOPIA

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ABSTRACT. Mung bean is an important cash crop and source of protein rich food for smallholder farmers in Ethiopia. However, it is a relatively new crop in the southern part of the country. Hence, a field experiment was conducted in Borda sub-site of Areka Agricultural Research center during the 2019 main cropping season to identify the most adaptable variety (V) and determine the optimum and economically feasible rate of NPS fertilizer (F). A field experiment was conducted using three mung bean varieties (Rasa, NVL-1 and Shewa robit) and four rates of blended NPS fertilizer (0, 50, 100 and 150 kg ha^{-1}) in a factorial arrangement (V x F) of randomized complete block design with three replications. Data on growth, grain yield, and yield attributing traits were recorded and subjected to analysis of variance (ANOVA). The results of the study indicated that the main and interaction effects of NPS fertilizer rate and variety significantly influenced the majority of growth parameters. Hence, the highest number of pods per plant (30.8), number of seeds per pod (13.03), and grain yield (1710 kg ha^{-1}) were recorded for NVL-1 variety grown on plots applied with 100 kg NPS ha^{-1}. Overall, better grain yield (1710 kg ha^{-1}) and the highest mean net benefit (birr 36,775 ha^{-1}) with an acceptable marginal rate of return (806.7%) was obtained for NVL-1 variety in a combination with 100 kg ha^{-1} NPS fertilizer application rate.

Keywords: *Blended Fertilizer, Growth, Yield components, Grain yield*

INTRODUCTION

Mung bean (Vigna radiata (L.) Wilczek) is one of the most important pulse crops, grown from the tropical to sub-tropical areas around the world [1]. It is also an important wide spreading and annual legume pulse crop cultivated mostly by traditional farmers [2]. Mung bean is a recent introduction in Ethiopian pulse production and grown in the north eastern part of Amhara region (North Shewa, Oromia special zone and Southern Wollo), SNNPR (Gofa area) and pocket areas in Oromia region Harerghe [3]. It is also an important pulse crop for smallholders that has recently gained attention and announced as sixth export commodity by Ethiopian Commodity Exchange [4]. Studies and reports showed that the yield of mung bean is very low in Ethiopia as compared to other countries of the world especially in relation to soil fertility apparently due to limited amendment through application of fertilizers [5]. The current national production area of mung bean in Ethiopia is estimated at 48,074.52 hectares with total production of 57,620.46 tons [6]. Similarly, the average productivity at national level is 1.2 ton ha^{-1} [6], but the average productivity reported at research center is 1.65 ton ha^{-1} [5]. The average productivity at farmer field compared to research center is low.

Particularly, the average yield of mung bean in Gofa Zone is far below (0.8 ton ha^{-1}) as compared to the national yield (1.2 ton ha^{-1}) and attainable yield which can reach to 1.5 tons ha^{-1} [7]. Studies and reports showed that the yield of mung bean is very low in Ethiopia as compared to other countries of the world due to less soil fertility, lack of improved varieties and inconsistency of the crop's performance [8]. Nitrogenous fertilizers are important for crops, because N is the main component of amino acid as well as protein. However, N deficiencies result in decreased crop leaf area, photosynthetic assimilation and seed growth. Nitrogen application (23 kg N ha^{-1}) increased the seed yield, which was related to higher number of pods per plant, number of seeds per pod and 1000-seed weight [9]. Mozumder [10] showed that increase of N up to 40 kg N ha^{-1} increased grain yield (1743 kg ha^{-1}) of mung bean.

Phosphorus is one of the very important plant nutrients for nodule formation and nitrogen fixation in legume crops [11]. Also adequate P availability improves the nodule number and N content in the tissues of mung bean [12]. Phosphorus application along with other micronutrients can increase biological activities, which result in improvements to plant height, number of nodules $plant^{-1}$, number of pods $plant^{-1}$ and enhanced straw quality [13]. Besides, sulfur plays a remarkable role in protein metabolism, synthesis of proteins, vitamins and chlorophyll. Sulfur is also an important nutrient for plant growth and its uptake by plants accounts 9 to 15% of N uptake [14].

Nutrient management is one of the important factors that greatly influence the growth and yield of mung bean [15]. Further, a proper management practice that combines high yielding varieties with balanced fertilizers can increase the seed yield to great extent. Since the crop was introduced recently in the study area, only scanty information is available on the cultural practices of production. Hence, popularization of the appropriate management practice that combines high yielding varieties with balanced fertilizers to boost production of the crop in the study area was conceived in order to improve the livelihood of the smallholder farmers. Research results revealed that mung bean yield and quality could be improved by the use of balanced fertilizers [16]. Therefore, this research was initiated to identify adaptable mung bean varieties for an economically feasible NPS fertilizer rate.

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was conducted at Boreda sub-site of Areka Agricultural Research Center (AARC), Gofa Zone, in Southern region, during 2019 cropping season. The experimental site is located at 6°19'59''N latitude and 36°56' 08'' E longitude and elevated at 1315 m above sea level. The site receives an average annual rainfall of 1384 mm in a bi-modal pattern. The average annual maximum and minimum temperature was 27^{O}C and 21^{O}C, respectively.

Experimental Design and Treatments

The treatments consisted of three mung bean varieties (Rasa, NVL-1, and Shewa robit) and four levels of NPS fertilizer (0, 50, 100 and 150 kg NPS ha^{-1}). The experiment was laid out as randomized complete block design in factorial arrangement with three replications. Blended NPS fertilizer contained (19% N, 38% P_2O_5, and 7% S). The plot size was 2.4m × 2 m = 4.8 m^2 which contained totally eight rows and net

plot size (the four central rows) was 1.2 × 2 m =2.4 m^2, which contained two border rows from each side were left as a border effect and one row next to the border rows on both sides were reserved for destructive sampling. The spacing between blocks and plots were 1 m and 0.8 m, respectively.

Experimental Procedure and Agronomic Management

Prior to sowing, the land was ploughed three times with oxen to a depth of 20-25cm and the plots were leveled and ridges were made manually for sowing. Treatments were assigned to each plot randomly. The outer most rows from each side and one plant from both ends of each row were considered as border plants. Two seeds per hill were sown at a depth of about 2.5cm and spacing of 30cm between rows and 10cm between plants to ensure adequate emergence. Fertilizer was hand drilled in rows at the time of sowing. Thinning of seedlings was done a week after emergence to allow one plant per hill. Weeds were controlled by hand as often as required.

Data Collection

Soil data

Before sowing of the seed, soil samples were taken by using a cylindrical auger from different spots at a depth of 0-30 cm by zigzag method and one composite sample was formed. From composite sample, soil physical and chemical properties were analyzed at Areka Agricultural Research Center soil laboratory. The soil was analyzed for soil texture, pH, organic carbon, electrical conductivity (EC), total nitrogen (TN), available phosphorus (AP), cation exchange capacity (CEC) and available sulfur (AS). Soil pH was measured potentiometrically in 1:2.5 soil-water suspensions with a standard glass electrode pH meter [17]. The Walkley and Black [18] method was used to determine the organic carbon content of the soil. Total N in the soil was determined by the Kjeldahl method [19]. Available soil P was determined by using the Olsen extraction method as described by [20]. Available S was analyzed by turbidimetric method [21]. The Bouyoucos hydrometer method was used to determine soil texture [22]. Electro-conductivity was determined by saturated soil paste methods. Soil Cation Exchange Capacity (CEC) was determined by ammonium acetate method [23].

Crop data

The growth parameter *total number of nodules* was determined by counting from five plants at 50% flowering from destructive rows in each plot. The nodules were separated from the soil by washing and the total numbers of nodules were determined by counting. *The number of effective nodules was determined by observing* the inside color of nodules by cutting. The pink colored nodules were considered as effective nodules and those nodules with white color were recorded as non-effective [24]. *Plant height (cm)* was measured as the height of five randomly selected plants per plot from the ground level to the apex of the plant at the time of physiological maturity from the net plot area. Number of primary branches per plant was determined by counting of primary branches on the main stem from randomly selected five plants at physiological maturity from the net plot area. *Leaf area (cm^2)* was measured using a leaf area meter from five randomly selected plants (from rows left for destructive sampling), when the plants attained maximum vegetative growth. Leaf area index (LAI) was calculated as the ratio of the total leaf area per plant to the respective ground area occupied by the plant 30cm x 10cm [25].

Yield and yield components

The *Number of pods per plant* was determined by counting the number of pods per plant from five randomly taken plants of each net plot area at harvest. *Number of seeds per pod* was calculated by counting the total number of seeds in the pods of five plants and divided by the total number of pods to obtain the number of seeds per pod. *Thousand seed weight (g)* was measured by counting thousand seeds with a seed counter and weighing it with a sensitive balance. *Above ground dry biomass yield (kg ha^{-1})* was recorded from the central rows at physiological maturity after sun drying. *Grain yield (kg ha^{-1})* was taken from whole plants harvested from the net plot area and weighing using a sensitive balance and adjusted to 10 % moisture level and converted to kg ha^{-1}. *Harvest index (HI %)* was obtained by calculating the ratio of grain yield (kg ha^{-1}) to total above ground dry biomass yield (kg ha^{-1}) and converting it to a percentage.

Agronomic efficiency (AE, kg kg^{-1}) was computed as follows (Eqn. 1):

$$\mathrm{AE} = \frac{G_f - G_u}{Q_A}$$

Eqn. 1

where Gf is the grain yield in the fertilized plot (kg), Gu is the grain yield in the unfertilized plot (kg) and QA is the quantity of nutrient applied (kg) [26].

Data analysis

All measured parameters were subjected to analysis of variance (ANOVA) using SAS statistical software package [27]. Whenever the effects of the factors were found to be significant, the means were compared using the Least Significant Differences (LSD) test at 5% level of significance.

Partial budget analysis

Partial budget analysis was done as described by CIMMYT [28]. All NPS rates and varieties were considered to compute the partial budget analysis in order to obtain the highest yielding variety with feasible application rate of NPS fertilizer to produce mung bean in the south Ethiopia region. Since both seed and stover are important for farmers, the partial budget analysis considered the mean seed and stover yields of the cropping season. Economic analysis was done using the prevailing market prices for inputs at planting and outputs at the time of crop harvest. The costs of NPS fertilizers were based on the market price of the agricultural input supply enterprise of Ethiopia. All costs and benefits were calculated on a hectare basis in Ethiopian Birr (ETB). Total variable costs (TVC) included the sum of the costs incurred for purchasing, transporting, and applying the blended NPS fertilizer. The costs were estimated from market and farm gate prices. Accordingly, Total Revenue (TR) (ETB ha^{-1}) was computed by multiplying field gate price (25 ETB kg^{-1}) that farmers receive for the crop when they sell it as adjusted yield. Total variable cost (TVC) (ETB ha^{-1}) was calculated by summing up the costs that vary, including the cost of NPS (15.00 ETB kg^{-1}) fertilizers at the time of planting (August 26, 2019) and according to Demba Gofa Woreda, farm daily payment of labor cost for application of NPS (four persons ha^{-1}, each 50 ETB day^{-1}). Actual seed and stover yields were adjusted downwards by 10% to reflect the difference between the experimental yield and the yield farmers would expect to get from the same treatment.

Then, the net benefit (NB) was calculated as the difference between the gross benefit (GB) and the TVC [28].

RESULTS AND DISCUSSION

Soil physico-chemical properties of the experimental site

The results of the soil's physical and chemical analysis are shown in Table 1. The soil textural class of the experimental area was sandy clay loam with the percentage of clay (32%), silt (6%) and sand (62%). Therefore, the soil textural class of the experimental area was suitable for mung bean production. The soil pH of the experimental site was 5.77 and rated as moderately acidic [29]. According to Nuru [30] mung bean grows on a wide range of soils, but prefers well-drained loams or sandy loams; with a pH range of 5-8 being optimum for mung bean production.

The electrical conductivity (EC) recorded in dS m^{-1} of a soil from the experimental site was 1.07 dS m^{-1}, which was low or non-saline [31]. The soil total N of the experimental area exhibited 0.08% (Table 1), that was rated as low [31]. Thus, external N inputs and gradual buildup of its organic matter levels is required to ensure sustainable productivity. Available P of soil sample of the experimental area was 35.5 ppm (Table 1), which falls within a high range of classification [31]. According to the classification of Landon [29], the soils of the experimental area had low CEC. This low CEC may be due to low organic matter in the experimental area implying poor quality for agricultural purposes, which indicates that the soil has low capacity to hold nutrient cations to supply the crop. Furthermore, soils low in CEC contents are considered as agriculturally infertile. The organic carbon (OC) content was 1.91%, which is rated as medium, according to the ratings of Hazelton and Murphy [32]. This medium range indicates the moderate potential of the soil to supply nutrients to plants through mineralization of organic carbon. The moderate amount of soil organic carbon might be due to low addition of crop residues and low organic matter in the soil. The available sulfur content in the soils was rated as low as per the classification of EthioSIS [21].

Table 1. Selected physical and chemical properties of the experimental site's soil before planting.

Soil Properties	Results	Rating	Reference
Soil texture			
Sand (%)	62		
Silt (%)	6		
Clay (%)	32		
Textural class	Sandy clay loam		
Soil pH	5.77	Moderately acidic	[29]
Organic carbon (%)	1.91	Medium	[32] (2007)
Total nitrogen (%)	0.08	Low	[31]
Available P (ppm)	35.5	High	[31]
Available S (ppm)	14.11	Low	[21]
Electro-conductivity (dS m^{-1})	1.07	Low	[31]
CEC (meq100g^{-1})	12	Low	[29]

Source: Areka Agricultural Research Center Soil Laboratory, South Ethiopia

Growth Parameters of Mung bean

Number of total nodules

The main effect of varieties and interaction of varieties with NPS rates had no significant effect on total number of nodules, while the main effect of NPS rates had highly significant ($P<0.001$) effect on total number of nodules (Supplementary Table 1). The result of the current study revealed that the highest total number of nodules (26.36) per plant was recorded from 100 kg NPS ha^{-1} fertilizer rate which was statistically at par with 150 kg NPS ha^{-1} fertilizer rate (23.78), while the lowest total number of nodules (6.4) was recorded from nil application of NPS fertilizer (Table 2).

Application of NPS resulted in a highly significant improvement of nodulation. It might be because of the role of S that plays essential role in nitrogenizing formation, which used in N fixation. In agreement with the findings of Nuru [30], increasing the NPS application rate from nil to 100 kg NPS ha^{-1} significantly increased total number of nodules per plant of mung bean. Rathod and Gawande [33] stated that mung bean number of nodules significantly increased due to NP fertilizers. In another study, Yadav [34] reported that P and S fertilizers showed significant effect on number and weight of nodules with the maximum number of nodules recorded at the highest level of P (40 kg P_2O_5 ha^{-1}) along with S (20 kg S ha^{-1}) on cluster bean. Moreover, P has constructive effects on nodulation, root development and growth, which plays a vital role in N_2 fixation, nutrient and water uptake [35]. In line with the findings of this study, Mulu [36] reported blended NPS rate had highly significant ($P<0.01$) effect on total and effective number of nodules per plant. This result agreed with the findings of Erman et al. [54] that stated P application (85 kg ha^{-1}) to field pea had significant effect on plant height, number of branches, roots and shoot dry weights, number of nodules. In another study, Ganeshamurthy and Sammi-Reddy [37] reported a significant increase in the mean total number of nodules of soybean with the application of S up to 20 kg ha^{-1}. In addition, Singh et al. [38] also reported that application of S showed significant influence on number of nodules per plant of mung bean.

Number of effective nodules

The main effect of varieties and the interaction of varieties with NPS rates had no significant effect on the effective number of nodules, whereas the main effect of NPS rates had a highly significant ($P<0.001$) effect on the effective number of nodules (Supplementary Table 1). The highest number of effective nodules per plant (21.91) was recorded from application of 100 kg NPS ha^{-1}, while the lowest number of effective nodules (3.82) was recorded from nil application of blended NPS fertilizer (Table 2). This result briefly indicated that the combined use of blended NPS fertilizer significantly increased the effective number of nodules in mung bean, suggesting the integrated effect of nutrients in NPS fertilizer, particularly N-initiated nodulation attributes, and P in NPS fertilizer improved root development and N fixation. The present study is in line with Nuru [30], who reported that increasing NPS application rate from nil to 100 kg NPS ha^{-1} significantly increased total number of nodules per plant of mung bean. Tang et al. [11] stated that nodulation, the effective number of nodules, and nitrogenous activities increased due to an increase in P rates up to 69 kg P_2O_5 ha^{-1}. Furthermore, the effect of S on nodule growth, nodule formation, and functioning was reported by Varin et al. [39]. The present result is in line with the

findings of Ganeshamurthy and Sammi-Reddy [37], who reported that significant increment in effective number of nodules of soybean with the application of S up to 20 kg ha^{-1}. Similarly, Scherer et al. [40] reported that the formation of nodules in black gram was increased in response to S application, which is involved in the formation of nitrogenous enzymes known to promote N fixation in legumes.

Table 2. *Main effect of NPS fertilizer rates and varieties on the number of total and effective nodules of mung bean at Demba Gofa during 2019* main cropping season

Treatment	Number of total nodules	Number of effective nodules
NPS rate (kg ha^{-1})		
0	6.4^{c}	3.82^{d}
50	15.44^{b}	12.04^{c}
100	26.36^{a}	21.91^{a}
150	23.78^{a}	18.87^{b}
LSD (0.05)	3.023	2.467
Varieties		
Rasa	17.28	13.87
NVL-1	19.58	15.03
Shewa robit	17.12	13.58
LSD (0.05)	NS	NS
CV (%)	17.2	17.8

Plant height (cm)

The analysis of variance revealed that main effect of NPS fertilizer rates and varieties had highly significant ($P< 0.001$) and significant ($P< 0.01$) effect on plant height, respectively. However, their interaction did not show significant difference on the plant height of mung bean (Supplementary Table 1). Regarding varieties, variety NVL-1 showed highest plant height over Rasa and Shewa robit (Table 3). This difference might be due to genetic differences in production of plant height among the varieties. This finding is in line with the result of Rasul et al. [41]. Similarly, Goswami et al. [42] stated that mung bean varieties had significant effect on plant height. Also, the existence of genotypic variation in plant height has been reported by Teame et al. [3] among mung bean varieties.

The tallest plant (64.91 cm) was recorded from 150 kg NPS ha^{-1} fertilizer rate, while the shortest plant (45.02 cm) was recorded from the control plant or nil fertilizer (Table 3). The significant increase in plant height in response to increased blended NPS application rate might be due to the maximum vegetative growth of the plants under higher N, P and S availability. This might be due to the role of N in chlorophyll formation, which in turn resulted in higher photosynthetic activity, vigorous vegetative growth and taller plants, P establishes strongly in shoot and root tips where high metabolism and rapid cell division occurs, and S promotes the formation of chlorophyll, higher photosynthetic activity and encouraged vigorous vegetative growth and taller plants [43]. This result is in agreement with the current finding that maximum vegetative growth of the plants was attained under higher N, P and S availability reported by Deresa [44]. Similarly, Nuru [30] reported that the highest plant height (65.24 cm) was produced at the rate of 150 kg NPS ha^{-1}, which was statistically at par with the application of 100 kg of NPS ha^{-1} as the highest plant height (64.24 cm) of mung bean. According to Rahman et al. [45], plant height of mung bean was

significantly influenced by application of NP fertilizers. In contrast to this current result, Fisseha and Rezene [46] reported no significant main and interaction effect of N and P levels on plant height of common bean. Alemayehu et al. [47] and Biruk et al. [48] indicated that plant height increased significantly with increasing levels of N fertilizer. Islam et al. [49] reported that plant height of mung bean was significantly influenced by S application. Also Jawahar et al. [50] reported that highest plant height, LAI, chlorophyll content and number of branches of black gram was obtained from S level of 40 kg ha^{-1}.

Number of primary branches

The analysis of variance revealed that main effect of NPS fertilizer rates and varieties had highly significant ($P< 0.001$) and significant ($P< 0.05$) effect on number of primary branches per plant, respectively. However, their interaction did not significantly influence the number of primary branches per plant of mung bean (Supplementary Table 2). Among varieties, variety NVL-1 showed highest number of branches over Rasa and Shewa robit (Table 3). This difference might be due to genetic variations in production of number of primary branches among the varieties. This result is in conformation with Goswami et al. [42], who stated that mung bean varieties had a significant effect on the number of branches per plant. The highest number of primary branches per plant (5.41) was recorded at the rate of 100 kg NPS ha^{-1}, while the lowest number of primary branches per plant (2.67) was recorded from the control (Table 3). The increase in number of branches per plant in response to the increased rate of blended NPS application indicates higher vegetative growth of the plants under higher N, P and S availability. Thus, it is in confirmation with Nuru [30], who reported that the number of primary and secondary branches per plant was significantly increased due to highest levels of blended NPS application on mung bean. Similarly, Rathod and Gawande [33] described that number of branches per plant significantly increased due to NP fertilizers on mung bean. Achakzai et al. [51] reported that application of 100 kg N ha^{-1} significantly increased number of branches per plant. Similarly, Asaduz [52] reported a significant effect on plant height of mung bean with N application up to 30 kg N ha^{-1}.

According to Tesfaye et al. [53], increased number of branches per plant with increased rate of P might be due to the importance of P in NPS fertilizer for cell division, leading to the increase in number of branches. This is in line with the results of Erman et al. [54], who showed that P application (85 kg ha^{-1}) to field pea had significant influence on number of branches per plant. Similarly, Umar et al. [55] observed that number of branches per plant was significantly increased by P application. Moreover, S in NPS plays a vital role in encouraging growth and physiological functioning of plants. Related to this study, Jawahar et al. [50] described that application of 40 kg S ha^{-1} recorded highest number of branches per plant in black gram.

Table 3. *Main effect of NPS fertilizer rates and varieties on plant height and primary branches of mung bean at Demba Gofa during 2019 main cropping season*

Treatments	Plant height (cm)	Primary branches
NPS rate (kg ha^{-1})		
0	45.02^{d}	2.67^{d}
50	54.44^{c}	4.09^{c}
100	59.2^{b}	5.41^{a}
150	64.91^{a}	4.87^{b}
LSD (0.05)	2.050	0.3574
Varieties		
Rasa	55.57^{b}	4.16^{b}
NVL-1	57.60^{a}	4.55^{a}
Shewa robit	54.50^{b}	4.07^{b}
LSD (0.05)	1.775	0.3095
CV (%)	3.8	8.6

Leaf area (cm²)

The analysis of variance revealed that main effect of NPS fertilizer rate and varieties had highly significant (P< 0.001) and significant (P< 0.01) effect on leaf area per plant, respectively. However, their interaction did not significantly influence the leaf area of mung bean (Supplementary Table 2). With respect to varieties, the highest leaf area (994 cm^2) was recorded for variety NVL-1, while the lowest leaf area (855 cm^2) was recorded for variety Shewa robit. The variation in leaf area of mung bean varieties could be partly due to the difference in genetic potential expressed in terms of variations in leaf width, leaf length, and leaf number and capacity to capture more solar radiation to produce more carbohydrates. This result is in conformation with Tollera et al. [56] that reported leaf area of maize was significantly influenced by use of varieties.

The highest leaf area (1116cm^2) was recorded at the rate of 100 kg NPS ha^{-1}, whereas the lowest leaf area (671cm^2) was recorded from no fertilizer treatment (Table 4). Thus, increased leaf area with increasing rates of NPS application might have been due to the positive effect on photosynthetic rate which contributes to leaf expansion, and to improve crop growth and canopy development by blended fertilizer. This result is in agreement with Orkaido [57] that reported leaf area was significantly affected by the application of N and P fertilizers. Also, Rathod and Gawande [33] stated that leaf area per plant of mung bean significantly affected by NP fertilizers. In another study, Amjed et al. [58] reported a significant effect on leaf area due to N and S application rates. The increase in N levels from control (N=0) to N 60 kg ha^{-1} resulted in significant increment in leaf surface area per plant. This result is in conformation with Mondal et al. [59] and Khalilzadeh et al. [60] that reported N application improves the mung bean leaf area. Additionally, Ayub et al. [61] reported that N fertilizer application significantly increased the forage yield of cluster bean.

According to Muller et al. [62], the increase in leaf area with increasing P fertilizer application rate occurs because P availability promotes leaf area expansion. This is because cell elongation and division of the crop are highly affected by the amount of ATP synthesized in the plant cell which is yet again highly dependent on the availability and assimilation of inorganic phosphorous. This result is in line with the finding of Veeresh [63] that reported a significant increment in leaf area of common bean with increased levels of P from 25 to 75 kg P_2O_5 ha^{-1}. In another study, Olivera et al. [64] reported that highest P application increased plant growth attributes and leaf area of bean. Similarly, P encourages formation of new cells, promotes plant vigor and hastens

leaf development, which helps in harvesting more solar energy and better utilization of N, which contributes towards higher growth attributes [65].

Leaf area index (LAI)

The analysis of variance revealed that main effect of NPS fertilizer rates and varieties had highly significant ($P< 0.001$) and significant ($P< 0.01$) effect on leaf area index per plant, respectively. However, their interaction did not significantly influence the leaf area of mung bean (Supplementary Table 2). Leaf area index (LAI) was significantly influenced by NPS rate and variety. It is an important growth parameter, which contributes for dry matter accumulation and the final seed yield. Among the three varieties, significantly higher LAI was recorded for NVL-1 than the other varieties. This difference in LAI among the mung bean varieties might be related to the genotypic variations of the varieties. In agreement with this result, Fanuel and Walelign [8] reported that mung bean varieties showed significant effect on LAI.

The highest LAI (3.72) was recorded at the rate of 100 kg NPS ha^{-1}, while the lowest LAI (2.24) was recorded from the control treatment (Table 4). The increase in LAI might be due to the improved leaf expansion in crop plants following increase in NPS rate, or the application of NPS contributed to improved leaf growth and development thereby resulting in increased leaf size to capture light for photosynthesis. The reason for the increased LAI could be attributed to development of more above ground biomass with the expanded leaves produced in response to N [66]. The increased application of P on LAI might be due to unique bonding properties of P that make it critical in nucleotide based metabolic processes and direct contribution of the nutrient in generation of high energy compound ATP, which is essential for establishing enzymatic machinery for energy storage and transfer, thereby playing a vital role in the leaves, synthesis of cellulose and hemicelluloses. Phosphorus also promotes rapid canopy development, contributing to root cell division and starch synthesis.

Sulfur increases uptake of N, since they are used for chlorophyll synthesis and activate enzymes. This result is in agreement with the result of Manzer et al. [67] that stated increasing level of nutrient combination up to $N_{90}P_{30}S_{51}$ kg ha^{-1} increased the leaf area index of rape seed and mustard cultivars. Similarly, Wondimu and Tana [68] reported an increase in common bean LAI as the NP rates increased from 0 kg N, 0 kg P_2O_5 to 36 kg N, 92 kg P_2O_5 ha^{-1}. According to Khalilzadeh et al. [60], LAI of mung bean increased significantly due to N application. Similarly, Kidist [69] reported an increased LAI as the N rate increased from 0 to 87 kg ha^{-1} due to the fact that N improves greenness of the vegetation and hence results in higher leaf area index by increasing N to the crop. The role of P in increasing photosynthesis and thereby increasing leaf area index of common bean varieties has been stated by Merkineh [70]. Similarly, Veeresh [63] reported a significant increment in common bean leaf area index with increased P application rate from 25 to 75 kg P_2O_5 ha^{-1}.

Table 4. *Main effects of NPS fertilizer rates and varieties on leaf area and leaf area index of mung bean at Demba Gofa during 2019 main cropping season*

Treatment	Leaf area (cm^2)	Leaf area index
NPS rate (kg ha^{-1})		
0	671^{d}	2.24^{d}
50	864^{c}	2.88^{c}
100	1116^{a}	3.72^{a}
150	1021.3^{b}	3.40^{b}
LSD (0.05)	92.8	0.309
Varieties		
Rasa	905^{b}	3.02^{b}
NVL-1	994^{a}	3.31^{a}
Shewa robit	855^{b}	2.85^{b}
LSD (0.05)	80.3	0.268
CV (%)	10.3	10.3

Yield and Yield Components

Number of pods per plant

The main effects of NPS fertilizer rates and varieties had a highly significant ($P< 0.001$) effect on number of pods per plant and their interaction effect was significant ($P< 0.01$) on number of pods per plant (Supplementary Table 2). Variety NVL-1 grown at 100 kg NPS ha^{-1} rate produced significantly highest number of pods per plant (30.8), whereas variety Rasa with 0 kg NPS ha^{-1} rate produced the lowest number of pods per plant (13.13) (Table 5). Variety NVL-1 produced highest number of pods per plant, which might be related to the genotypic variation of the varieties in producing pods. In agreement with this result, Samant [71] reported that mung bean varieties showed significant effect on number of pods per plant. Further, several authors observed significant variation in pods per plant among mung bean varieties [72].

The increase in number of pods per plant with the increased NPS rates might be due to adequate availability of N, P and S which might have facilitated the production of primary branches and plant height, which might in turn have contributed to the production of higher number of pods per plant. This highest number of pods recorded at the rate of 100 kg NPS ha^{-1} might be attributed to the fact that NPS improves establishment of beans, promote the formation of nodes, canopy development and pod setting. This is in agreement with the findings of Nuru [30], who reported that combined application of NPS fertilizer rate with mung bean varieties produced significantly highest number of pods per plant. Further, Deresa [44] reported that high levels of N, P, K and S fertilizer significantly increased the production of primary branches and plant height, which might in turn have contributed for enhanced pod number per plant.

Sadeghipour et al. [73] reported that combined application of N and P fertilizer increased number of pods per plant of mung bean. Similarly, Tesfaye et al. [53] showed that application of 92/69 N P_2O_5 kg ha^{-1} produced the highest pod yield of snap bean. Moreover, Das et al. [74] observed that in Chickpea increasing the application of P-S fertilizer had significant effect on total number of pods per plant. The increment in the number of pods per plant due to the increased application of P might be due to the function of P fertilizer obtained from NPS, which promotes the formation of nodes in legumes and various enzymatic activities, which contribute to flowering and pod formation. Veeresh [63] observed the significantly highest number of pods (28.08) per plant at an application rate of 75 kg P_2O_5 ha^{-1} of mung bean. Similarly, Dereje et al. [75] found that the number of pods per plant of common bean significantly increased in

response to increasing rate of P up-to the highest rate (92 kg P_2O_5 ha^{-1}). Moreover, Caliskan et al. [76] reported that the number of pods per plant of soybean increased with N doses up to 80 kg ha^{-1}.

Table 5. *Interaction effect of varieties and NPS fertilizer rates on number of pods per plant of mung bean at Demba Gofa during 2019 main cropping season*

Varieties	**NPS (kg ha^{-1})**			
	0	**50**	**100**	**150**
Rasa	13.13^{g}	19.6^{e}	27.83^{bc}	28.6^{abc}
NVL-1	16.2^{f}	26^{cd}	30.8^{a}	29.2^{ab}
Shewa robit	14.6^{fg}	23.93^{d}	26.53^{cd}	24.8^{d}
LSD (0.05)	2.642			
CV (%)	6.7			

Number of seeds per pod

The main effect of NPS fertilizer rates and varieties had a highly significant ($P< 0.001$) effect on the number of seeds per pod, and their interaction had a significant ($P< 0.05$) effect on the number of seeds per pod (Supplementary Table 2). Variety NVL-1 grown at 100 kg NPS ha^{-1} produced the highest number of seeds per pod (13.03), which was statistically at par with the application of 150 kg NPS ha^{-1} with the same variety NVL-1 (Table 6). On the other hand, variety Rasa with 0 kg NPS ha^{-1} gave the lowest number of seeds per pod (9.75). The variety NVL-1 gave highest number of seeds per pod. This might be due to varietal differences in their growth performance, which is also reflected in the yield-attributed traits. In agreement with the results of the current study, Ahmad et al. [77] reported differences in seeds per pod among the mung bean varieties.

The increment of seeds per pod with increasing NPS fertilizer application up to optimum level might have resulted from an adequate supply of nutrients such as N, P and S through NPS fertilizer, which are important for nodule formation, protein synthesis, leaf area development, dry matter accumulation and re-translocation of dry matter for economic parts of the crop. In this study the highest number of seed per pod might be due to the combination of photosynthesis function of N [73], seed formation ability of P [43] and metabolic energy ability of S [49]. Sadeghipour et al. [73] reported that application of N and P fertilizers increased number of seeds per pod of mung bean. Similarly, Habtamu et al. [78] reported highest number of seeds per pod with the application of 46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1} of N. Meseret and Amin [79] reported that the number of seeds per pod of common bean was increased significantly with increased levels of P (92 kg P_2O_5 ha^{-1}). Moreover, increased levels of S application enhanced its availability to the crop and increases the photosynthetic activity of the crop. Similarly, Jawahar et al. [50] reported that application of 40 kg S ha^{-1} recorded the highest number of seeds per pod of black gram.

Table 6. Interaction effects *of varieties and NPS fertilizer rates on number of seed per pod of mung bean at Demba Gofa during 2019 main cropping season*

Variety	NPS (kg ha^{-1})			
	0	**50**	**100**	**150**
Rasa	9.75^{g}	10.97^{cde}	11.92^{b}	11.83^{bc}
NVL-1	10.71^{def}	11.79^{bc}	13.03^{a}	12.81^{a}
Shewa robit	9.88^{fg}	11.44^{bcd}	12.29^{ab}	10.55^{efg}
LSD (0.05)	0.8754			
CV (%)	4.5			

Thousand Seed weight (g)

Main effect of NPS fertilizer rates had highly significant (P< 0.001) effect on thousand seed weight of mung bean, while the main effect of varieties and the interaction of both factors were not significant (Supplementary Table 3). The highest 1000-seeds weight (57.44 g) was recorded at 100 kg of NPS ha^{-1} application, whereas the lowest 1000-seeds weight (36.33 g) was recorded from plots which were not fertilized with NPS (Table 7). The result of the current study revealed that an increasing rate of blended NPS fertilizer application showed a significant effect on thousand seed weight. The findings generally mentioned that increase in seed weight with fertilizer application might be due to improved nutrient use efficiency by crop at optimum level of N, P and S [44]. Similarly, Nuru [30] reported that the interaction of NPS fertilizer with varieties had significant influence on 1000-seeds weight of mung bean. Sadeghipour et al. [73] showed the interaction of N and P fertilizers had significant influence on 1000-seeds weight (g) of mung bean. In another study, Hossain et al. [80] reported the combination of N, P and K had significant effect on 1000-seed weight of mung bean. Additionally, Khan et al. [1] observed that the maximum 1000 seed-weight was recorded from 45 kg P_2O_5 ha^{-1}. Similarly, Abdulkadir et al. [81] reported that P fertilized crop when compared with the control produced more pods per plant that were better filled with heavier seeds and this converted to higher grain yield.

A soil fertility study in mung bean conducted by Basu and Bandyopadhyay [82] showed that the number of pods per plant, seeds per pod and 100 seeds weight were increased with increasing N rates up to 30 kg N ha^{-1}. The better growth and development of crop plants due to S supply and N uptake might have increased the supply of assimilates to seed, which eventually gained more seed weight. It also indicated increased yield due to S application might be attributed to increased pods per plant and grains per pod along with heavier grains. This result was in line with that of Tesfaye [83] who reported that 1000 seed weight of mung bean increased significantly with application of N at 50kg ha^{-1}. Similarly, Ogutu et al. [84] also reported that increasing N rate from 0 kg ha^{-1} to 50 kg ha^{-1} increased 1000 seed weight from 301.19 g to 311.63 g. In the same manner, Nebret [85] reported that increasing S rate from 0 kg ha^{-1} to 20 kg ha^{-1} increased 100 seed weight from 35.7g to 36.8 g.

Above-ground dry biomass yield (kg ha^{-1})

The aboveground dry biomass yield was highly significantly (P<0.001) affected by main effect of NPS fertilizer rates and varieties. However, the interactions of NPS fertilizer rates with varieties had no significant effect on aboveground dry biomass yield (Supplementary Table 3). Regarding varieties, variety NVL-1 recorded the highest aboveground dry biomass yield (5268 kg ha^{-1}), whereas the lowest aboveground dry biomass yield was recorded for variety Shewa robit (4727 kg ha-1). This difference might indicate presence of genetic differences in production of aboveground dry

biomass yield among the varieties. This result was in line with Melese et al. [86] that reported mung bean varieties showed significant effect on aboveground dry biomass yield.

The blended NPS rate had highly significant ($P<0.001$) effect on aboveground dry biomass yield per plant. The current study showed an increase in aboveground dry biomass yield when NPS application increased from the lowest to the highest rate. Thus, the highest dry biomass yield (5353 kg ha^{-1}) was produced at the rate of 150 kg NPS ha^{-1} which was statistically at par with the application of 100 kg of NPS ha^{-1} (5316 kg ha^{-1}), whereas the lowest dry biomass yield (4233 kg ha^{-1}) was exhibited by the control plot (Table 7). This increment in dry matter production with application of NPS fertilizer might be due to the adequate supply of N, P and S that in turn could have increased the number of branches per plant, and leaf area. Increasing the number of branches per plant, and leaf area further leads to increased photosynthetic area and number of pods per plant thereby resulting in increased dry matter accumulation. This result was in agreement with Nuru [30] that reported the highest aboveground dry biomass yield (5769.30 kg ha^{-1}) produced from the application of 150 kg NPS ha^{-1}, which was statistically at par with application of 100 kg of NPS ha^{-1} (5730.9 kg ha^{-1}). Similarly, Dame and Tasisa [87] reported that the highest aboveground dry biomass yield (8718 kg ha^{-1}) was recorded from the application of highest rate of NPS fertilizer 200 kg NPS ha^{-1}. The lowest (6910 kg ha^{-1}) biomass yield was obtained from control plot.

The result generally showed an increase in biomass production with increase in the rate of blended NPS fertilizer. The increase in biomass might be due to the role of P in most metabolic processes that happens above the ground. This result was in line with Amanullah et al. [88] that reported P levels had significant influence on biomass yield of mung bean. Similarly, Getachew and Angaw [89] reported that biomass yield increased significantly due to increased P application in faba bean. This could be due to the fact that improved availability of N significantly increased plant height, number of primary branches per plant and overall vegetative growth of the plants that contributed to higher aboveground dry biomass yield. This result is in line with Veeresh [63], who reported that total dry matter production increased significantly due to increased N application from 40 to 120 kg N ha^{-1} on French bean. Similarly, N increases shoot dry matter, which is positively related with grain yield in legumes. Mian and Hossain [90] reported that N application rate of 40 kg ha^{-1} significantly increased the biological yield in mung bean. Fazli et al. [91] showed that lack of S limits efficiency of added N; therefore, S addition becomes necessary to attain maximum efficiency of applied nitrogenous fertilizer.

Table 7. *Main effects of NPS fertilizer rates and varieties on dry biomass yield and thousand seed weight of mung bean at Demba Gofa during 2019 main cropping season*

Treatment	AGBY (kg ha^{-1})	TSW(g)
NPS rate (kg ha^{-1})		
0	4233^{c}	36.33^{d}
50	4910^{b}	42.56^{c}
100	5316^{a}	57.44^{a}
150	5353^{a}	50.33^{b}
LSD (0.05)	239	4.042
Varieties		
Rasa	4863^{b}	44.83
NVL-1	5268^{a}	48.50
Shewa robit	4727^{b}	46.67
LSD (0.05)	207	NS
CV (%)	4.9	8.9

Grain yield (kg ha^{-1})

The analysis of variance revealed that grain yield was highly significantly (P< 0.001) affected by the main effect of NPS fertilizer rates and varieties, and their interactions also had a highly significant (P< 0.001) effect on grain yield (Supplementary Table 3). The highest (1710 kg ha^{-1}) grain yield of mung bean was recorded from interactions of variety NVL-1 along with 100 kg NPS ha^{-1}, while the lowest (980 kg ha^{-1}) grain yield was obtained from variety Rasa at nil NPS application (Table 8). The variety NVL-1 produced the highest grain yield over Rasa and Shewa robit varieties at all rates of NPS suggesting genetic differences in response to applied NPS fertilizer application and environmental conditions. This result is in line with Nuru [30], who reported that the maximum grain yield (1820.67 kg ha^{-1}) was produced from combined application of 100 kg NPS ha^{-1} which was statistically at par with the application of 150 kg of NPS ha^{-1} (1704.64 kg ha^{-1}). On the other hand, variety Rasa with 0 kg NPS ha^{-1} produced the lowest grain yield per plant (957.67 kg ha^{-1}) of mung bean.

The increase in grain yield with NPS fertilizer application might be related to higher number of pods per plant, number of seeds per pod and 1000-grains weight. The final grain yield of a crop is a function of the cumulative contribution of growth and yield components [108]. This result is in agreement with the findings of Chadha [92] who showed that N, P and S alone or in combination play a remarkable role in increasing grain yield and improving the quality of mung bean. Arega and Zenebe [93] reported that application of a high rate of NPKSB blended fertilizer increased common bean grain yields by 34% over the control plots. Nitrogen at initial growth stages motivated vegetative growth and formed conditions favorable to high yield, played a remarkable role in formation of chlorophyll and protein, directly increasing plant protein content, boosting yield [73]. This result is in conformation with Mozumder et al. [10], who showed that increase of nitrogen up to 40 kg N ha^{-1} increased grain yield of mung bean (1743 kg ha^{-1}). Similarly, Zabir and Abdullah [94] reported that application of 45 kg N ha^{-1} produced greater grain yield.

According to Bhatt et al. [95], the improvement in grain yield is attributed to increase in root nodulation due to P application. Since P is an essential nutrient for plant growth and development, that motivates blooming and seed formation, it could lead to

increased grain yield. The enhanced cellular respiration in the metabolism of the starch, protein and fats, which motivate blooming and seed formation, thereby increased grain yield [96]. This result is in agreement with the findings of Tariq et al. [97], that reported grain yield and its components of mung bean were increased significantly by application of P at 70 kg P_2O_5 ha^{-1} (1733 kg ha^{-1}). Similarly, Yadav et al. [98] reported that grain yield of mung bean was increased significantly by application of P up to 60 kg P_2O_5 ha^{-1} (1381 kg ha^{-1}). Ahmad et al. [77] reported that plots treated with 80 kg P ha^{-1} produced the highest grain yield (1139 kg ha^{-1}) being at par with 100 kg P ha^{-1}, while the lowest grain yield (617 kg ha^{-1}) was recorded in control plots. Similarly, Ali et al. [2] reported a highly significant effect of P application rate on seed yield of mung bean.

Table 8. *Interaction effects of varieties and NPS fertilizer rates on grain yield (kg ha^{-1}) of mung bean at Demba Gofa during 2019 main cropping season*

Varieties	NPS (kg ha^{-1})			
	0	**50**	**100**	**150**
Rasa	980^{g}	$1239.4d^{e}$	1442^{c}	1505^{c}
NVL-1	1160.3^{ef}	1408^{c}	1710^{a}	1611.2^{b}
Shewa robit	1093.4^{f}	$1205d^{e}$	1272.4^{d}	1445^{c}
LSD (0.05)	97.60			
CV (%)	4.3			

Harvest Index

The analysis of variance revealed that main effect of NPS fertilizer rates and varieties had highly significant ($P< 0.001$) and ($P< 0.05$) effect on harvest index respectively. However, the interaction did not show significant effect on harvest index of mung bean (Supplementary Table 3). Among varieties, variety NVL-1 produced the highest harvest index (28.03%), while the lowest harvest index (26.48%) was recorded from variety Rasa (Table 9). This might be due to genetic makeup of the varieties. Harvest index is useful in measuring nutrient partitioning in crop plants, which provides an indication of how efficiently the plant utilized attained nutrients for grain production. Higher harvest index indicates higher partitioning of dry matter into economic yield. This result was in line with that of Rasul et al. [41] that reported significant difference in harvest index among mung bean varieties that ranged from 26.14% to 11.44%. Similarly, Nuru [30] reported significant variation in harvest index among mung bean varieties.

With respect to the effect of NPS fertilizer rate, the highest harvest index (28.70%) was recorded from 150 kg NPS ha^{-1}, while the lowest harvest index (25.50%) was recorded from plots with nil NPS fertilizer (Table 9). This might be caused by the higher NPS fertilizers rate that had high influence on vegetative growth than nutrient translocation from plant biomass to seed yield or economic yield. This result was in line with that of Nuru [30] that reported highest harvest index (28.55%) was produced from 150 kg NPS ha^{-1}, while the lowest harvest index (24.38%) was recorded from plots with no NPS fertilizer. Further, Nuru [30] reported that the highest harvest index of lentil was obtained when 45 kg P ha^{-1} and 30 kg S ha^{-1} were applied. Additionally, Masresha and Kibebew [99] reported that the highest mean HI of soybean obtained from application of 46 kg P_2O_5 ha^{-1}, which resulted in 19.1% increase over the control. Basu

and Bandyopadhyay [82] showed that harvest index of black gram increased up to 25% with increasing N rates up to 30 kg N ha^{-1}.

Table 9. *Harvest index of mung bean as influenced by the main effect of NPS rates and varieties at Demba Gofa during 2019 main cropping season*

Treatment	HI%
NPS rate (kg ha^{-1})	
0	25.50[c]
50	26.20[c]
100	27.65[ab]
150	28.70[a]
LSD (0.05)	1.487
Varieties	
Rasa	26.48[b]
NVL-1	28.03[a]
Shewa robit	26.53[b]
LSD (0.05)	1.288
CV (%)	5.6

Agronomic efficiency

Agronomic efficiency is the amount of additional grain yield produced for each additional amount of fertilizer applied [100] The agronomic efficiency of three tested varieties decreased with increasing NPS application rate and then showed an increasing trend with decrease in NPS rate. The highest agronomic efficiency (5.5 kg/kg) was recorded from variety NVL-1 at NPS rate of 100kg ha^{-1} followed by variety Rasa and NVL-1 at NPS rate of 50kg ha^{-1} with mean agronomic efficiency of (5.2kg/kg) and (5.0kg/kg) respectively, while the lowest agronomic efficiency value was recorded from variety Shewa robit (1.8 kg/kg) at NPS rate of 100kg ha^{-1} (Table 10). This result is in conformation with Uddin et al. [101], who reported that the highest agronomic efficiency (13.32kg/kg) and (9.45kg/kg) was recorded from variety Nasir and Hawassa Dume at NPS rate of 100kg ha^{-1}, respectively. The lowest agronomic efficiency (2.02 kg/kg) was recorded from variety Hawassa Dume at NPS rate of 50 kg ha^{-1}.

Decreasing trend of agronomic efficiency could be related to the increasing of NPS supply to the maximum level or limitation of yield potential of bean cultivars. Moreover, increasing the nutrient levels may lead to decrease in AE after certain point. This implies that higher nutrient addition (beyond optimum level) results in luxury nutrient uptake that might not help to physiological processes. It may be due to the application of excess nutrients, which was not efficiently utilized by the crop and the rate of production was reduced per unit of nutrients application [102] The agronomic efficiency of applied P showed a decreasing trend in increasing rates of P application levels. Related to this study, Shehu et al. [103] described that agronomic efficiency (AE) on sesame increased when the P levels increased above a certain optimum. Similar findings on AE of P were reported by Mojid et al. [104]. In another study, Fisseha and Rezene [46] reported the agronomic use efficiency (AUE) of N and P fertilizer that showed an increasing trend for both fertilizers.

The AE of applied N showed a decreasing trend in response to increasing rates of N application level. Similar findings on AE showed that N decreased when N fertilization

increased [105]. Also, Nano [106] reported that a decreasing trend in AE with increasing N levels. Accordingly, the highest (40.72 kg kg^{-1}) AE was recorded at the lowest (23 kg N ha^{-1}) N level. The results indicated efficient use of N at lower rate of application (23 kg N ha^{-1}), which is in agreement with previous results described by other authors [106]

Table 10. *Agronomic efficiency (kg/kg) of the response of mung bean varieties to the application of NPS fertilizer rates at Demba Gofa during 2019 main cropping season*

NPS (kg ha^{-1})	Agronomic efficiency of NPS rate and varieties		
	Rasa	**NVL-1**	**Shewa robit**
0	-	-	-
50	5.2	5.0	2.24
100	4.6	5.5	1.80
150	3.5	3.0	2.36

Economic analysis

The partial budget averaged of the twelve (12) treatments calculated from income and expenses based on variable cost (Table 11). The average yields of mung bean were adjusted down wards by 10% to reflect the difference between the experimental and farmers' field yields [28]. The net benefit was computed taking the interaction of varieties with application of NPS fertilizer. Economic analysis revealed that the highest net benefit of 36775 Birr ha^{-1} with marginal rate of return 806.7 % was obtained from treatment combination of 100 kg NPS ha^{-1} application rates for variety NVL-1, while the lowest net benefit (22050 Birr ha^{-1}) was obtained from the treatment combination of 0 kg NPS ha^{-1} application rates for variety Rasa (Table 11). According to CIMMYT [28], the minimum acceptable marginal rate of return (MRR %) should be between 50 and 100%.

Therefore, production of NVL-1 variety with the application of 100 kg NPS ha^{-1} can be recommended for producers or farmers in the study area (Table 11). In agreement with this result, Sharma et al. [107] reported that the highest net benefit (34167.56 Birr ha^{-1}) was obtained due to application of 150 kg NPS ha^{-1}, while the lowest net benefit (19228.69 Birr ha^{-1}) was obtained from nil application on common bean. Similarly, Nuru [30] reported that the highest net benefit of (29589.1 Birr ha^{-1}) was obtained from application of 100 kg NPS ha^{-1}, while the lowest net benefit (14652.35 Birr ha^{-1}) was obtained from nil application on mung bean.

Table 11. Summary of partial budget analysis of the response of mungbean varieties to the application of NPS fertilizer rates

Treatment Combination	Unadjusted yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Total Revenue (Birr ha^{-1})	TVC (Birr ha^{-1})	Net benefit (Birr ha^{-1})	MRR (%)
Rasa +0	980	882	22050	0	22050	-
Rasa +50	1239	1115	27875	950	26925	513.2
Rasa +100	1442	1297.8	32445	1700	30745	509.3
Rasa +150	1505	1354	33862	2450	31412	D
NVL-1 + 0	1160	1044	26100	0	26100	216.8
NVL-1 + 50	1408	1267	31675	950	30725	486.84
NVL-1 +100	1710	1539	38475	1700	36775	806.7
NVL-1 +150	1611	1450	36250	2450	33800	D
Shewa robit +0	1093	983.7	24592	0	24592	375.84
Shewa robit +50	1205	1084	27100	950	26150	164.0
Shewa robit+100	1272	1145	28620	1700	26920	102.7
Shewa robit +150	1445	1300	32500	2450	30050	417.3

MRR (%) = Marginal Rate of Return; Fertilizer application cost = 200 Birr ha^{-1}; One kg NPS cost =15.00 Birr kg^{-1}; Mungbean grain local selling price =25 Birr kg^{-1}; D= Dominated Treatment; TVC = Total Variable Cost.

CONCLUSION

The results of this study demonstrated that the growth, yield, yield components, and agronomic efficiency were significantly influenced by the interaction effect of NPS fertilizer and variety. A maximum grain yield of 1,710 kg ha^{-1} mung bean was recorded in response to the interaction of NVL-1 variety with 100 kg ha^{-1} NPS fertilizer. However, the lowest grain yield (980 kg ha^{-1}) was recorded in Rasa variety planted with no fertilizer application. Overall, the grain yield produced in response to the interaction of NVL-1 variety with 100 kg ha^{-1} NPS fertilizer was about 74.5% higher than with no fertilizer application on variety Rasa. In general, for a better grain yield (1,710 kg ha^{-1}) and the highest mean net benefit (birr 36,775 ha^{-1}) with an acceptable marginal rate of return (806.7%), farmers are advised to use NVL-1 variety in a combination with 100 kg ha^{-1} NPS fertilizer. Since this study was conducted in one location and one season using three varieties of mung bean, the outcome of the experiment is not sufficient to give a conclusive recommendation. Therefore, additional investigations across locations, seasons and diverse genotypes should be conducted for full recommendation. Meanwhile, further research that evaluates integration of blended NPS fertilizer and organic fertilizers is suggested for soil health and higher productivity.

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