SOIL & CROP SCIENCES | RESEARCH ARTICLE

Performance of mung bean (Vigna radiata L.) varieties at different NPS rates and row spacing at Kindo Koysha district, Southern Ethiopia

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Abstract: Mung bean (Vigna radiata L.) is a pulse crop with multiple uses, yet the crop was not introduced in the study area. Further, there is a lack of information on improved agronomic technologies for the crop in the study area. Hence, a field trial was conducted to evaluate the effects of inter-row spacing and fertilizer rate on the performance of mung bean varieties at Kindo Koysha district, in 2018. The experiment comprised factorial combinations of two varieties (Shewarobit, N-26), three inter-row spacing of planting (20, 30 and 40 cm) and four NPS fertilizer rate (0, 50, 100 and 150 kg ha⁻¹) was laid out using randomized complete block design with three replications. The results indicated that the three-way interaction effect of variety, fertilizer and row spacing significantly influenced above-ground dry biomass. Further, the two-way interaction effect of variety with fertilizer rate significantly (P < 0.05) influenced yield and yield attributing traits. Accordingly, the maximum number of pod per plant (14.7), grain yield ha⁻¹ (1294.7 kg ha⁻¹) and harvest index were recorded for N-26 variety at 150 kg NPS ha⁻¹. Moreover, economic analysis also indicated that the highest net benefit of 33168.00 ETB ha⁻¹ was recorded for mung bean variety N-26 grown at 100 kg NPS ha⁻¹. Based on the result

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PUBLIC INTEREST STATEMENT

Mungbean is amongst an important lowland pulse crop in Ethiopia regardless of its recent introduction. The crop is adapted to low land areas and high-temperature areas. The crop is nutritious and rich source of proteins, carbohydrate, fats and fiber. However, the crop is yet not introduced in the study area. To this end, generating some agronomic information regarding the adaptability of varieties and agronomic technologies could help to introduce the crop in the study area. Hence, according to the findings of this study, production of mungbean variety N-26 at 100 kg NPS ha⁻¹ can boost the productivity of the crop and income of the farmers in the study area.
of this study, it can be tentatively concluded that producing variety N-26 at the rate of 100 kg NPS ha\(^{-1}\) found to be promising treatment combination for better productivity and higher economic return in the study area.

Subjects: Agriculture & Environmental Sciences; Botany; Soil Sciences

Keywords: economic returns; fertilizer rates; mung bean; varieties; yield

1. Introduction

Mung bean (Vigna radiata L.) commonly known as green gram is an ancient and well-known pulse crop that belongs to family Papilionoideae and originated from South East Asia (Mogotsi, 2006). Mung beans are mainly grown for human food, in the form of boiled dry beans, stew, flour, sprouts and immature pods as a vegetable. The dry beans are sometimes used for animal food, mainly poultry, when they are either roasted or boiled while its biomass is used as fodder (Winch, 2006). Thus, it has great value as food and fodder. It is a cheap source of protein for human consumption.

According to Dainavizadeh and Mehranzadeh (2013), the nutrient composition of the seed of mung bean contains 20–24% protein, 9.4% moisture, 2.1% oil, 2.05% fats, 6.4% fiber, 343.5 kcal per 100 gram energy, carbohydrates and a fair amount of vitamin A and B. In addition, the protein and carbohydrates of mung bean are more easily digestible than proteins derived from other legumes. On the other hand, the same source indicated that mung bean fixes atmospheric N\(_2\) and enriches the soil with N nutrient for the growth of succeeding crops. Moreover, the crop can be successfully grown on marginal lands where other crops perform poorly and most suitable for green manure use (Dainavizadeh & Mehranzadeh, 2013). Mung bean is a recent introduction to Ethiopia pulse production and it is mostly produced by small-scale farmers of Amhara National Region. Particularly, the crop is grown in some areas of North Shewa, Debere Sina, Qallu and South Wollo as well as in some districts of Benishangul Gumuz Regional State (CSA, 2018). The crop is also produced in moisture stress areas of the country such as Gofa, Konso, South Omo zone and Konta special district (Asrate et al., 2012; Wedajo, 2015).

Mung bean has special features such as its earliness in maturity, supply of good yield, drought-resilient property that makes it highly responsive in scanty rainfall and its ability to stimulate striga without being parasitized (Georgis, 2010). The crop also has good nutritive value and reasonable cost for the consumers (Asrate et al., 2012; Wedajo, 2015). According to CSA (2018) report, the area covered under mung bean in Ethiopia in 2017/18 cropping was 41,630.20 ha with a productivity of 1,235 kg ha\(^{-1}\). This is far below the average productivity reported at the research center, which is 1,650 kg ha\(^{-1}\) (Asrate et al., 2012). This shows low productivity of the crop at farmer field compared to the research center. The major reasons for its low productivity are lack of experience of farmers’ as it is a recently introduced crop which is not known in the area, less attention of farmers to production, limited use of modern inputs and inappropriate agronomic practices like inadequate or imbalanced fertilizer application, planting spaces and other management practices (Asrate et al., 2012).

Pulses fix N from the atmosphere, regardless of this application of N-containing fertilizers found to boost crop yield (Ardeshna et al., 1993). Addition of nitrogen (N) and phosphorus (P) fertilizer enhances root development, which improves the supply of other nutrients and water to the growing parts of the plants, resulting in an increased photosynthetic area and thereby more dry matter accumulation. The application of P to mung bean has been reported to increase yield and yield attributes (Mitra et al., 1999). Hossain et al. (2011) also reported that grain yield of legumes increased with increasing P\(_2\)O\(_5\) up to 50 kg ha\(^{-1}\). Further, sulfur (S) is one of the 16 essential elements required for plant growth and is a component of amino acids needed for protein synthesis (Jan et al., 2002). Mondal et al. (2003) reported that the application of S at the rate of (S\(_1\) = 22.2 kg...
$S_1 = 44.44$ kg ha$^{-1}$ and $S_2 = 44.44$ kg ha$^{-1}$) significantly increased grain yield of mung bean. Different researchers also reported a significant effect of blended NPS application on yield and yield attributing traits of legumes (Dame & Tasisa, 2019; Deresa et al., 2018; Lake & Jemaludin, 2018).

It is evident that optimum inter- and intra-row spacing can significantly improve crop yield (Ihasanullah, et al., 2002; Kabir & Sarkar, 2008). For instance, Kabir and Sarkar (2008) reported that the highest seed yield of mung bean was obtained by maintaining $30 \times 10$ cm spacing between rows and plants, respectively. Plant density of 40 plants m$^{-2}$ at $25 \times 10$ cm planting was the optimum for achieving higher productivity (Singh et al., 2011). Nawale (2001) concluded that the optimum plant population for mung bean was 667,667 plants per hectare obtained through the configuration of 30 and 10 cm between rows and plants within the row, respectively.

Despite the multiple uses of the crop for improving soil fertility and nutrient-rich food, the crop is not yet introduced in the study area. Besides, no information is available on agronomic practices and site-specific technologies such as improved varieties, inter-row spacing and NPS fertilizer application rates. Therefore, the objectives of this study were to determine the effects of row spacing and NPS rates on yields of two mung bean varieties and to investigate the economic feasibility of fertilizer utilization.

2. Materials and Methods

2.1. Description of the Experimental Site

Field experiment was conducted at Molticho of Kindo Koysha district Southern region. The site has an approximate geographical coordinates 6°9′06″N latitude and 37°5′E longitude having an altitude 1094 m a.s.l. The area is characterized by an erratic rainfall pattern with annual precipitation of 400–800 mm, with bimodal pattern (“Meher” and “Belg”). The “belg” cropping season extends from February to June, whereas “Meher” from July to October. The mean maximum and minimum temperature of the area is 32°C and 19.2°C, respectively (Baza, 2019).

2.2. Physical and Chemical Properties of Soils of Experimental Site

Soil samples were collected in a zigzag pattern compositied and used to determine soil pH; organic matter; total N; available P CEC and soil textural following standard soil testing procedures described by Okalebo et al. (2002). The soil analysis results revealed that soil pH, available P, CEC and total N were 5.92, 6.26, 2.29 and 0.10, respectively. According to the ratings of London (Landon, 1991), the experimental soil is moderately acidic, low in total N (0.10%) and organic carbon (0.94%), respectively. According to the present study, the soil textural class was grouped as clay loam in the study locations. Similarly, available P (6.26 mg kg$^{-1}$ soil) was low according to Olsen et al. (1954).

2.3. Description of experimental materials

The fertilizer material used for this experiment was NPS (N 19%, P 38% and S 7). Further, mung bean varieties used for this experiment were obtained from Mekassa Agricultural Research Center. Mung bean varieties used for this experiment have wide adaptability. Description of the varieties used for this experiment is indicated in Table 1.

2.4. Treatments and Experimental Design

Treatments consisted of two varieties mung bean (Shewarobit and N-26), four NPS rates (0, 50, 100, 150 kg ha$^{-1}$) and three row spacings ($20 \times 10$ cm (60 plants m$^{-1}$), $30 \times 10$ cm (40 plants m$^{-1}$) and $40 \times 10$ cm (30 plants m$^{-1}$)). Mung bean varieties used in the trial were well adapted to an altitude of 990–1,600 m a.s.l and released by Mekassa Agricultural Research Center in 2011. The treatments were arranged in factorial and laid out in a randomized complete block design with three replications. The plot size was $3 \times 2.1$ m with a gross area of 6.3 m$^2$. The seeds were hand-planted in respective row spacing following the planting time of the area. The proposed NPS rates were applied to each plot at planting in composed fertilizer NPS with N 19%, P 38% and S 7%.
2.5. Agronomic Practice
Prior to planting, the experimental field was oxen-ploughed and leveled to get smooth seedbed for planting. Cultivation, weeding and other crop management were carried out as desired during crop growing period.

2.6. Crop Data Collected

2.6.1. Yield and Yield Components
The number of pods per plant was counted from five randomly selected plants from the net plot area at harvest. The number of seeds per pod: It was counted from five pods from each of five plants used for pod count at harvest. Thousand-seed weight was determined by weighing 1,000 randomly selected dry seeds from the harvested net plot using a sensitive balance and the weight adjusted to 10% seed moisture content. Above-ground dry biomass (kg ha\(^{-1}\)) was recorded by harvesting from each net plot. It was sun-dried up to constant weight, weighed and then converted into kg ha\(^{-1}\). Grain yield was determined by harvesting from net plot and adjusting moisture content at 10%. Harvest index (HI) (%) was the proportion of grain yield kg per hectare to above-ground dry biomass yield and multiplied by 100 and expressed as percentage.

2.7. Economic Analysis
The partial budget analysis was carried out by using the methodology described in CIMMYT (1988). Variable costs of NPS fertilizer were largely used for partial budget analysis. Market prices of mung bean at the time of harvest were used for estimating gross income. Price fluctuations during the production season were also considered. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of mung bean due to the application of each rate to the total cost of NPS fertilizer applied at each rate. This enables to identify the economically optimum rate of NPS fertilizer for mung bean production (CIMMYT, 1988).

Unadjusted Grain Yield (UGY) (kg ha\(^{-1}\)) was an average yield of each treatment. Adjusted Grain Yield (AGY) (kg ha\(^{-1}\)) was the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmers. Gross Field Benefit (GFB) (ETB ha\(^{-1}\)) 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\(^{-1}\)) was calculated by summing up the costs that vary, including the cost of NPS (14 ETB kg\(^{-1}\)) fertilizers at the time of planting (3 August 2018). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding and chemical spraying, harvesting and threshing were 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.

### Table 1. Description of mung bean varieties

| Characteristics          | Varieties N-26 Shewarobit |
|--------------------------|---------------------------|
| Altitude (m.a.s.l)       | 990–1,600                 |
| Rain fall (mm)           | 350, 550                  |
| Fertilizer rate (kg ha\(^{-1}\)) | \(\text{P}_2\text{O}_5:46, \text{N}:18\) | \(\text{P}_2\text{O}_5:46, \text{N}:18\) |
| Maturity days            | 65–80                     |
| Flower color             | Yellow                     |
| Yield on research (kg ha\(^{-1}\)) | 800–1,500                 |
| Yield on farmer (kg ha\(^{-1}\)) | 500–1,000                |
| Year release             | 2011                      |
| Breeder                  | MARC                       |

Source: Melkasa Agricultural Research Center.

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(GFB) for each treatment. NB = GFB − TVC. 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.

2.8. Statistical Analysis
Data collected were subjected to the analyses of variance using SAS (SAS, 2002) statistical package. Significant treatment means were separated using least significant difference (LSD) test at 5% probability level.

3. Result and Discussion
3.1. Yield and Yield Components
3.1.1. Number of Pods per Plant
The productive capacity of mung bean plant is ultimately considered by the number of pods per plant. The interaction of variety with NPS rates resulted in a significant difference in the number of pods per plant. Variety N-26 grown on plots receiving 150 kg ha⁻¹ blended NPS rates produced the highest (14.7) number of pods per plant, while Shewarobit grown on control plot produced the lowest number of pods per plant (9.8) (Table 2). The highest number of pods at the highest rates of NPS might be attributed to the fact that improved availability of N, P and S enhances the canopy developments which in turn improve better solar radiation use through photosynthesis, thereby improving drymatter accumulation which later re-translocated to yield forming traits such as number of pods per plant. Similarly, Deresa et al. (2018) pointed out that the increase in number of pods per plant with the increased NPS rates might possibly be due to adequate availability of N, P and S, nutrients which might have facilitated the production of more branches and canopy development, which might, in turn, have contributed for the production of higher number of total pods. This result was in conformity with the finding of Arega and Zenebe (2019), who reported that number of pods per plant was significantly (P < 0.05) affected due to common bean varieties and blended NPKSB fertilizer application rates. Several authors also reported an increase in the number of pods per plant with an increase in the rates of NPSZnB/NPKSB fertilizer for common bean (Deresa et al., 2018); (Lake & Jemaludin, 2018). On the other hand, Dame and Tasisa (2019) reported non-significant interaction effect of soybean varieties and blended NPS fertilizer application rates on number of total pods per plant soybean.

3.2. Number of Seeds per Pod
The results revealed that two-way interaction effects of varieties with NPS fertilizer rates had highly significant (P ≤ 0.01) effect on number of seeds per pod. Variety Shewarobit, grown on plots applied with 150 NPS ha⁻¹, produced significantly highest number of seeds per pod (8.84), while

| Treatment  | 0  | 50  | 100 | 50  |
|------------|----|-----|-----|-----|
| Shewarobit | 9.8* | 11.0* | 12.9d | 12.2c |
| N-26       | 10.2d | 13.6d | 13.7c | 14.7b |
| LSD (0.05) | 0.3** |      |      |      |
| CV (%)     | 2.56 |      |      |      |

LSD (0.05): Least Significant Difference at 5% level; CV%: coefficient of variation; NP: Number of pod per plant; *: significant at 5% level of significance; **: significant at 1% level of significance; ns: non-significant.
the lowest (7.37) number of seeds per pod was recorded for the same variety grown at nil NPS rate (Table 3). The increment in number of seeds per pod with increasing NPS fertilizer application rates might be due to the fact that P is an essential component in seed formation. Furthermore, the supply of adequate nutrients might have facilitated the vegetative growth, which might, in turn, have contributed for the production of higher number of seed per pod. In line with this, Baza (2019) also observed significant variation in number of seeds per pod due to the interaction effect of NPS levels and mung bean varieties. On the contrary, Dame and Tasisa (2019) reported non-significant interaction effect of NPS fertilizer rate and soybean varieties.

Further, interaction effect of varieties with row spacing was significant. Accordingly, the highest (8.73) number of seeds per pod was recorded for variety N-26 grown at a row spacing of 40 cm, which also is statistically significant with shewarobit grown at a row spacing of 30 and 40 cm, while the lowest number of seeds per pod was recorded for shewarobit at a row spacing of 20 cm. This result is in line with Baza (2019) who reported significant (P < 0.05) interaction effect of NPS levels and mung bean varieties on number of seeds per pod. Maguje et al. (2017) also reported that a highly significant (P < 0.01) interaction effect of common bean variety and inter-row spacing was on the number of seeds per pod. On the other hand, Agajie (2018) reported non-significant interaction effect of chickpea varieties and row spacing on number of seeds per pod.

### 3.2.1. Thousand Seed Weight

Blended NPS fertilizer rates significantly (P ≤ 0.05) affected 1,000-seed weight. Application of 150 kg NPS ha⁻¹ produced significantly greater 1,000-seed weight (52.55 g) compared to the control plot (49.51 g), but which was statistically at par with the application of 50 and 100 kg of NPS ha⁻¹ (Table 4), while the lowest seed weight (49.51) was recorded at the control plot. The increase in seed weight with increased rates of NPS fertilizer could be due to the fact that legumes including common bean have high P requirement as the main storage site of P in seed. In conformity with this finding, different researchers reported a significant effect of blended NPS (Deresa et al., 2018) NPSZnB (Lake & Jemaludin, 2018) and NP50N (Arega & Zenebe, 2019) fertilizer application rates on hundred seed weight.

In addition, mung bean varieties significantly (P ≤ 0.05) affected 1,000-seed weight. Hence, the highest 1,000-seed weight was obtained from variety N-26 (56.95 g) and the lowest 1000-seed weight (45.32 g) was recorded for Shewarobit. In agreement with this, different researchers observed significant variation in hundred weights due to varieties for different crops (common bean (Deresa et al., 2018) and soybean (Dame & Tasisa, 2019)). The difference in seed weight among mungbean cultivars might be attributed to genotypic variation in mungbean cultivars.

### Table 3. Number of Mungbean seeds as affected by two-way interaction varieties with NPS fertilizer rates and varieties with row spacing at Kindo Kaysha in 2018

| Variety  | NPS Rate |       |       |       |       |       |       |
|----------|----------|-------|-------|-------|-------|-------|-------|
|          | 0        | 50    | 100   | 150   | 20    | 30    | 40    |
| Shewarobit | 7.37     | 8.50  | 8.48  | 8.84  | 7.78  | 8.60  | 8.58  |
| N-26     | 8.06     | 8.32  | 8.42  | 8.37  | 8.03  | 8.13  | 8.73  |
| LSD (0.05%) | 0.26     |       |       |       | 0.22  |       |       |
| P-Value  | **       |       |       |       |       |       |       |
| CV(%)    | 3.31     |       |       |       |       |       |       |

LSD (0.05) = Least Significant Difference at 5% level; CV%: coefficient of variation; NS: number of seed; *: significant at 5% level of significance; **: significant at 1% level of significance; ns: non-significant.
3.2.2. Grain Yield

Interaction effects of mungbean varieties and blended NPS rate were significant on grain yield. Hence, the maximum grain yield (1244.7 kg ha\(^{-1}\)) was recorded for variety N-26 at 150 kg ha\(^{-1}\), which was statistically at par for the same variety at 100 kg ha\(^{-1}\) (1219.2 kg ha\(^{-1}\)), while the lowest grain yield was recorded for Shewarobit at nil rate of NPS (655.7 kg ha\(^{-1}\)) (Table 5). The improved performance of N-26 variety at 100 and 150 kg NPS ha\(^{-1}\) might be attributed to higher growth and dry matter production due to applied NPS and genotypic variation in using of the applied NPS fertilizer. In agreement with the results, different researchers reported significant interaction effect of variety and blended NPS fertilizer on grain yield of pulses (Baza, 2019; Deresa et al., 2018).

Further, significant effect of single application of NPKSB/NPS on grain yield of pulses was also reported by different authors (Arega & Zenebe, 2019; Dame & Tasisa, 2019).

3.3. Above-Ground Biomass Yield

The productivity of a crop is largely determined by the biological yield. Production of large amount of biomass is among one of the attributes of seed yield. The results of this study showed that the three-way interaction effect of variety, NPS rate and inter-row spacing were significant for above-ground biomass. Accordingly, the highest above-ground biomass was recorded for variety N-26 at the rate of 100 kg ha\(^{-1}\) with 20 cm, while the lowest above-ground biomass was recorded for Shewarobit, grown on plots receiving nil NPS rate at the inter-row spacing of 40 cm (Figure 1).

### Table 4. Mung bean 1,000-weight as affected by main effect of varieties and fertilizer rates at Kindo Koyisha in 2018

| Variety  | TSW    |
|----------|--------|
| Shewarobit | 45.32<sup>b</sup> |
| N-26     | 56.95<sup>a</sup> |
| LSD(0.05) | 1.7**  |

| Fertilizer Rate (kg ha\(^{-1}\)) |  |
|----------------------------------|--|
| 0      | 49.51<sup>b</sup> |
| 50     | 50.26<sup>ab</sup> |
| 100    | 52.23<sup>a</sup> |
| 150    | 52.55<sup>a</sup> |
| LSD(0.05) | 2.46*  |

CV (%): 7.19

LSD (0.05): Least Significant Difference at 5% level; CV%: coefficient of variation; NP: number of pod per plant; *: significant at 5% level of significance; **: significant at 1% level of significance; ns: non-significant.

### Table 5. Mung bean grain yield, as affected by two-way interaction (VR × FR) at Kindo Koysha woreda in 2018

| Treatment | Fertilizer rate (kg ha\(^{-1}\)) |
|-----------|----------------------------------|
|           | 0      | 50     | 100    | 150    |
| Shewarobit | 655.7<sup>f</sup> | 831.3<sup>d</sup> | 1061.7<sup>c</sup> | 1160.3<sup>b</sup> |
| N-26      | 757.3<sup>e</sup> | 1033.2<sup>c</sup> | 1219.2<sup>b</sup> | 1244.7<sup>a</sup> |
| LSD (0.05) | 31.75** |

CV (%): 0.9

LSD (0.05): Least Significant Difference at 5% level; CV%: coefficient of variation; BM: biomass; *: significant at 5% level of significance; **: significant at 1% level of significance; ns: non-significant; V1: Shewarobit, V2: N-26; FR: fertilizer rate; VR: variety.
might be due to improved growth under narrow intra-row spacing for better utilization of light and adequate supply of nutrients added from the applied NPS fertilizer. In agreement with the present finding, Deresa et al. (2018) reported that interactions of NPS fertilizer application with variety significantly influenced above-ground dry biomass yield. Further, this finding is in conformity with the findings of Kazemi et al. (2012), who reported that more biomass was produced at narrow row spacing than wider spacing. Similarly, reported that narrower row spacing produced higher biomass yield than wider row spacing in rice.

3.4. Harvest Index (%)

The results revealed that the interaction effect of variety and blended fertilizer rates showed a significant effect for harvest index. Accordingly, maximum harvest index (39.56%) was recorded from N-26 with 150 kg ha\(^{-1}\) (33.63%), while minimum was recorded from Shewarobit with control (Table 6). This might be due to the influence of increased rate of NPS rate on translocation of dry matter from vegetative part to economic yield. In conformity with the finding, Deresa et al. (2018) reported significant effect of interaction of variety with blended NPS fertilizer rate. The same authors recorded the highest harvest index (0.53) for a variety of Angar at the application rate of 150 kg NPS ha\(^{-1}\). On the other hand, Arega and Zenebe (2019) reported non-significant effect of

### Table 6. Mung bean Harvest index, as affected by two-way interaction (VR × FR), at Kindo Koysha woreda in 2018

| Varieties     | Fertilizer rate (kg ha\(^{-1}\)) |
|---------------|----------------------------------|
|               | 0      | 50     | 100    | 150    |
| Shewarobit    | 33.6\(^e\) | 37.5\(^bc\) | 35.5\(^d\) | 37.5\(^bc\) |
| N-26          | 34.4\(^c\) | 36.9\(^c\) | 38.55\(^d\) |          |
| LSD (0.05)    | 1.11\(^**\) |          |          |          |
| CV (%)        | 3.19   |        |        |        |

LSD (0.05): Least Significant Difference at 5% level; CV%: coefficient of variation; HI: Harvest index; *: significant at 5% level of significance; **: significant at 1% level of significance; ns: non-significant.
interaction of NPKSB with varieties on harvest index. The increased harvest index with an increase in NPS rates of fertilizer is in agreement with the findings of Chiezey et al. (1992) related to lower value of harvest index at low level of phosphorus application to poor development of plants at different growth stages of soybean. Similarly, Singh et al. (1999) reported the highest harvest index of lentil was obtained when 45 kg P ha$^{-1}$ and 30 kg S ha$^{-1}$ were applied. Likewise, Fageria et al. (2010) reported that at a higher N rate, the grain harvest index of common bean was also increased. Taleei et al. (1999) reported significant differences in harvest index among different varieties.

3.5. Partial Budget Analysis

Cost-benefit analysis was undertaken with different fertilizer treatments to determine the highest net benefit with acceptable marginal rate of return. The results revealed that the maximum net benefit was obtained from N-26 + 150 kg NPS ha$^{-1}$ + 30 cm (Table 7). The results show a general increase in benefit-cost ratio with an increase in the level of fertilizers. This implies that the profitability of mung bean production is partly related to the right type, rate of input (fertilizer) usage and right row spacing and the cost incurred for these inputs (Gigaw et al., 2014). Thus, on the basis of marketable yield, net income and cost-benefit ratio, it can be concluded that among the fertilizer rates and variety tested, N-26 + 150 kg NPS ha$^{-1}$ + 30 cm and N-26 + 100 kg ha$^{-1}$ + 30 cm was the most recommended and

| Treatment combination | Total revenue (Birr ha$^{-1}$) | TVC (Birr ha$^{-1}$) | Net return (Birr ha$^{-1}$) | MRR % |
|-----------------------|-------------------------------|----------------------|-----------------------------|-------|
| V1 + 0 + 20 cm        | 17,496.00                     | 0                    | 17,496.00                   | D     |
| V1 + 0 + 30 cm        | 19,701.90                     | 0                    | 19,701.90                   | D     |
| V1 + 0 + 40 cm        | 15,911.10                     | 0                    | 15,911.10                   | D     |
| V1 + 50 + 20 cm       | 22,013.10                     | 800                  | 21,213.10                   | 662.75 |
| V1 + 50 + 30 cm       | 24,183.90                     | 800                  | 23,383.90                   | D     |
| V1 + 50 + 40 cm       | 21,141.00                     | 800                  | 20,341.00                   | D     |
| V1 + 100 + 20 cm      | 28,917.00                     | 1,500                | 27,417.00                   | 1,010.85 |
| V1 + 100 + 30 cm      | 30,564.00                     | 1,500                | 29,064.00                   | D     |
| V1 + 100 + 40 cm      | 26,514.00                     | 1,500                | 25,014.00                   | D     |
| V1 + 150 + 20 cm      | 31,293.00                     | 2,200                | 29,093.00                   | 582.71 |
| V1 + 150 + 30 cm      | 31,887.00                     | 2,200                | 29,687.00                   | D     |
| V1 + 150 + 40 cm      | 30,788.10                     | 2,200                | 28,588.10                   | D     |
| V2 + 0 + 20 cm        | 20,069.10                     | 0                    | 20,069.10                   | D     |
| V2 + 0 + 30 cm        | 22,459.41                     | 0                    | 22,459.41                   | D     |
| V2 + 0 + 40 cm        | 19,178.10                     | 0                    | 19,178.10                   | D     |
| V2 + 50 + 20 cm       | 27,000.00                     | 800                  | 26,200.00                   | 877.73 |
| V2 + 50 + 30 cm       | 30,000.51                     | 800                  | 29,200.51                   | D     |
| V2 + 50 + 40 cm       | 26,684.10                     | 800                  | 25,884.10                   | D     |
| V2 + 100 + 20 cm      | 32,049.00                     | 1,500                | 30,549.00                   | 666.41 |
| V2 + 100 + 30 cm      | 34,676.10                     | 1,500                | 33,176.10                   | D     |
| V2 + 100 + 40 cm      | 32,553.90                     | 1500                 | 31,053.90                   | D     |

MRR (%) : Marginal Rate of Return; Fertilizer application cost = 100 Birr ha$^{-1}$; NPS cost = 14.00 Birr kg$^{-1}$; Mung bean grain local selling price = 30 Birr kg$^{-1}$; TVC: total variable cost; D: Dominated treatment.
4. Conclusion

The result of this study showed that variety N-26 grown on plots receiving 150 and 100 kg NPS ha\(^{-1}\) resulted in maximum grain yield. From economic point of view, the highest net benefit of 33,168.00 ETB ha\(^{-1}\) was obtained from variety N-26 grown on plots receiving 100 kg NPS ha\(^{-1}\). Thus, based on the present findings, it can be concluded that growing variety N-26 at 100 kg ha\(^{-1}\) can ensure better yield with the highest economic return for the farmers in the study area. However, further research should be conducted across representative locations of the district to generate more information.

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**Competing Interests**

The authors declare no competing interests.

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**correction**

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