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Research Article

Response of Haricot Bean (*Phaseolus vulgaris L.*) Varieties to NPSB Fertilizer Rates in Buno Bedele Zone, Southwestern Oromia, Ethiopia

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Abstract

Haricot bean (*Phaseolus vulgaris* L) is one of the most important pulse crops contributing to food security and livelihoods for the majority of farmers in Ethiopia. However, low soil fertility and absence of recovering package practices are major constraints that limit the production and productivity of haricot bean in the study area. Therefore, the study was conducted to determine the optimum NPSB rates and identify the best performing haricot bean varieties that reply successfully to a specific application rate of NPSB fertilizers and select economically viable treatment/s that can increase the productivity of haricot bean. Factorial combination of five levels of NPSB (0, 50, 100, 150 and 200 kg ha^{-1}) and two Haricot bean varieties (SER-119 and SER-125) were laid out in a Randomized Complete Block Design (RCBD) with three replications. The results shown that plant height, number of pods per plant, number of seed per pod, 100 seed weight and grain yield were significantly affected by main effect of varieties. Likewise, number of pod per plant, plant height, and grain yield (1574.9 kg ha^{-1}) were significantly affected by the main effects of NPSB fertilizer rates. The highest net benefit (55357.2 Birr ha^{-1}) and Marginal Rate of Return (358.61%) were obtained from SER-125 variety applied with the combination of 100 kg NPSB ha^{-1}. Therefore, producing haricot bean with the application of 100 kg NPSB ha^{-1} was most productive for economical production. Furthermore, emphasis and consideration are required to the issue in future research studies; since the soil is dominantly acidic, there the limiting macro and micro nutrients in the study area, and therefore, more attention must be given to treating the soil by lime.

Keywords

Haricot Bean, NPSB Fertilizer and Varieties, Yield

1. Introduction

The Haricot bean is one of the utmost vital pulse crops, providing calories, proteins, dietary fibers, minerals, and vitamins to millions of people in both developing and developed countries [1]. It is the highest vital food and cash crops the global [2]. Africa is the third haricot bean grower (21.3% of the world production) after Asia (43.9%) and America (32.2%) [3]. In Africa, the major haricot bean-producing countries include Burundi, DR Congo, Ethiopia, Kenya, Rwanda, Tanzania and Uganda, indicating that East Africa is the most appropriate bean production region on the continent [4, 5].

Haricot bean is the most cash crops and the minimum lim-

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ited protein source for grower in many of Ethiopia. It is also exported to earn foreign exchange [6, 7]. Haricot bean holds great potential for fighting hunger, growing income and refining soil fertility. Haricot bean also has the economic and environmental benefit of associating with nitrogen-fixing bacteria that gives an advantage to fix atmospheric nitrogen and leaving phosphorous (P) for plant growth [8]. There are two main types of beans, red and white. Growers typically farming the red bean types for home consumption, while white haricot beans are produced almost exclusively for the export market [9].

The total production and productivity of haricot bean in the 2021/22 cropping season in Ethiopia were 4,125,926.43 quintals and 17.13 Qt ha^{-1} [10]. The agro-ecologies of Buno Bedele are suitable for farming of haricot bean crop. The area of haricot bean in Buno Bedele 704.79 ha^{-1} with production and productivity of 12,936.34 and 18.35 quintal ha^{-1} respectively [10] which is below the potential yield range of 22-30 quintals ha^{-1} obtained at research stations [11]. The low yield may be due to a combination of numerous production constraints. Among the limitation, improper fertilizer rates and scarcity of improve varieties are main constraint [12] a number of haricot bean varieties have been released in the country.

However, in most cases recommended rates of fertilizer for the released varieties are not available. Selection of best variety with right fertilizer rate is very imperative to improve the productivity of haricot bean varieties. Determination appropriate rates of fertilizer are the main constraint that hinders haricot bean production. Obviously, N and P are not the only yield constraining issues, but others such as S, Zn, B, Fe, Cu and K-deficiency are common soil fertility problems due to characteristic soil fertility status and poor management [13].

To resolve the problem of nutrient deficiency balanced fertilizers containing N, P, S, B, Fe and Zn have been recommended for site specific nutrient deficiencies and thereby increase crop production and productivity. The major newly recommended blended fertilizers for Buno bedele is NPSB [14]. However the best rates of the recommended blended fertilizer for haricot bean crop is not yet identified for study area. However, the evidence on the application rate of blended (NPSB) fertilizer rate for haricot bean production is limited in the study area. Understanding the plant nutrients requirement of a given area has a vital role in enhancing crop production and productivity on a sustainable basis.

Farmers around study area area have been using 100 kg ha^{-1} NPSB fertilizer rate and other growers below 100kg ha^{-1}. Haricot bean differently responded to application of NPSB fertilizers which could be due to genetic variation among the cultivars as haricot bean has high diversity. Therefore, determination of NPSB fertilizer rates to increase haricot bean productivity. According to some informal surveys and information from Bureau of Agriculture and Rural Development, there were no research conducted concerning fertilizers rates and Varieties (Personal communication).

Hence, there is a need to study the effect of different NPSB rates and varieties on the yield components and yield of haricot bean. Selection of best variety accompanied with right fertilizer rate is very important to enhance the productivity of haricot bean varieties. Hence, this study was initiated with the objectives to study optimum and economically feasible NPSB rate for haricot bean varieties in the study areas to increase yield of the crop.

2. Material and Methods

2.1. Description of the Study Area

The experiment was conducted at Dabo Hana and Bure Districts districts during 2022-2023 main cropping seasons. Dabo Hana and Gechi districts are located in Buno Bedele Zone, Oromia Region, Southwest Ethiopia. The relative distance of the Dabo Hana and Gechi districts are 519 km and 475 km away from the capital city of the country, Addis Ababa, respectively. Dabo Hana district is located between 08°30’28.7” to 08°41’34.6”N and 036°26’19.2” to 036°30’41.1” E with altitude ranging from 1791 to 1990 m.a.s.l with minimum and maximum annual air temperatures are 12.9 and 25.8 ℃, respectively [15]. The Gechi district receives an average annual rainfall of 1850 mm with maximum and minimum temperatures of 21^0c and 18^0c, respectively. The predominant soil type in Southwestern Ethiopia in general and the study area in particular, is Nit sols according to the soil classification system [15]. Nit sols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia [15].

2.2. Experimental Materials

The fertilizer material used for this experiment was NPSB (18.1 N, 36.1 P2O5, 6.7S, and 0.71B) and two improved haricot bean varieties (SER-119 and SER-125) were used as a test crop.

2.3. Soil Sampling and Analysis

A typical composite soil sample was taken using auger from a surface layer of 0-20 cm from the whole experimental field prior to planting. The composed soil samples were air dried ground and sieved using 2 mm mesh size sieve for analysis of selected soil physico-chemical properties, i.e. total N, soil pH, available phosphorus, organic carbon, cation exchange capacity and texture analysis. The selected soil physico-chemical properties were analyzed at Bedele Agricultural Research Center Soil Laboratory section.

2.4. Treatments and Experimental Design

The experiment was consist of two improved haricot bean varieties (SER -119 and SER -125) and five different rates of

NPSB fertilizer (0, 50, 100, 150 and 200), plus 100 kg ha^{-1} urea was applied to all plots equally except control. Nutrients amounts in each fertilizer treatment are presented in (Table 1). The experiment was laid out as a Randomized Complete Block Design in a 2 x 5 factorial arrangement and replicated three times per treatment. There were 10 treatment combinations, which were assigned to all plot randomly. The total number of plots is 30 and each plot had a gross plot size of 3 m × 2.8 m = 8.4 m^2. The spacing between blocks and plots were 1.0 m and 0.5 m, respectively. Each plot has 7 rows spaced 40 cm apart. The spacing between plants within row was 10 cm.

Table 1. *Treatments combination for effect of NPSB and Varieties for Haricot bean crop.*

Varieties	Rates NPSB (Kg ha^{-1})	NPSB fertilizer composition (kg ha^{-1})				Combination
		N	P_2O_5	S	B	
SER119	0	0	0	0	0	SER 119
SER119	50	9.45	18.85	3.48	0.05	50 SER 119
SER119	100	18.9	37.7	6.95	0.1	100 SER 119
SER119	150	28.35	56.55	10.43	0.15	150 SER 119
SER119	200	37.8	75.5	13.9	0.2	200 SER 119
SER125	0	0	0	0	0	SER 125
SER125	50	9.45	18.85	3.48	0.05	50 SER 125
SER125	100	18.9	37.7	6.95	0.1	100 SER 125
SER125	150	28.35	56.55	10.43	0.15	150 SER 125
SER125	200	37.8	75.5	13.9	0.2	200 SER 125

2.5. Experimental Procedure and Crop Management

The land was tilled harrowed and leveled manually. The different rates of blended NPSB were applied by drilling in prepared rows before planting. The seeds were planted by hand at a specified spacing (40 cm × 10 cm) by placing two seeds per hill and later thinned to one plant per hill after emergence. Furthermore, all necessary cultural and agronomic practices were carried out uniformly for all plots as per the recommendation for the crop at all stages of growth and development.

2.6. Collected Data

Data's on phonological and growth parameters like days to 50% flowering, physiological maturity and plant height were collected following the standard procedures. Also, yield and yield components parameters like number of pods per plant, number of seeds per pod, hundred seed weight and grain yield were collected.

Days to flowering (Day): The number of days from emergence to 50% of the plants in the plot reaching flowering stage.

Days to maturity (Day): The number of days from sowing up to 50% of the plants in the plot reaching physiological maturity stage.

Plant height (cm): The length from the base of the stem of the main tiller to the tip of the main shoot panicle at maturity was recorded as the average of ten plants per plot and measured in centimeter.

Number of pods (count): all seed contained pods from ten randomly taken plants were counted.

Number of seeds (count): the total numbers of seeds in pods from ten randomly plants were counted.

Hundred seed weight (g): 100 randomly counted seeds from the middle harvestable rows was weighed using sensitive balance.

Grain yield (kg ha^{-1}): the grain yield was measured from the middle harvestable rows using sensitive balance and converted to hectare base.

2.7. Agronomic Efficiency

Agronomic efficiency was calculated in units of yield increase per unit of nutrient applied. The formula for agronomic efficiency for fertilizer application rate AE = Y-Y0/FA *100 Where, Yo = Yield derived from control plot, Y=Yield obtained from application of NPSB $kg^{-1,}$ FA=Fertilizer Applied (NPSB).

2.8. Data Analysis

All composed parameters were subjected to analysis of variance were carried out using Statistical Analysis Software (SAS) version 9.2 [16]. Whenever treatment effects will significant, mean separations, made using the least significant difference (LSD) test at the 5% level of probability.

2.9. Partial Budget Analysis

The partial budget analysis was done following CIMMYT [17] to determine the economic feasibility of fertilizer rates of food barley varieties. The net benefit was calculated as the difference between the gross field benefit (ETB ha^{-1}) and the total costs (ETB ha^{-1}). The average open market price (Birr kg ha^{-1}) of haricot bean and the official prices of NPSB fertilizer were used for analysis. Labor cost for fertilizer application estimated as three, five and seven man per day required to apply 23, 46 and 69 kg Nitrogen ha^{-1} urea, respectively. Each person-day labor cost 75 Birr. Following the CIMMYT partial budget analysis method, total variable costs, gross benefits and net benefits were calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 100% and the highest net benefit is said to be economically profitable [17]. *Marginal rate of return (MRR):* was computed by dividing the marginal net benefit (i.e., the change in net benefits) by the marginal cost (i.e., the change in costs) and multiplied by hundred and expressed as a percentage.

3. Result and Discussion

3.1. Soil Physico-Chemical Properties of the Experimental Site

The result of laboratory shown that the soil texture of the study area is dominated by clay and the textural class of soil of experimental site is clay (Table 2). The soil pH of experimental site is 5.12, which is strongly acidic according to Tekelign [18]. The organic carbon content of the soil is 3.58% which is medium according to the rating of Landon [19]. The medium organic carbon content of the soil might be attributed to the intensive cultivation and continuous removal of crop residues. Thus, amending the soils with organic fertilizers is important for enhancing crop yields as well as soil health. Total nitrogen (0.30%) was medium according to the rating of Landon [19] who classified soil nitrogen content very high (>0.5), high (0.25-0.50), medium (0.15-0.25), low (0.05-0.15) [14]. The available soil phosphorus (0.79 mg kg^{-1}) of the experimental site was very low according to the rating of Bray [20]. Very low available phosphorus could be attributed to the high phosphorus sorption and due to high P fixing capacity of the soil at Bedele area. The CEC of soil were classified as high (20.39 cmol (+) [18]. High CEC of the soil might be due to high soil acidity in the area.

Table 2. *Physico-chemical properties of the experimental site soil before planting of two years in Gechi and Dabo districts.*

	Gechi district				Dabo Hana district	
Soil Characteristics	**2022**	**2023**	**2022**	**2023**	**Value**	**Reference**
Soit texture						
Sand (%)	28.36	30.21	28.36	25		
Silt (%)	21.28	22.64	21.28	23		
Clay (%)	50.36	47.15	50.36	52		
Textural class	Clay	Clay	Clay	Clay		
pH	5.27	4.85	5.38	5.12	Strongly Acidic	Tekalign [18]
OC	3.51	2.85	3.04	3.58	medium	Tekalign [18]
Total N (%)	0.3	0.25	0.26	0.31	Medium	Ethio SIS [14]
Ava P	0.79	0.88	1.04	1.34	very low	Bray [20]
CEC	26	20.6	32.63	30.56	high	Landon et al [19]

3.2. Analysis of Variance

The analysis of variance shown that the main effect of varieties had highly significant (P<0.01) number of seed per pod and 100 seed weight (Table 3). Besides, the main effect of fertilizer had highly significant (P<0.01) effect on days to maturity (Table 3). Besides, main effect of varieties and fertilizer had highly significant of plant height, number of pod per plant, number of seed per pod and grain yield. While the analysis of variance showed that the interaction of varieties and blended NPSB fertilizer rate had not significant (P>0.05) effect on all collected parameters (Table 3).

Table 3. *Effect of NPSB fertilizer rates on phonological, yield, and yield components of Haricot bean varieties.*

SV	DF	DF	DM	PH	NPPP	NSPP	HSW	GY
Rep	2	40.43NS	1276.76NS	556.37NS	83.73NS	0.33NS	5.06NS	28436.37NS
Var	1	8.01NS	0.41NS	1302.58*	656.60**	20.85*	1.02**	8098386.92**
Fert	4	27.55NS	113.17*	238.99*	136.26**	7.26NS	26.78NS	990039.25**
Year	1	0.08NS	3.68NS	15.64NS	1841.30**	634.71NS	1912.01NS	17122312.04**
Var*Fert	4	57.03NS	25.08NS	103.26NS	38.49NS	1.07NS	4.03NS	288733.9NS
Var*Year	1	2.41NS	10.21NS	80.03NS	25.48NS	39.28**	7.02NS	6225.26NS
Fert*Year	4	21.72NS	10.59NS	3.61NS	202.45*	7.12NS	4.03NS	288279.63NS
Error	54	16.87	34.07	91.55	45.74	5.19	17.76	196711.34

Key: SV=Source of variation, Rep=Replication, Var=Variety, Fert=fertilizer= Df= Degree of freedom, DF= Days to flowering, DM =Day to Maturity, PH= Plant height, NPPP= Number of pods per plant, NSPP= Number of seeds per pod, TSW= Thousand seed weight, GY= Grain yield, NS=Non-significant,*=significant and **=Highly significant

3.3. Phenological and Growth Parameters

3.3.1. Days to 50% Flowering (Day)

The results of analysis of variance showed that application of different NPSB rate and varieties did not influenced the days needed to attain at 50% flowering date haricot bean varieties. Even though no statistical different between varieties there was numerical difference. Hence, Varieties 'SER-119 took 42 and SER-125' took 41 days to 50% flowering. The difference between the earliest and the late varieties to reach 50% flowering was one day (Table 3). This difference in day to flowering among the varieties might be due to genetic variation between the cultivars. This result is agreed by that of Tedesse [21] who reported non-significant interaction effects of nitrogen and sulfur on days to flowering of haricot bean.

3.3.2. Days to Physiological Maturity (Days)

Days to physiological maturity was significantly (p<0.01) influenced by the main effect of NPSB fertilizer but not by main effect of varieties and interaction effect. The use of different rates of NPSB fertilizer significantly affected the days needed to attain at physiological development in haricot bean varieties but, the varieties were not significant (Table 3). Increasing the rates of NPSB from nil NPSB ha^{-1} to 200 kg NPSB ha^{-1} lengthy the number of days needed to achieve at physiological development from 65.17 days to 70.08 days (Table 3). The lengthiest number of days required to physiological maturity was recorded with 200 kg NPSB ha^{-1} while the shortest was recorded in control.

The results showed that days to maturity in most cases were prolonged in increased NPSB rates that endorsed vegetative growth. In line with the results, Etana and Nebiyu [22] reported that increasing NPS rate from nil kg NPS ha^{-1} to 100 kg NPS ha^{-1} prolonged the quantity of days needed to arrive at physiological development from 70.56 days to 73.72 days. The prolonged days to physiological maturity in response to the increased levels of blended NPSB can be attributed to the role of nitrogen in the NPSB that promoted vegetative growth. This revealed that the nutrients taken up by plant roots from the soil were used for increased cell division and synthesis of carbohydrates, which will predominantly be partitioned to the vegetative sink of the plants, resulting in plants with a luxurious foliage growth.

Besides, the results showed that days to maturity were generally extended in response to elevated levels of blended NPSB, which can be attributed to the sulfur and nitrogen in the mixed fertilizer, which stimulate enzymatic activity and chlorophyll formation, which increases the amount of solar radiation intercepted, factors that influence growth parameters, foster plant development, and consequently lengthen days to physiological maturity. Besides, application of N also delayed leaf senescence, maintained leaf photosynthesis throughout the active crop growth stage, and prolonged the growth of the vegetative period [23]. Likewise, Etena and Nebiyu [22] reported a positive correlation between delay in leaf senescence and higher yield has been observed in cultivars of haricot bean.

3.3.3. Plant Height (cm)

The main effects of NPSB rate and varieties highly significantly ($p<0.01$) influenced plant height. Conversely, their interaction did not showed a significant influence on plant height (Table 3). Likewise, there was adequate variation imitated by two haricot bean varieties and five different rates of NPSB with respect to plant height (Table 3). The tallest plants were recorded from SER-125 variety (51.44 cm) while the shortest plant was recorded from SER-119 variety (44.86 cm) (Table 4). The difference of plant height between the varieties might be due to genetic variation among the cultivars as haricot bean has high diversity in their physiological growth characters. On the other hand the tallest plant (50.47 cm) was recorded when 100 kg ha^{-1} NPSB fertilizer rate applied statically similar with 200 kg ha^{-1} and 150 kg ha^{-1} and 50 kg ha^{-1} while the shortest plant was recorded from control plot. The tallest plant height might also be ascribed of better root formation due to sulfur, which in turn activated higher absorption of N, P, K and sulfur from soil and improved metabolic activity inside the plant [24]. Similarly, Turuko and Mohammed [25] and Wondimu and Tana [26] also reported that P rate at 0 - 40 kg ha^{-1} had a significant effect on plant height in common bean.

3.4. Yield and Yield Components Parameters

3.4.1. Number of Pods per Plant (Count)

Number of pods per plant was significantly ($p < 0.01$) affected by the main effect of Haricot bean varieties and NPSB fertilizer. However, the study yielded non-significant results attributed to interaction effect between different NPSB rates and varieties with regard to number of pod per plant (Table 3). The result was supported by the earlier works of Etana and Nebiyu [22] who reported that number of pods per plant showed significant difference between different haricot bean varieties.

Hence, the maximum number of pods per plant (27.19) was recorded from SER-125 variety while the minimum number of pods per plant was recorded from SER-119 variety (22.51). The difference was due to genetic makeup of the varieties for producing pods. The result was agree with the finding of Nuru [23] which gained the maximum mean number of pods per plant for the variety Hawassa Dume than varieties red Wolaita and Omo-95. Regarding to fertilizer application, the highest number of seeds per pod (26.41) was recorded with the application of 100 kg^{-1} NPSB fertilizer rate; while the least was (20) recorded from the control (Table 4). A sufficient supply of N, P, S and B may have boosted the development of primary branches and height of the plant, leading to a concurrent production of more pods, which may explain the increase in the number of pods per plant.

The increment may be up to sufficient application of NPSB and decrease number of pod per plant at maximum application of NPSB (200 Kg ha^{-1}). Phosphorus fertilizer also encourages the formation of nodes and pods in legumes which is confirmed by the increase in the number of pods per plant as a result of P fertilizer application. The result is concurrent with Zewude et al [27] result which shown that the number of haricot bean pods per plant (31.37) significantly improved in response to increasing rates of phosphorus up to the highest rates. Besides, the result is also consistent with that of Shumi et al [28] who reported that the number of pods per plant of the haricot bean increased by increasing the rate of NPS fertilizer.

3.4.2. Number of Seeds per Pod (Count)

The number of seeds per pod was significantly ($p<0.01$) affected due to varieties, but not significantly affected due to main effect of NPSB and the interaction of varieties with blended NPSB fertilizer rates (Table 3). The highest number of seeds per pod (7.6) was recorded from the variety SER-125; while the lowest number (5.86) was recorded from variety SER 119 (Table 4). The important difference among the varieties for seed number pod^{-1} might be attributed to their genetic difference than the management. Consistent with the results of this study, Derese [29] observed significant variations in number of seeds per pod among haricot varieties and NPS. Hence, the result was similar with the work of Mourice and Tryphone [30] who showed significant variations in number of seeds per pod among haricot bean varieties.

3.4.3. Hundred Seed Weight (g)

Hundred seed weight was significantly ($P<0.01$) affected due to the main effects of varieties. However main effects of fertilizer application rates and interaction effect were not significant (Table 2). Maximum (30.12 g) and minimum (28.57 g) hundred seed weight were recorded on variety SER-125 and SER-119, respectively (Table 4). This result is agree with the finding of Nuru [23] who reported significant differences in hundred seed weight among haricot bean varieties. Variation in hundred seed weight might have occurred due to the presence of difference in seed size among the common bean varieties as hundred seed weight increases with the increase in the seed size. In line with this result Nuru [23] stated that the number of seeds per pod and weights of hundred seeds were strongly controlled genetically in haricot bean.

Table 4. *Combined Mean of yield related parameters Effect of NPSB Fertilizer Haricot bean Varieties for two consecutive years cropping season at Gechi and Dabo Hana district.*

Varieties	DTF	DTM	PLH	NPPP	NSPP	HSW(g)
SER-119	42	67.77	44.86^{b}	22.51^{b}	5.86^{b}	28.57^{b}
SER-125	41	67.65	51.44^{a}	27.19^{a}	7.69^{a}	30.12^{a}
LSD (0.05)	NS	NS	3.01	4.44	0.35	1.12
NPSB (kg ha^{-1})						
0	42	65.17^{b}	42.67^{b}	20.76^{c}	5.44	28.63
50	43	66.13^{b}	48.89^{a}	24.74^{b}	6.74	29.42
100	43	67.42^{b}	50.47^{a}	26.43^{a}	6.81	27.38
150	43	69.13^{a}	50.03^{a}	26.1^{a}	6.11	27.92
200	43	70.08^{a}	48.69^{a}	26.16^{a}	6.29	29.96
LSD (0.05)	NS	3.17	4.77	3.10	NS	NS
CV %	9.83	8.17	17.31	19.13	26.96	24.42

DTF= Days to Flowering, DTF= Days to Maturity, PLH= Plant height (cm), NP/PL= Number of pod per plant, NS/P= Number of seed per Pod, HSW=Hundred seed weight, LSD= Least significant different, CV= Coefficient of variation, NS= Non-significant

3.4.4. Grain Yield (kg ha^{-1})

Grain yield was highly significantly ($p < 0.001$) affected by both the main effect of different nitrogen rates and haricot bean varieties but their interaction did not have a significant effect (Table 3). Due to the main effects of varieties maximum (1678.67 kg ha^{-1}) and minimum (1159.11 kg ha^{-1}) grain yield was obtained from variety SER125 and SER119, respectively (Table 5). The significant difference among the varieties could be associated with the difference reported for yield components such as plant height (r=0.22*), number of pod per plant (r=0.83**), number of seed per pod (r=0.53**) and 100 seed weight (r=0.43**). Gobeze and Legese (2015) reported significant variations in seed yield among haricot bean varieties due to genotypic variations from haricot bean varieties. Regarding to Fertilizer rates Maximum grain yield (1574.9 kg ha^{-1}) was recorded when was applied (100 kg ha $^{-1}$ NPSB); which was statistically the same results were recorded with fertilizer rates of 150 kg ha^{-1} and 200 NPSB (1570.44 kg ha^{-1}) and 1554.81 kg ha^{-1}) respectively. But, the minimum grain yield 1176.09 kg ha^{-1}) was obtained from the control treatment (Table 4). The increase in grain yield in response to the increased blended NPSB application rate might be because of macro and micronutrients in blended fertilizers rate. Likewise, Arega and Zenebe [31] showed high seed yield (2923.8 kg ha-1) were recorded from the maximum rate of blended NPKSB rate (61.5: 69: 60: 10.5: 0.15 kg NPKSB ha-1) applied.

Table 5. *Combined mean seed yield (kg ha^{-1}) Effect of NPSB Fertilizer Haricot bean Varieties for two consecutive cropping season at Gechi and Dabo Hana district.*

	Gechi		Combine	D/Hana	D/Hana	Combine	Over All
Varieties	2022	2023	2022-2023	2022	2023	2022-2023	
SER-119	1283.30^{b}	1007.54^{b}	1167.66^{b}	1561.3	1040.79	1150.56^{b}	1159.11^{b}
SER-125	1706.50^{a}	1365.87^{a}	1637.30^{a}	1942.1	1250.4	1720.04^{a}	1678.67^{a}
LSD (0.05)	226.5	154.79	253.61	NS	NS	400.7	228.57
NPSB (kg ha-1)							
0	559.90^{c}	904.76^{c}	985.12^{c}	782.10^{b}	799.6	1367.06	1176.09^{b}

Varieties	Gechi 2022	2023	Combine 2022-2023	D/Hana 2022	D/Hana 2023	Combine 2022-2023	Over All
50	1297.60^{b}	1136.91^{bc}	1217.26^{bc}	1710.30^{a}	727.98	1219.15	1218.20^{ab}
100	1777.00^{a}	1137.20^{bc}	1507.44^{ab}	2156.70^{a}	1127.98	1642.36	1574.90^{a}
150	1779.00^{a}	1441.47^{a}	1610.62^{ab}	1956.40^{a}	1104.17	1530.26	1570.44^{a}
200	1960.00^{a}	1312.50^{ab}	1691.96^{a}	2152.80^{a}	718.25	1417.66	1554.81^{a}
LSD (0.05)	357.52	244.76	400.99	696.4	NS	NS	361.4
CV %	19.72	17	24.33	22.67	14.83	25.74	28.51

LSD (0.05)= least significant differences and CV (%)= coefficient of variation, NS=Non-significant

3.4.5. Agronomic Efficiency (%)

Agronomic efficiency was high significantly affected by NPSB rates. The highest agronomic efficiency (399 %) was obtained at application of 100 kg NPSB ha^{-1} while the lowest value (189%) was recorded for 200 kg NPSB ha^{-1} (Figure 1). The increase in agronomic efficiency at lower rate of NPSB application and its decrease at higher rates might be due to the rate of increase in seed yield was lower than the rate of increase in NPSB supply. In line with the result, Devi et al [32] reported decreases in agronomic efficiency with increasing in P supply for common bean.

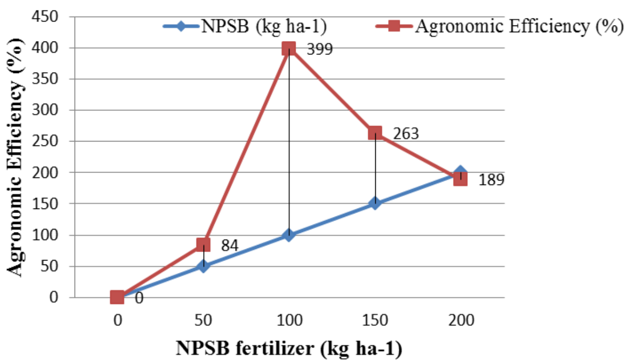

Figure 1. Agronomic efficiency.

4. Partial Budget Analysis

Partial budget analysis revealed that the maximum marginal rate of return was recorded from the application of 100 kg ha^{-1} NPSB with an MRR of 358.61%. According to CIMMYT [17] showed that the minimum rates of return acceptable to farmers were between 50 and 100%. In the current study, the treatment that had between 50 and 100% marginal rate of return was recommended for the growers, with treatments that had a small number of variable costs. The best recommendation for treatments subjected to a marginal rate of return was not necessarily based on the maximum marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit, relatively low variable cost together with an acceptable MRR becomes the recommendation CIMMYT [16]. The partial budget analysis indicated that planting of the variety SER-125 produced the highest net benefit 55357.2 compared to SER 119 (29321.2). Furthermore, compared to other NPSB rates, the highest net benefit (31935.3-birr ha-1) with an acceptable marginal rate of return was obtained when NPSB was applied at the rates of 100 kg ha^{-1} (Table 6). Therefore, the production of the SER-125 variety with the application of 100 kg NPSB ha-1 was the most economical as compared to SER-119 variety.

Table 6. Result of economic analysis for response of Haricot bean grain yield to NPSB fertilizer rates.

Varieties	AGY	GFB	TVC	NB	MRR%
SER-119	366.52	29687.715	366.515	29321.2	-
SER-125	691.97	56049.165	691.965	55357.2	8000
NPSB kg ha-1					
0	1058.481	26462.025	0	26462	-
50	1096.38	27409.5	1750	25659.5	D

Varieties	AGY	GFB	TVC	NB	MRR%
100	1417.41	35435.25	3500	31935.3	358.61
150	1413.396	35334.9	5250	30084.9	D
200	1399.329	34983.225	7000	27983.2	D

Note:- Ad GY = Adjusted grain yield kg ha-1, GB = Gross Benefit, AdSY = Adjusted Straw Yield kg ha^{-1}, TVC = Total Variable Cost; NB: Net Benefit; MRR: Marginal Rate of, D: dominated

5. Correlation Analysis

Plant height showed positive significant (p<0.05) relationship to grain yield (r=0.22*). Besides, number of pod per per plant positive and a highly significant (P<0.01) relationship with number of seed per pod (r=0.69**) and grain yield (r=0.83**). Moreover, number of seeds per pod showed a positive and a highly significant (P<0.01) relationship with grain yield (r = 0.53**). Negative and highly significant (p<0.01) relationship was observed between 100 seed weight and number seeds/pod (r = -0.36**) which agrees with the findings of [28]. Grain yield had a positive relationship with 100 seed weight (r = 0.43**) (Table 7).

Table 7. *Correlation analysis.*

Parameters	Plant height	Number of pod/pant	Number of Seed/pod	100 seed Weight	Grain yield
Plant height	1				
Number of pod per plant	0.17ns	1			
Number of seed per pod	0.16ns	0.69**	1		
100 seed weight	0.17ns	0.19ns	-0.36	1	
Grain yield	0.22*	0.83***	0.53**	0.43**	1

6. Conclusion

Haricot bean farming faces certain challenges in enhancing its production and productivity. Among such challenges, limited information concerning how different Haricot bean Varities reply to numerous nutrient management practices, inadequate availability of improved barley varieties and improper application rates of NPSB fertilizers. Hence, this study was conducted to determine optimum rate of NPSB for Haricot bean varieties to produce better seed yield. Data on phonological, growth, yield and yield components were collected and analysed. According to the present study results, the main effect of NPSB fertilizer rates and varieties were significantly affected plant height, number of pod per plant and grain yield. Similarly, number of seed per pod and 100 seed weight significantly affected only main effect of varieties. While days to maturity was significantly affected by main effect of NPSB fertilizer rates. The interaction of NPSB blended fertilizer rates and varieties had a non-significant effect on all collected parameters. Significantly the highest grain yield (1574.90 kg ha^{-1}) was recorded at 100 kg ha^{-1} NPSB blended fertilizer rate. Varieties were also significantly affected plant height, number of pod per plant and grain yield. From two varieties, SER-125 gave significantly maximum plant height (54.44 cm), number of Pod per plant (27.19) and grain yield (1678.67 kg ha^{-1}). The partial budget analysis revealed that the highest net benefit obtained (55357.2 birr ha^{-1}) and (31935.3 birr ha^{-1}) from variety SER-125 and 100 kg ha^{-1} NPSB fertilizer rate respectively. Thus, the production of SER-125 variety with 100 kg ha^{-1} NPSB fertilizer rate is most productive and economically profitable and can be recommended for the study area. Besides, emphasis and consideration required to the issue in the future research study; since, the soil is dominantly acidic soil, there is the limiting macro and micro nutrient in the study area, and therefore, more attention must be given to treat the soil by lime.

Abbreviations

BeARC	Bedele Agricultural Research Center

CEC	Cation Exchange Capacity
CSA	Central Statistical Agency
CIMMYT	International Centre for Wheat and Maize Improvement
ETB	Ethiopian Birr
EthioSIS	Ethiopian Soil Information System
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agriculture Organization Statistical Database
LSD	Least Significant Difference
Masl	Meters Above Sea Level
MoA	Ministry of Agriculture Ministry of Agriculture
MRR	Marginal Rate of Return
SAS	Statistical Analysis Software

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Conflicts of Interest

The authors declare no conflicts of interests.

References

[1] Pandey, M. and Kumar, N. (2024). Diversity of traditional grain legumes of himalayan region of uttarakhand: A review. Agricultural Reviews. 45(1): 96-102. https://doi.org/10.18805/ag.R- 2362

[2] Wodajo, D., Shimelis, A. and Belay, D. (2021). Geometric characteristics and mass-volume-area properties of haricot beans (*Phaseolus vulgaris* L.) effect of Variety. International Journal of Food Properties. 24(1): 885-894.

[3] Food and Agriculture Organization of the United Nations (FAO). (2023). Faostat. https://www.fao.org/faostat

[4] Buruchara, R., Rowland, C., Sperling, L., Claire, M., Jean-Claude, R., Mutonhi, R. and Mathew M. A. (2011). Development and delivery of bean varieties in Africa: the Pan-Africa Bean Research Alliance (PABRA) model. African Crop Science Journal. 19(4): 227-245.

[5] Tigist, S., Julia, S., Assefa, A. and Gemechu, K. (2023). Agromorphological and physiological performance of Ethiopian common bean (*Phaseolus vulgaris* L.) genotypes under different agroecological conditions. Plants. 12(12): 23-42.

[6] Zebire Asefa, Gelgelo Samuel (2019). Effect of phosphorus fertilizer levels on growth and yield of haricot bean (*Phaseolus vulgaris*. L.) in South Ommo Zone, Ethiopia. Agricultural Science Digest. 39(1): 55-58. https://doi.org/10.18805/ag.A-294

[7] Cholo, M., Marisennayya, S., Bojago, E., Leja, D. and Divya, R. K. (2023). Determinants of adoption and intensity of improved haricot bean (*Phaseolus vulgaris* L.) varieties: A Socio-agronomic study from southern Ethiopia. Journal of Agriculture and Food Research, 13, 100656.

[8] FAOSTAT. Food and Agriculture Organizations of the United Nations. Statistics Division; 2022. https://www.fao.org/faostat/en/#data/QCL

[9] Chilot, Y., Shahidur, R., Befekadu, B., & Solomon, L. (2010). Pulses Value Chain Potential in Ethiopia: Constraints and opportunities for enhancing exports. International Food Pol icy Research Institute (IFPRI).

[10] Central Statistical Agency (CSA). (2022). Agricultural Sample Survey Series: Report on Area and Production for Major Crops (Private Holdings, Main Season). Addis Ababa, Ethiopia.

[11] Asfaw A, Blair MW (2014) Quantification of drought tolerance in Ethiopian common bean varieties. Agricultural Sciences 5(2): 124-136.

[12] Girma W, Yeshialem M, Tsegaye B. (2017) Response of Haricot Bean (Phaseolus Vulgaris L.) to Lime Application and Rhizobium Inoculation on Nitosols at Bench-Maji Zone, Southwestern Ethiopia. J Plant Biol Soil Health.

[13] Ethio-SIS (Ethiopia Soil Fertility Status). 2016. Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples' Regional State, Ethiopia. pp81.

[14] EthioSIS (Ethiopian Soil Information System), (2014). Soil analysis report Agricultural Transformation Agency.

[15] Chimdessa D, "Determination of NPS Fertilizer Rate Based on Calibrated Phosphorus for Maize in Dabo Hana District, Buno Bedele Zone, Western Oromia," vol. 10, no. 4, pp. 105 110, 2022, https://doi.org/10.11648/j.plant.20221004.13

[16] SAS (Statistical Analysis System Institute). 2014. SAS Version 9.4 © 2002-2012. SAS Institute, Inc., Cary, North Carolina, USA.

[17] CIMMYT (International Maize and Wheat Improvement Center). 1988. From Agronomic Data to Farmer Recommendations: An Economics Workbook. Mexico, D. F.: CIMMYT.

[18] Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

[19] Landon JR (Ed.). 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York 474.

[20] Bray and Kurtz. 1945. Determination of total, organic, and available forms of phosphorus soil. science 59(1) 39-45.

[21] Tadesse N, Dechassa N (2012) Effect of nitrogen and sulphur application on yield components and yield of common bean (Phaseolus vulgaris L.) in Eastern Ethiopia. Acad Res J Agric Sci Res 5: 77-89.

[22] Etana, D. and Nebiyu, A. (2023). Response of common bean (*Phaseolus vulgaris* L.) to lime and TSP fertilizer under acid soil. Heliyon, 9(4).

[23] Nuru Seid, 2020. Effect of Blended NPS Fertilizer and Rhizobium Inoculation on Yield Components and Yield of Common Bean (Phaseolus Vulgaris L.) Varieties at Mekdela District, South Wollo, Ethiopia. Academic Journal of Research and Scientific Publishing: 18(2), 2706-6495.

[24] Jawahar, S. V., Vaiyapuri, V., Suseendran, K., Kalaiyarasan C., and Sriramachandra sekharan, M. V. 2017. Effect of sources and levels of sulphur on growth and yield of rice fallow blackgram (Vigna mungo). International Journal of Chemistry, ISSN: 2123-2845(online). http://irjc.petsd.org Accessed on 8 March 2017.

[25] Turuko, M. and Mohammed, A. 2014. Effect of Different Phosphorus Fertilizer Rates on Growth, Dry Matter Yield and Yield Components of Haricot Bean (Phaseolus vulgaris L.). World Journal of Agricultural Research, 2014, Vol. 2, No. 3, 88-92.

[26] Wondimu W, Tana T. 2017. Yield response of common bean (Phaseolus vulgaris L.) varieties to combined application of nitrogen and phosphorus fertilizers at Mechara, Eastern Ethiopia. J Plant Biol Soil Health. 4(2): 7.

[27] Zewde P. 2016. Effect of phosphorous rates on yield and yield related traits of common bean varieties on NitisolsatWolaita Sodo, southern Ethiopia [A Thesis]. Haramaya University, Ethiopia.

[28] Shumi D. Response of common bean (Phaseolus vulgaris L.) varieties to rates of blended NPS fertilizer in Adola district, Southern Ethiopia. Afr J Plant Sci. 2018; 12(8): 164–79.

[29] Deresa S, Demissie A, Tekalign A, Belachew D. Response of Common bean (Phaseolus vulgaris L.) Varieties to Rates of Blended NPS Fertilizer in Adola District, Southern Ethiopia. J Plant Biol Soil Health. 2018; 5(1): 1–10.

[30] Mourice, S. K. and Tryphone, G. M. 2012. Evaluation of common bean (Phaseolus vulgaris L.) genotypes for adaptation to low phosphorus. International Scholarly Research Network Agronomy. ISRN Agronomy, 2012, Research Article.

[31] Arega A, Zenebe M. 2019. Commonbean (Phaseolus Vulgaris L.) varieties response to rates of blended NPKSB fertilizer at Arba Minch, Southern Ethiopia. Adv Crop Sci Technol. 7(3): 429.

[32] Devi, M. J., Sinclair, T. R., Beebe, S. E. and Rao, I. M., 2013. Comparison of common bean (Phaseolus vulgaris L.) genotypes for nitrogen fixation tolerance to soil drying. Plant and Soil, 364(1), pp. 29-37.