

Effects of NPS Fertilizer Rates on Growth, Yield and Yield Components of Mungbean [*Vigna radiata* (L.) Wilczek] Varieties under Irrigation at Gewane, Northeastern Ethiopia

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Abstract – Mungbean is becoming an important pulse crop in dry land area of Ethiopia because of its use as sources of food and cash. However, appropriate management practice that combines high yielding varieties with balanced fertilizers are lacking in the study area. Thus, a field experiment was conducted to assess the effects of NPS fertilizer rates on growth, yield and yield components of mungbean varieties during 2019 cropping season at Gewane, Ethiopia. Treatments consisted of factorial combinations of four mungbean varieties (Boreda, Rasa, Shewa robit and NVL-I) with four NPS fertilizer rates (0, 50, 100 and 150 kg ha⁻¹) laid out in Randomized Complete Block Design (RCBD) with three replications. The results of the main effects of NPS fertilizer rate showed significantly the highest plant height (65.91 cm), primary branches (5.81), secondary branches (9.08), total number of nodules (26.10), effective number of nodules (15.32), hundred seed weight (4.75 g), aboveground biomass (5769.3 kg ha⁻¹) and harvest index (28.55%) from 150 kg NPS ha⁻¹, which was statistically at par with 100 kg NPS ha⁻¹. Interaction of varieties with NPS fertilizer rate showed significant effect on days to 50% flowering, days to 90% physiological maturity, number of pod per plant, number of seeds per pod and seed yield. The highest days to flowering (54.22 days) and days to physiological maturity (81.22 days) were recorded from variety Rasa with 150 kg NPS ha⁻¹ whereas the highest number of pods per plant (26.22), number of seeds per pod (12.21), and seed yield (1820.67 kg ha⁻¹) was recorded from the combination of Boreda variety with 100 kg NPS ha⁻¹. Moreover, the combination of 100 kg NPS ha⁻¹ with variety Boreda also gave the highest net-return (29,589.1 Birr ha⁻¹) with MRR of 855.16%. Thus, the results of this study, it can be tentatively concluded that the use of 100 kg ha⁻¹ NPS with variety Boreda to be best for the production of mungbean in the study area.

Keywords – Boreda, Mungbean, NPS fertilizer, NVL-I, Rasa, Shewa Robit.

I. INTRODUCTION

Mungbean is a warm season annual grain legume crop. The crop is characterized by fast growth under warm conditions, low water requirement, and excellent soil fertility enhancement via nitrogen fixation [1]. Mungbean is grown widely for use as a human food; it can be used as a green manure crop and as forage for livestock [2].

The crop is becoming increasing important in dry land areas of Ethiopia in view of its high market and nutritional value and early maturity. For instance, its production has increased in Ethiopia from 14,562.00 ha with average seed yield of 966 kg ha⁻¹ in 2014/15 cropping season [3] to 24,038.85 hectares with average productivity of 1003 kg ha⁻¹ in 2015/16 cropping season [4].

The low yield of mungbean at Gewane is attributed to various constraints related to lack of improved varieties, poor cultural practices including the farmer do not use fertilizer, disease and pests and environmental degradation. Especially, the farmers have a wrong idea on the need of fertilizer for legume including mungbean [5]. Whereas nitrogen, phosphorus and sulfur alone or in combination play a remarkable role in increasing yield

and improving the quality of mungbean [6].

Nitrogen is an important major nutrient element for plant. For legumes, it is more useful because it is the main component of amino acids as well as proteins. Adequate supply of nitrogen is essential for normal growth and yield [7]. 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-grains weight. Similarly, showed that increase of nitrogen up to 40 kg N ha^{-1} increased seed yield of mungbean [7]. Phosphorus is one of the three macronutrients that plants must obtain from the soil. It is a major component of compounds whose functions relate to growth, root development, flowering and ripening [8]. Phosphorus application ($69 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$) to mungbean has increased plant height, number of branches, and number of pods per plant, number of grains per pod, 1000-grains weight, biological yield and grain yield [9]. Sulphur is also an important nutrient for plant growth and its uptake by plants accounts 9 to 15% of nitrogen uptake [10]. Deficiency of S has long been recognized as limiting nutrient for crop production [11].

The management of fertilizer is one important factor that greatly affects the growth and yield of the crop. Moreover, appropriate management practice that combines high yielding varieties with balanced fertilizers can increase the seed yield to great extent since higher productivity can be achieved through a combination of an ideal cultivar associated with proper environment and appropriate agronomic practices. Research results revealed that mungbean yield and quality could be improved by the use of balanced fertilizers [6]. Reported that application of NPK at $25\text{-}50\text{-}75 \text{ kg ha}^{-1}$ gave the highest mungbean grain yield of 1666 kg ha^{-1} [12].

Thus, the objective of this study was to assess the effects of NPS fertilizer rates on growth, yield components and yield of mungbean varieties.

II. MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at **Gewane Agricultural Technical and Vocational Training College** demonstration site, Afar Regional State during 2019 cropping season. It is located in Gewane Woreda at $10^{\circ}10'$ N latitude, $40^{\circ}32'$ E longitude, and 356 km North East from Addis Ababa. The altitude of the site is about 626 meters above sea levels [21]. The experimental area is characterized as a semi-arid climatic zone with an average annual rainfall of about 400 mm. The rainfall is erratic and low due to which crop production is not possible under rain-fed condition. The mean annual temperature of the experimental site is about 30°C with 39°C maximum and 22.5°C minimum [21].

Soil Sampling and Analysis

Before sowing of the seed, soil sample was taken from ten spots of 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 Werer Agricultural Research Centre. The soil was analyzed for soil texture, pH, organic matter (OM), 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 standard glass electrode pH meter. The Walkley and Black method was used to determine organic matter content of the soil.

Total Nitrogen in the soil was determined by the Kjeldahal method. Available soil Phosphorus was determin-

-ed using the Olsen extraction method. Available sulphur was analyzed by turbidimetric method. The Bouyoucas hydrometer method was used to determine soil texture. Electro-conductivity was determined by standard glass electrode using EC meter. Soil Cation Exchange Capacity (CEC) was determined by ammonium acetate method.

Treatments and Experimental Design

The treatments consisted of four varieties of mungbean (Boreda, Rasa, Shewa robit, and NVL-1) and four levels of NPS fertilizer rates (0, 50, 100, 150 kg ha⁻¹). The experiment was laid out as randomized complete block design in factorial arrangement with three replications.

Table 1. Nutrient composition of the fertilizer treatment.

Treatments	NPS (kg ha ⁻¹)	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	S (kg ha ⁻¹)
T1	0	0	0	0
T2	50	9.5	19	3.5
T3	100	19	38	7
T4	150	28.5	57	10.5

Experimental Procedure and Crop Management

The experimental field was plowed and harrowed one times with a tractor to a depth of 25-30 cm and the plots were leveled and ridges were made manually. The gross plot area was 2.4 m × 3.0 m (7.2 m²) consisting of 8 rows of 3 m length. The spacing between plots and between blocks was 0.8 m and 1 m, respectively. Treatments were assigned to each plot randomly. The spacing between rows and plants was 30 cm and 10 cm, respectively. Thus, the net plot size was 2 m x 2.40 m (4.8 m²) with 6 net numbers of rows.

Two seeds per hill at the specified spacing were sown at a depth of about 2.5 cm to ensure adequate emergence in the month of December 2019. Fertilizer was hand drilled in rows at the time of sowing. The plants were thinned to one plant per hill 10 days after emergence. Irrigation water source was Awash river in the whole growing period. A generator was used to pump the water and furrow irrigation was used as water distribution system in the field. The first irrigation was made at sowing and the last irrigation was made 15 days before harvesting. Seven days' irrigation intervals were maintained throughout the crop growing period. During each irrigation time the water was applied to field capacity. Weeding and cultivation were done as per the recommendation for the crop. Harvesting was done at harvest maturity when the bottom of the mungbean pods started to dry [13].

Crop Data Collected

Phenological Data

Days to 50% flower initiation: this was determined by counting the number of days from planting to the time when first flowers appeared in 50% of the plants in a plot by counting the number of plants.

Days to physiological maturity: it was determined as the number of days from planting to the time when 90% of the plants started senescence of leaves (yellowing of the foliage) and pods started to turn yellow. This was done by counting the number of plants.



Growth Parameters

Number of total Nodules Per Plant:

Bulk of the root of 10 randomly taken plants from destructive rows in each plot was carefully exposed at 50% flowering and uprooted for nodulation study. Roots were carefully washed using tap water on a sieve and nodules were separated and counted.

Number of Effective Nodules Per Plant:

For determination of effective number of nodules, the inside color of nodules was observed by cutting each nodule with the help of sharp blade and the pink colored nodules were considered as effective nodules, while green colored nodules were considered as non-effective.

Plant Height (cm):

It was measured at physiological maturity from the base to the tip of a plant for randomly pre-tagged ten plants in harvestable rows using meter tape and averaged on a plant basis.

Number of Primary Branches Per Plant:

It was determined by counting the total number of branches on randomly pre-tagged ten plants in the net plot at physiological maturity and averaged on per plant basis.

Number of Secondary Branches Per Plant:

The number of branches arising from the primary branches was counted at the time of physiological maturity for 10 randomly taken plants and the average was recorded on per plant basis.

Yield Components and Yield

Crop Stand Count:

The initial plant stand count was recorded by counting the total number of plants per net plot area immediately after thinning and final plant stand count was taken from net plot areas when the plants attained 90% of physiological maturity.

Number of Pods Per Plant:

It was recorded based on five pre-tagged plants in each net plot area at harvest and the average was taken as number of pods per plant.

Number of Seeds Per Pod:

The total number of seeds in the pods of five plants was counted and divided by the total number of pods to find the number of seeds per pod.

Hundred Seed Weight (g):

The weight of 100 seeds was determined for each plot using a sensitive balance. The weight was adjusted to a moisture content of 10%.

Above Ground Dry Biomass Yield (kg ha⁻¹):

At physiological maturity, five plants randomly taken from the destructive rows of each plot were used to determine aboveground dry biomass yield, which was measured after sun drying till a constant weight. The dry biomass per plant was then multiplied by the total number of plants per net plot and was converted into kg ha⁻¹. This value was used to calculate the harvest index as well.

Grain Yield (kg ha⁻¹):

Grain yield was measured by harvesting and threshing of the crop from the net plot area. The moisture was adjusted to 10%.

Harvest Index (HI):

Harvest index was calculated by dividing grain yield per plot by the total above ground dry biomass yield per plot.

II. RESULTS AND DISCUSSION

Selected Physio-Chemical Properties of Soil of the Experimental Site

Selected physio-chemical properties were analyzed for composite soil (0-30 cm depth) samples collected from experimental site before planting. The result of the soil analysis are indicated in (Table 3) showed that at a pH of 8.28 (alkaline). The area has silt clay loam soil texture. Mungbean grows on a wide range of soils but prefers well-drained loams or sandy loams, with pH ranging from five to eight. It is somewhat tolerant of saline soils [17]. The electrical conductivity (EC in mS/cm) of a soil in the site recorded EC 6.92 mS/cm, which was slightly saline according to [17]. It 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 (0.08%) was poor requiring application of nitrogenous fertilizer.

In general, soils high in CEC contents are considered as agriculturally fertile. According to [17] 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 33.86 Cmol kg⁻¹. The CEC value of the soil was high in the study area which indicates that the soil has the capacity to hold nutrient cations and supply to the crop. The Netherlands commissioned a study by Ministry of Agriculture and Fisheries classified soil organic carbon (%) >3.50, 2.51-3.5, 1.26-2.50, 0.60-1.25 and < 0.60 as very high, high, medium, low and very low, respectively. Thus, the organic carbon content of the soil (1.41%) is in the medium range.

According to [17] available sulphate sulphur (21.07 mg kg⁻¹) is in the medium range. Thus, considering the soil parameters at the experimental site of the soil is suitable for mungbean production.

Table 2. Results of soil physical and chemical properties of the study site before sowing of mungbean.

Soil Properties		Results	Rating	Reference
Soil particle size	Clay (%)	28.75		
	Silt (%)	53.75		

Soil Properties		Results	Rating	Reference
	Sand (%)	17.50		
Textural class		Silt clay loam		
Soil pH (1:2 H ₂ O)		8.28	Alkaline	Moore (1998)
Electro-conductivity (mS/cm)		6.92	Medium	Tekalign <i>et al.</i> (1991)
Organic carbon (%)		1.41	Medium	N MoAF (1995)
Total nitrogen (%)		0.08	Very low	Tekalign <i>et al.</i> (1991)
Available phosphorus (ppm)		12.4	Medium	Tekalign <i>et al.</i> (1991)
SO ₄ -S (mg kg ha ⁻¹)		21.07	Medium	Lewis (1999)
Cat-ion exchange capacity		33.86	High	Tekalign <i>et al.</i> (1991)
(CEC) (Cmol ⁺ kg ⁻¹)				

Crop Phenological Parameters

Days to 50% Flowering

Main effects of variety and NPS fertilize rate had highly significant ($p < 0.01$) effect on days to 50% flowering and the interaction of the factors had significant ($p < 0.05$) effect on days to 50% flowering.

Variety Rasa with 150 kg NPS ha⁻¹ rate had the longest days to reach 50% flowering (54.22 days) and it was statistically at par with 100 kg NPS ha⁻¹ (53.52 days) for the same variety, while the variety Boreda with 0 kg NPS ha⁻¹ rate was the earliest to flower (40.93 days) (Table 3). The other varieties and fertilizer rates were intermediate to reach 50% flowering. At all rates of NPS, variety Rasa was late flowering while variety Boreda was early maturing. This might be due to varietal characteristics and due to the addition of nitrogen, phosphorus and sulfur blended fertilizer. The addition of nitrogen and phosphorus fertilizer might have contributed to the availability of soil nutrients to plant growth whereby the nitrogen fertilization delayed days to flowering. This variation may be due to stimulatory effect of phosphorus on growth hormones, induce early flowering in common bean. This result was in line with the findings of [14] who reported that increasing the NP application rate from 0 kg N, 0 kg ha⁻¹ P₂O₅ to 36 kg N, 92 kg ha⁻¹ P₂O₅ significantly shortened the time required to attain 50% flowering. Previous reports also showed that variety Boreda was earlier than varieties Rasa [15]. Similarly, the finding of [16] who reported that duration of reproductive growth period was significantly influenced by the interaction effect of N and P on lentil.

Table 3. Interaction effects of varieties and NPS fertilizer rate on days to 50% flowering of mungbean at Gewane in 2019.

Varieties	0	NPS (kg ha ⁻¹)		
		50	100	150
Boreda	40.93 ^h	43.18 ^{efgh}	44.27 ^{efg}	45.13 ^{cde}
NVL-I	41.42 ^{gh}	43.21 ^{efgh}	47.67 ^{bcd}	48.50 ^b

		NPS (kg ha ⁻¹)		
Shewa robit	41.60 ^{gh}	38.6 ^{ef}	44.82 ^{def}	45.87 ^{bcd}
Rasa (N-26)	42.16 ^{feh}	47.76 ^{bc}	53.52 ^a	54.22 ^a
LSD (0.05)	2.88			
CV (%)	3.80			

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

Days to 90% Physiological Maturity

Main effects of variety and NPS fertilize rates had highly significant ($p < 0.01$) effect on days to 90% physiological maturity and the interaction of both factors had significant ($p < 0.05$) effect on days to 90% physiological maturity.

Variety Rasa (N-26) with 150 kg ha⁻¹ had the longest days to reach 90% physiological maturity (81.22 days) and it was statistically at par with 100 kg NPS ha⁻¹ (80.52 days) for the same variety, whereas the variety Boreda with 0 NPS kg ha⁻¹ rate was the earliest to reach 90% physiological maturity (67.93 days).

This variation might be attribute by genotypic differences of the respective varieties and rates of NPS application. Phenological characteristics are genetically controlled and individual varieties have different growing habit, flowering and maturity days. Previous reports also showed that variety Boreda to be significantly earlier maturing than other varieties [15]. Similarly, [18] reported that Boreda was earliest in days to flowering (43.2) and days to maturity (58.8).

The result clearly indicated that days to maturity were prolonged in response to the increased levels of NPS. The delay in days to maturity at highest NPS rate could be due to the fact that N fertilization increases the vegetative growth of plants. In line with this result, [19] reported that appearance of phenological stages and growth period increased with increasing of nitrogen fertilizer rates (20 kg ha⁻¹) in chickpea and soybean, respectively.

Table 4. Interaction effects of varieties and NPS fertilizer rate on days to 90% of physiological maturity of mungbean at Gewane in 2019.

		NPS (kg ha ⁻¹)			
Varieties	0	50	100	150	
Boreda	67.93 ^h	74.55 ^{cd}	71.27 ^{efg}	72.13 ^{cde}	
NVL-I	68.42 ^{gh}	71.24 ^{efg}	74.68 ^{bcd}	75.50 ^b	
Shewa robit	68.60 ^{gh}	70.21 ^{efgh}	71.82 ^{def}	72.88 ^{bcd}	
Rasa (N-26)	69.12 ^{feh}	74.77 ^{bc}	80.52 ^a	81.22 ^a	
LSD (0.05)	2.88				
CV (%)	3.80				

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

Growth Parameters

Number of total and Effective Nodules

The main effect of NPS fertilizer rates was highly significant ($p < 0.01$) on total and effective number of nodules per plant while the main effects of varieties and the interaction were non-significant.

Significantly highest number of total and effective nodules per plant were recorded from the application of 100 kg NPS ha⁻¹ and 150 kg NPS ha⁻¹ which were at par with each other while the lowest number of total and effective nodules were recorded from the control (Table 5).

The increase in total and effective number of nodules may be due to application of nitrogen and sulfur fertilizer that stimulate nodule formation and also enhance yield of pulse including mungbean. Application of phosphorus as got significant effect on legumes yield and agronomic parameters. Showed that phosphorus application (85 kg ha⁻¹) to filed pea had significant effect on plant height, number of branches, roots and shoot dry weights, number of nodules [22]. Seed yield, and biomass yield, number of pods, phosphorus content of the seeds. In conformity with this result, [23] reported that, in nitrogen deficient soils, small starter doses of applied nitrogen (20 kg ha⁻¹) may stimulate nodule formation and enhance the grain yield of legumes. Similarly, [22] reported that application of nitrogen in the range of 22 to 33 kg N ha⁻¹ enhanced both nodulation and seed yield. Moreover, [25] found a significant increase in the number of active nodules with the application of sulphur up to 20 kg ha⁻¹, at which point nodule production reached a plateau and did not increase further. Also reported that the formation of nodules in black gram was increased in response to sulphur application up to 30 kg ha⁻¹ which is involved in the formation of nitrogenous enzyme known to promote nitrogen fixation in legumes [24]. (Similarly, phosphorus also needed to promote the development of extensive root systems and good nodule development.

Table 5. Main effect of NPS fertilizer rates and varieties on numbers of total and effective nodules per plant of mungbean at Gewane in 2019.

Treatment	Number of Total Nodules	Number of Effective Nodules
NPS rate (kg ha⁻¹)		
0	3.09 ^c	3.01 ^c
50	8.65 ^b	6.41 ^b
100	26.10 ^a	15.25 ^a
150	24.70 ^a	15.32 ^a
LSD (0.05)	4.00	2.19
Varieties		
Boreda	15.79	9.67
Rasa	16.14	10.60

Treatment	Number of Total Nodules	Number of Effective Nodules
Shewa robit	14.87	9.48
NVL-1	16.56	10.32
LSD (0.05)	N.S	N.S
CV (%)	30.32	26.32

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.

Plant Height

Main effects of NPS fertilize rate had highly significant ($p < 0.01$) effect on the plant height of the crop. But, the main effect of varieties and the interaction effect of both were not significant on the pant height of mungbean.

The tallest plant height (65.24 cm) was recorded from 150 kg NPS ha⁻¹ fertilizer rate which was statistically at par with 100 kg NPS ha⁻¹ fertilizer rate (64.24 cm) while the shortest plant height (35.85 cm) was found from the control. The increase of plant height with the increment of the rates of NPS fertilizer might be due to the fact that nitrogen, phosphorus and sulfur nutrients are 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 NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability and P also, plays a pivotal role in early root proliferation that might increase the nutrient up take of the plant consequently resulted in increased vegetative growth. This result is in conformity with the finding of [26] who reported an increase in plant height of mungbean in response to nitrogen and phosphorus application (20 kg N ha⁻¹ and 69 kg P₂O₅ ha⁻¹).

There was no significant difference among the varieties which was in agreement with [18] who reported no significant difference in plant height among varieties Boreda, N-26 and Shewarobit.

Table 6. Main effect of NPS fertilizer rates and varieties on plant height, primary and secondary branches per plant of mungbean at Gewane in 2019.

Fertilizer	Plant Height	Primary Branches	Secondary Branches
0	35.85 ^c	2.48 ^c	3.59 ^b
50	48.34 ^b	3.76 ^b	3.25 ^b
100	64.24 ^a	5.81 ^a	8.62 ^a
150	65.91 ^a	5.74 ^a	9.08 ^a
LSD	2.85	0.29	0.71

Varieties

Boreda	54.44	4.50	6.57
Rasa	53.17	4.57	6.57

Shewa robit	53.69	4.42	6.73
NVL-1	53.05	4.30	6.66
LSD (0.05)	N.S	N.S	N.S
CV (%)	6.38	7.91	12.94

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.

Number of Primary and Secondary Branches

Main effect of NPS fertilize rate had highly significant ($p < 0.01$) effect on number of primary branches and secondary branches per plant of the crop. But, the main effect of varieties and the interaction effect of both factors had no significant effect on number of primary and secondary branches per plant of mungbean.

The highest number of primary branches per plant (5.81) was recorded from 100 kg NPS ha⁻¹ fertilizer rate and it was statistically at par with 150 kg NPS ha⁻¹ fertilizer rate (5.74), whereas the lowest number of primary branches per plant (2.48) was recorded from the control. Similarly, the highest number of secondary branches per plant (9.08) was recorded from 150 kg ha⁻¹ NPS fertilizer rate and statistically at par with 100 kg ha⁻¹ NPS fertilizer rate. On the hand the lowest number of primary branches per plant was recorded from control (3.59) (Table 6). The increase of number of primary and secondary branches per plant with the increment of the rates of NPS fertilizer might be that nitrogen; phosphorus and sulfur nutrients are involved in vital plant functions and contributed to enhanced growth in the height of the crop.

Moreover, the increase in number of primary and secondary branches per plant in response to the increased NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability and P also, plays a pivotal role in early root proliferation that might increase the nutrient up take of the plant consequently resulted in increased vegetative growth. In agreement with this result, [26] reported that the number of primary and secondary branches increased with increase in N rate (20 kg ha⁻¹) in chickpea and soybean, respectively. Similarly, [18] reported significantly higher number of secondary branches (9.15) with 50 kg P₂O₅ha⁻¹ over the control on soybean.

Yield Components and Yield

Number of Pods Per Plant

Main effects of varieties and NPS fertilize rates had highly significant ($p < 0.01$) effect on number of pods per plant and the interaction of both factors had significant effect ($p < 0.05$).

Variety Boreda with 150 kg NPS ha⁻¹ produced significantly highest number of pods per plant (26.22), which was statistically at par with the application of 100 kg NPS ha⁻¹ with the same variety (Table 7). In contrast, variety Rasa (N-26) with 0 kg NPS ha⁻¹ rate gave the lowest number of pods per plant (12.92). The highest number of pods per plant for variety Boreda might be due to varietal characteristics as individual varieties have different growing habit. 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 per plant. This highest number of pod at the highest rates of NPS (150 kg ha⁻¹) might be attributed by the fact that NPS enhance establishment of beans, promote the formation of nodes, canopy development and pod setting. And also the increase in number of pods with these levels might be due to various enzymatic activities which controlled flowering and pod formation. In line with this result [30] reported increase in number of pods per plant of chickpea occurs due to the increased leaf area with additional N being associated with more reproductive nodes. A greater leaf area also results in a corresponding increase in assimilate supply which has been reported to determine pod number in French bean (*Phaseolus vulgaris*). Corroborating this result [28] reported that number of pod per plant increased with increase in N rate in chickpea. It also reported that the number of pods per plant of soybean increased with N doses up to 80 kg ha⁻¹.

The result was in conformity with the finding of [29] who reported significant increase in number of pods per plant on common bean due to increased P fertilization up to 69 P₂O₅kg ha⁻¹. Similarly, [27] observed significantly more number of pods (28.08) per plant at application rate of 75 kg P₂O₅ ha⁻¹ on mungbean.

The variety Boreda gave highest number of per pod per plant over Shewa robit, NVL-1 and Rasa varieties over all the rates of NPS. Similarly, [18] reported that vareity Boreda gave the highest number of pod per plant (8.6) over Shewa robit (7.8) and Rasa varieties (5.8).

Table 7. Interaction effects of varieties and NPS rate on pod number of mungbean at Gewane in 2019.

Varieties	NPS (kg ha ⁻¹)			
	0	50	100	150
Boreda	14.15 ^{fgh}	19.76 ^{ab}	25.52 ^a	26.22 ^a
NVL-I	13.41 ^{gh}	16.23 ^{efg}	19.67 ^{bcd}	20.50 ^b
Shewa robit	13.59 ^{gh}	15.20 ^{efgh}	16.81 ^{def}	17.87 ^{abcde}
Rasa (N-26)	12.92 ^h	15.17 ^{efgh}	16.27 ^{efg}	17.12 ^{cde}
LSD (0.05)	2.88			
CV (%)	9.88			

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.

Number of Seeds Per Pod

Main effects of varieties and NPS fertilize rate had highly significant (p< 0.01) effect on number of seeds per pod and the interaction of both factors had significant effect (p< 0.05).

Variety Boreda with 150 kg NPS ha⁻¹ produced significantly highest number of seeds per pod (12.21), which was statistically at par with the application of 100 kg NPS ha⁻¹ with the same variety (Table 8). On the other hand, variety Rasa with 0 kg NPS ha⁻¹ gave the lowest number of seeds per pod (5.14). Due to varietal characteristics, individual varieties have different growth habit. The variety Boreda gave highest number of seed per pod over Shewa robit, NVL-1 and Rasa varieties. Similarly, [18] reported that variety Boreda gave highest number of seed per pod (7.8) over Shewa robit (6.6), and Rasa varieties (6.4).

The increment in number of seeds per pod with increasing NPS fertilizer application rates might be due to the fact that P is essential component in seed formation. Phosphorus plays key role in protein synthesis, phospholipids and phytin all of which are important in the growth of the plant [31]. The result of the present study was in agreement with the finding of [29] and [32] who reported that the number of seeds per pod of common bean was increased significantly with increased levels of P (92 kg P₂O₅).

Table 8. Interaction effects of varieties and NPS rate on number of seeds per pod of mungbean at Gewane in 2019.

Varieties	NPS (kg ha ⁻¹)			
	0	50	100	150
Boreda	5.89 ^{de}	11.38 ^a	12.48 ^a	12.21 ^a
NVL-I	4.67 ^e	7.97 ^{bc}	11.41 ^a	12.23 ^a
Shewa robit	5.32 ^{de}	6.94 ^{cd}	8.55 ^{bc}	9.61 ^b
Rasa (N-26)	5.14 ^e	6.90 ^{de}	8.00 ^{bc}	8.85 ^b
LSD (0.05)	1.74			
CV (%)	12.15			

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.

Crop Stand Count

Analysis of variance for the number of plants at harvest compared to the initial count (stand count after thinning) was highly significant ($p < 0.01$) due to the main effects of NPS fertilizer. However, there were non-significant effects due to varieties and interaction of both factors. Among the different NPS levels, the highest stand count rate (98.88%) was exhibited from highest dose of NPS (150 kg ha⁻¹), which was statistically at par with 100 kg of NPS ha⁻¹ (97.87%) while the lowest plant stand count (81.58%) was obtained from plots which receive no NPS fertilization (Table 9).

This might be due to the increased NPS level that improves plants growth and development by better up take of all nutrients, increased translocations photosynthetic materials and reduce the mortality of plants due to competition for nutrient which in turn resulted in increasing seed yield. Moreover, the individual increment of different doses of NPS fertilizers had positive effect on the crop stand count which might be due to as nutrient level decreased the proportion of mortality rate of the plant increases due to competition and this competition might have increased the plant mortality. The result of this experiment was in agreement with previous studies of [7] who reported 33 to 34 % increase in stand density of UW85- treated soybean at 28 DAP ha⁻¹.

Hundred Seed Weight

Hundred seed weight was highly significant ($p < 0.01$) affected by NPS fertilizer rate while the main effects of varieties and interaction of both factors were not significant.

The highest hundred seeds weight (4.75 g) was recorded at 100 kg of NPS ha⁻¹ application, which was statistically at par with the application of 150 kg of NPS ha⁻¹ (4.62 g) while the minimum hundred seeds weight

(3.49 g) was recorded from plots which were not fertilized with NPS (Table 9). As the level of NPS increased the hundred seed weight was increased proportionally. This might be because nutrient use efficiency by crop was enhanced at optimum level of NPS since grain weight indicates the amount of resource utilized during critical growth periods. And also due to the supply of phosphorus that increase the formation of seed. In line with this result [33] reported that in mungbean, 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. reported that phosphorus application significantly increased dry matter production and resulted in greater partitioning of dry matter to pods and leads to seed quality and quantity [34]. The result of this experiment also agreed with the finding of [35] who reported that 100 seed weight was increased with increased phosphorus application rate (4.45) on soya bean. Similarly [36] also reported that 100 seed weight in common bean increased with increase in P fertilizer application (69 kg ha⁻¹).

Aboveground Dry Biomass Yield

The study result indicated highly significant ($p < 0.01$) effect of NPS fertilizer application rate on the aboveground plant dry biomass yield of the crop. However, the main effects of varieties and interaction did not show significant effect on the aboveground biomass yield of mungbean (Table 9).

The result generally showed that, an increase in aboveground dry biomass production when NPS application increased from the lowest to the highest rate. The highest dry biomass yield (5769.30 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 (5730.9 kg ha⁻¹) while the lowest dry biomass yield (3786.20 kg ha⁻¹) was obtained at 0 kg NPS ha⁻¹ (control) (Table 9). The increment in the aboveground dry biomass yield due to added phosphorus might be that phosphorus is essential in most metabolic processes that happen above the ground. 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. Reported that total dry matter production per plant increased significantly from 12.0 to 16.03 g due to increased nitrogen application from 40 to 120 kg N ha⁻¹ [13]. Similarly, reported from a field trial conducted at Sardar Krushinagar (Gujarat) that application of 120 kg N ha⁻¹ significantly increased the dry weight (13.06 g) per plant in French bean during the winter season. The interaction of nitrogen and phosphorus increase the aboveground dry biomass. This could be due to the cumulative effect of NP in root, vegetative and reproductive growth and development of beans. Therefore higher biological yield was obtained due to vigor stands, good canopy development and dry matter production in response to NP fertilization. This result was confirm with [38] who found a significant increment in biological yield of common bean with increased rates of NP fertilizers from 0 N kg, 0 kg P₂O₅ to 27 N, 69 kg P₂O₅ kg ha⁻¹ (150 kg DAP).

Table 9. Main effect of NPS fertilizer rates and varieties on stand count, aboveground dry mass, and hundred seed weight of mungbean at Gewane in 2019.

	Stand Count Percent	Aboveground Dry Biomass Mass (kg)	Hundred Seed Weight (g)
Fertilizer			
0	81.58 ^c	3786.2 ^c	3.49 ^b
50	87.93 ^b	4960.2 ^b	3.64 ^b

	Stand Count Percent	Aboveground Dry Biomass Mass (kg)	Hundred Seed Weight (g)
100	97.87 ^a	5730.9 ^a	4.75 ^a
150	98.88 ^a	5769.3 ^a	4.62 ^a
LSD	1.88	452.67	0.29

Varieties

Boreda	91.83	5230.5	4.12
Rasa	91.70	4803.6	4.15
Shewa robit	91.13	5024.2	4.10
NVL-1	91.13	5188.3	4.13
LSD (0.05)	N.S	N.S	N.S
CV (%)	2.47	11.26	8.69

Table 10. Interaction effects of varieties and NPS fertilizer rates on grain yield (kg ha⁻¹) of mungbean at Gewane in 2019.

Varieties	NPS (kg ha ⁻¹)			
	0	50	100	150
Boreda	1196.67 ^{gh}	1430.33 ^{def}	1820.67 ^a	1704.67 ^{ab}
NVL-I	1098.67 ^{hi}	1401 ^{ef}	1562 ^{bode}	1688.33 ^{ab}
Shewa robit	1131.67 ^{gh}	1322 ^{fg}	1602.33 ^{bcd}	1658.33 ^{abc}
Rasa	957.67 ^h	1112.33 ^{hi}	1469.33 ^{cdef}	1483.33 ^{cdef}
LSD (0.05)	196.3			
CV (%)	8.99			

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.

Harvest Index

The main effect of varieties showed highly significant ($p < 0.01$) difference and the main effect of NPS fertilizer application rate showed significant ($p < 0.05$) influence on the harvest index of the crop.

There was an increase in harvest index with an increase of NPS fertilizer rate from 0 to 150 kg NPS ha⁻¹ where the highest harvest index (30.61%) was registered for variety Boreda while the lowest harvest index (27.68%) was recorded for variety Rasa (Table 11). The highest harvest index (28.55%) was registered from 150 kg NPS ha⁻¹, which was statistically at par with 100 kg NPS ha⁻¹ 27.73%), while the lowest harvest index (24.38%) was recorded from plots with no NPS fertilization (Table 12). The reason for low harvest index is due to the enhancement of the biomass yield more than seed yield. This study was in agreement with the study of [32] who recorded that harvest index of black gram was increased up to 25% with increasing N rates up to 30 kg N ha⁻¹. Similarly [39] reported lower value of harvest index (27%) at low level of phosphorus application (85 kg ha⁻¹) to poor development of plants at different growth stages of mungbean.

Table 11. The main effects of varieties and NPS on harvest index of mungbean at Gewane in 2019.

Treatment	Harvest index (%)	Treatment	Harvest index (%)
Varieties		NPS	
		Fertilizer Rate	
Boreda	30.61 ^a	0	24.38 ^b
Rasa	21.85 ^c	50	25.81 ^{ab}
Shewa robit	26.32 ^b	100	27.73 ^a
NVL – 1	27.68 ^{ab}	150	28.55 ^a
	LSD (0.05)	3.02	
	CV (%)	13.64	

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.

III. CONCLUSION

Mungbean is one of the most important pulse crops. The management of fertilizer is an important factor that greatly affects the growth and yield of the crop. Moreover, appropriate management practice that combines high yielding varieties with balanced fertilizers are lacking in the study area. Thus, study was conducted to assess the effects of NPS fertilizer rates on growth, yield components and yield of mungbean varieties; and to assess cost-benefit of different NPS fertilizer rates for production of mungbean. Treatments consisted of factorial combinations of four mungbean varieties (Boreda, Rasa, Shewa robit and NVL-I) with four NPS fertilizer rates (0, 50, 100 and 150 kg ha⁻¹) laid out in RCBD with three replications.

The results of the experiment revealed that the plant height, primary branches, secondary branches, total number of nodules, effective number of nodules, stand count, hundred seed weight, aboveground dry biomass and harvest index were highly significantly (<0.01) affected by the main effects of NPS fertilizer rates. The highest plant height (65.91 cm), secondary branches (9.08), effective number of nodules (15.32), percentage of stand count (98.88%), aboveground bio mass (5769.3 kg ha⁻¹), harvest index (28.55%) was recorded from 150 kg NPS ha⁻¹ which was statistically at par with 100 kg NPS ha⁻¹. The highest number primary branches (5.81), total number of nodules (26.10), highest hundred seed weight (4.75 kg ha⁻¹) was recorded from 100 kg NPS ha⁻¹ which was statistically at par with 150 kg NPS ha⁻¹.

The main effect of the varieties also showed highly significantly difference in harvest index where the highest harvest index (30.61%), was recorded from variety Boreda. The interaction of varieties and NPS fertilization significantly (P<0.05) influenced days to 50% flowering, days to 90% physiological maturity, number of pod per plant, number of seed per pod, and grain yield of mungbean. The maximum number of days to flowering (54.22), physiological maturity (81.22) was recorded from Rasa variety with 150 NPS kg ha⁻¹, which was statistically at par with 100 NPS kg ha⁻¹ with the same variety. Whereas, The highest number pod per plants (26.22), number of seed per pod (12.48) and grain yield (1821.67 kg ha⁻¹) were recorded from Boreda variety at 100 kg ha⁻¹, which was statistically at par with 150 NPS kg ha⁻¹ with the same variety. In contrary, the minimum numbers of days to flowering (40.93 days) and physiological maturity (62.93 days) were recorded from variety

Boreda with the control (0 kg NPS ha⁻¹). The lowest number of pod per plant (12.92), number of seed per pod (12.21) and grain yield (957.67 kg ha⁻¹) were recorded from variety Rasa with the control (0 kg NPS ha⁻¹). Thus, it can be concluded from the result of present study that the use of variety Boreda with application of 100 kg NPS ha⁻¹ could be recommended to enhance the productivity of mungbean in the study area. However, the result of the present study need to be validated and verified in different agro-ecologies and seasons in order to give a comprehensive recommendation for wide range of mungbean production.

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