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Effect of NPSB Fertilizer Rates on Growth, Yield, and Yield Components of Haricot Bean (Phaseolus vulgaris L.) Varieties at Mid-altitude of Hadiya, Ethiopia

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Abstract

Haricot bean is among the most important pulse crops cultivated in Ethiopia. Nevertheless, its productivity in the country remains far below the genetic potential to be attained. This is partly due to low soil fertility management and a lack of improved varieties. The study was conducted to evaluate the effects of blended NPSB fertilizer rates on growth, yield, and yield components of haricot bean varieties and to identify economically feasible rates of blended NPSB fertilizer at Misrak Badawcho woreda, Hadiya Zone of Southern Ethiopia during the 2019 main cropping season. The treatments have consisted of the factorial arrangements of five rates of blended NPSB fertilizer (0,50,100,150 and 200 kg ha^{-1}) and three varieties of haricot bean (Hawassa Dume, Ibado, and Nasir). These treatments were laid out in factorial combinations using randomized complete block design (RCBD) and replicated three times. Data on phenological, growth, yield and yield components were collected and analyzed. The results of the study revealed that significantly the highest number of pods plant^{-1} (34.26) and plant height (54 cm) were recorded from variety Nasir, the highest number of primary branches plant^{-1} (4.9), number of seeds pod^{-1} (4.7), grain yield (2048 kg ha^{-1}), harvest index (56%) was recorded from variety Hawassa-Dume, whereas hundred seed weight (74.2g) and above-ground dry biomass (4819.67 kg ha^{-1}) were recorded from variety Ibado. The highest number of primary branches plant^{-1} (5.22), plant height (53 cm), number of seeds pod^{-1}(4.38), grain yield (2199.8 kg ha^{-1}), and harvest index (51.22%) were recorded from the maximum NPSB blended fertilizer rate of 200 kg ha^{-1} applied, however, it was statistically at par with rates of 100 and 150 kg NPSB ha^{-1}, while maximum above-ground dry biomass (5462.5 kg ha^{-1}) was recorded from 150 kg NPSB ha^{-1}, however, it was statistically at par with treatment 100 kg NPSB ha^{-1}.

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Partial budget analysis showed that the variety Hawassa-Dume and application of blended NPSB fertilizer rate of 100kg ha^{-1} resulted from maximum net benefit of (28635.3-birr ha^{-1}) and (25127.93-birr ha^{-1}) respectively. Thus, blended fertilizer at the rate of 100 kg NPSB $ha^{-1}$and variety Hawassa-Dume proved to be superior concerning yield and economic advantage for the study area.

Keywords: Blended fertilizer; boron; haricot bean varieties; nitrogen; phosphorus; sulfur Desta Abayechaw.

1. Introduction

Haricot bean (Phaseolus vulgaris L.) is an annual pulse crop with considerable variation in growth habit, vegetative characters, flower color and size, shape and color of the pods and seeds (Onwueme and Sinha, 1991). It is not drought-tolerant; it generally needs moist soil throughout the growing period. However, rainfall towards the end of growing periods is undesirable. It can be grown successfully on most soil types, from light sands to heavy clays, but friable, deep, and well-drained soils are best preferred [1]. Haricot beans have been cultivated as a field crop and are an important food legume produced in Ethiopia [2]. It is considered the main cash crop and protein source for the farmers in many low and mid-altitude zones of the country [3]. In Ethiopia, haricot bean is grown predominantly under smallholder producers as an important food crop and source of cash. It is one of the fast-expanding legume crops that provide an essential part of the daily diet and foreign earnings for most Ethiopians [4]. In addition to the domestic markets, Ethiopia is supplying white beans to the export canning industry in the European Union (EU) and other eastern European markets. The major haricot bean-producing areas of Ethiopia are the central, eastern, and southern parts of the country. Nutritionally, haricot beans contribute greatly to a balanced and healthy diet. This is because the grain has high protein content and good micro-nutrient concentration. Some people say that because of its high protein content, it is a poor man's meat. Moreover, their amino acid composition is useful to complement the amino acid profile of cereal proteins. Thus, the haricot bean is an important crop in addressing the issue of nutrition security in southern Ethiopia where people’s diet is dominated by maize, root, and tuber crops [5]. Crop productivity in the developing world faces several constraints. One of the major constraints is the unavailability of soil nutrients in the appropriate amount and form to crops [6]. Plants need a specific amount of nutrients for a certain period for their growth and development. The roles of both macro and micro-nutrients are crucial in crop nutrition and thus important for achieving higher yields [7]. The drive for higher agricultural production without the balanced use of fertilizers created problems of soil fertility exhaustion and plant nutrient imbalances not only for the major ones but also for secondary macro and micro-nutrients. The deficiencies of secondary macro-and micro-nutrients will arise if they are not replenished timely under intensive agriculture [8, 9, 10]. Low soil fertility is one of the bottlenecks to sustainable agricultural production and productivity in Ethiopia [11]. In this regard, it is important to apply balanced fertilizers to increase productivity [12]. As a result, it enhances sustainable production and provides nutrient needs to crops according to their physiological requirements and expected yields [13, 14]. In the country, the fertilizer management program has been focused mainly on the use and application of nitrogen (N) and phosphorous (P) fertilizers in the form of Di-ammonium phosphate (DAP) (18-46-0) and Urea (46-0-0) or blanket recommendation for the major food crops. Continuous application of N and P fertilizers without due consideration of other nutrients led to the depletion of other important nutrient elements such as potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), and micro-nutrients in soils [15]. Hence, balanced fertilization is the key to sustainable crop production and the maintenance of soil health. It has both economic and environmental considerations. An imbalanced fertilizer use results in low fertilizer use efficiency leading to less economic returns and a greater threat to the environment [15]. Moreover, recently acquired soil inventory data revealed that the deficiencies of most the nutrients such as N, P, S, B, and Zn are widespread in Ethiopian soils and similarly in the study area [16]. However, the information 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. Nevertheless, increasing crop yields through the application of N and P alone can deplete other nutrients [17]. Fertilizers are an efficient exogenous source of plant nutrients [18] since plant growth and crop production require an adequate and balanced supply of nutrients to maximize productivity by optimizing the plant nutrient uptake [19]. Several studies reported that chemical fertilizers are the major nutrient sources to improve crop productivity [20]. In addition, some reports also indicated that the supply of micro-nutrients along with NPK fertilizer can increase the nutrient use efficiency of crops [21]. Balanced application of mineral fertilizer was reported to maximize crop yields and reduce N and P losses to the environment [22]. In contrast, chemical fertilizers specifically DAP and Urea were used for major crop production including haricot bean over decades in Ethiopia. Considering this gap, the Agricultural Transformation Agency (ATA) of Ethiopia suggested the general improvement of the soil fertility management system by considering the inclusion of more nutrients in the fertilizer program. For instance, the ATA suggested some blended fertilizers such as NPS, NPSB, NPSBCu, NPSCu, NPSZnBCu, and K fertilizers for crop production in Ethiopia. According to Ethio-SIS (2016) fertilizer type recommendation map /atlas, eight types of fertilizer blends are identified for southern Ethiopia. Similarly, two types of fertilizers: NPSB and NPSBCu were recommended for Misrak Badawacho woreda. However, there is no detailed investigation in the area to confirm the amounts of fertilizer rate suitable for haricot beans production. Therefore, determination of best yielding haricot bean varieties, the study of crop nutrient sources beyond N and P, especially fertilizers containing S, B, and other macro and micro-nutrients are quite important to increase haricot bean productivity. Thus, the present study attempted to identify the high-yielding haricot bean varieties and to determine NPSB fertilizer rates for growth, yield, and yield components of haricot bean varieties, and to determine the economic feasibility in Misrak Badawacho woreda, of Hadiya Zone of Southern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Misrak Badewaccho Woreda Hadiya Zone of SNNPR, during the 2019 main cropping season. Geographically the Woreda is located at 7°.05’ North and 37-38°. 46’ East. The altitude is ranging from 1580 to 2050 m.a.s.l. The mean annual temperature of the Woreda is 20.1°C and the annual rainfall ranges between 800 mm to 1500 mm, and it is bimodal.

2.2. Treatments and Experimental Design

The study consisted of the factorial combinations of five rates of NPSB (0, 50,100,150 200 kg ha^{-1}) blended fertilizer and three haricot bean varieties (Ibado, Nassir, and Hawassa- Dume). The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times

Table 1: Rates of fertilizer and their nutrient content kg ha^{-1}.

No	Blended NPSB Fertilizer rates (kg ha^{-1})	P_2O_5	N	S	B
1	0	0	0	0	0
2	50	37.7	18.9	6.95	0.1
3	100	75.4	37.8	13.9	0.2
4	150	113.1	56.7	20.85	0.3
5	200	150.8	75.6	27.8	0.4

2.3. Soil Sampling and Analysis

Initial soil samples were collected from the experimental field before planting, in a zigzag manner from the experimental site/area from a depth of 0-20 cm using an auger and composited to make one homogenous sample. After manual homogenization, the sample was air-dried and ground to pass 2-mm sieves for laboratory analysis. The soil Physico-chemical parameters analysis was done at Horticoop Ethiopia PLC soil and water Analysis laboratory. Soil texture was measured by bouycouos hydrometer and soil pH was determined by water suspension in a 1:2.5 (soil: water) [23]. Soil organic carbon was determined by [24] method. Total N was determined by Kjeldahl method [24]. Available Phosphorus was determined by the Olsen method [25]. Sulfur was determined by the Turbid metric method. Exchangeable cations and CEC were determined by using ammonium acetate (1N NH4OAc) at pH 7.0 [26]. Born was determined by the hot water extraction procedure.

2.4. Data Collection and Measurement

2.4.1. Phenological data

Days to emergence were recorded as the number of days from the date of planting to the date when 50% of the seedlings in a plot emerged above the ground. Days to flowering were recorded as the number of days from the date of planting to the date when 50% of the plants in a plot produced at least one flower. Days to physiological maturity were recorded as the number of days from planting to 75% of the plants in the plot matured. The yellowness and drying of leaves were used as an indication of physiological maturity.

2.4.2. Growth parameter

The numbers of primary branches per plant were determined as the average number of primary branches that emerged directly from the main shoot from five randomly taken plants at physiological maturity. Plant height was determined as the average height from the ground to the top of the plant of five randomly taken plants from central rows of each experimental plot at physiological maturity. Leaf area index was determined from five sampling plants taken from the central row during mid- flowering. The leaf areas of these sampled plants were measured and the mean of the leaf area was considered as leaf area per plant. Then, the leaf area per plant was divided by land area allocated to one plant to determine the leaf area index.

2.4.3. Yield and yield components

The number of pods per plant was determined as the average number of pods from five randomly taken plants from the net plot area at harvest. To determine the number of seeds per pod, total pods from five randomly taken plants were threshed and the seeds were counted and total numbers of seeds were divided by a total number of pods to compute an average number of seeds per pod. Hundred seed weight (g) was determined by weighing 100 randomly taken seeds from the harvested yield using a sensitive balance and the weight was adjusted to 10% seed moisture content. Above-ground dry biomass (g plant-1) was determined at physiological maturity; five plants from the central 5 rows were randomly taken close to the ground surface. The plant samples were oven-dried at 70oC for 24 hours. Then after the dried samples were weighted by using sensitive balance and the average of the sample weight was taken as above-ground dry biomass per plant. To determine, grain yield (kg ha-1) at harvest maturity, whole plants from the central 5 rows of net plot size 2 x 3m (6 m2) were harvested and threshed manually. The seed yield was adjusted to a moisture level of 10%. Finally, yield per plot was converted to a ha-1 basis and reported as kg ha-1. Harvest index (%) was determined as the ratio of adjusted seed yield to the above-ground dry biomass yield in kg ha-1.

2.5. Data Analysis

The collected data were subjected to Analysis of Variance (ANOVA) using SAS software (version 9.4) and a comparison among treatment means was made using the Least Significant Difference (LSD) test at a 5% level of significance.

2.6. Partial Budget Analysis

The economic feasibility of the blended NPSB fertilizer application for haricot bean production was analyzed based on [27]. The field price of haricot bean that farmers receive from the sale was based on the market price at Shone Market. The price of the blended NPSB fertilizer and best yielding haricot bean varieties at the time of harvest was considered as the price of the respective fertilizers and variety. The total variable cost as the sum of all cost that was variable or specific to treatment was determined against the control. Net benefit was calculated by subtracting total variable cost from the gross benefit of haricot bean.

3. Results and Discussion

3.1. Pre-Soil Physico-Chemical Properties of the Experimental Site

The optimum soil pH for haricot bean growth is reported to be in the range of 5.2–6.8. According to the soil laboratory analysis results, the study area soil was slightly acidic propriety (5.28) with clay loam textural class which is suitable for haricot bean production. Haricot bean is intolerant of poor soil aeration due to soil compaction and can tolerate flooded soil for only about 12 hrs. It can grow on a wide range of soils, from sandy to clay, provided water and drainage are adequate. The results of soil analysis for soil chemical and physical properties such as soil pH, total N, organic matter, available phosphorus, S, B; CEC, and soil texture are indicated in (Table 2).

Table 2: Pre-physico-chemical properties of the soil of the experimental site.

Soil characters	Unit	Value	Rating	References
Acidity(pH)	-	5.28	Slightly acid	[30]
Available phosphorus	mg kg^{-1}	21.84	Low	[30]
Total Nitrogen	%	0.15	Moderate	[30]
Sulfur	mg kg^{-1}	23.07	Moderate	[31]
Boron	mg kg^{-1}	2.42	High	[31]
Organic carbon	%	2.15	Moderate	[32]
CEC	Meq 100-1g	19.34	Moderate	[30]
Texture				
Sand			-	
Clay	%	37	-	
Silt	%	34	-	
Textural class	%	29	Clay loam	

3.2. Effect of NPSB Fertilizer on Phenological Parameters of Haricot bean Varieties

Significant (P<0.001) difference was observed among the varieties of haricot bean in days to 50% flowering (Appendix 1). Varieties 'Ibado' took 44.3 and Nassir' took 50 days to 50% flowering. The difference between the earliest and the late varieties to reach 50% flowering was 5.7 days (Table 3). This difference in days to flowering among the varieties might be due to genetic variation among the cultivars as haricot bean has high diversity in their phenological characters. Days to flowering were also significantly (P<0.05) affected by NPSB blended fertilizer application rate (Appendix 1). Significantly longest days (47.1) to flowering was recorded due to the application of 200 kg ha^{-1} of NPSB fertilizer rate while the earliest days to flowering (46) was recorded for the control (Table 3). The result showed delayed days to flowering with increasing rates of NPSB fertilizer indicating favor of each NPSB nutrient source for vegetative growth. This could be due to the delaying effect of nitrogen obtained from mineral fertilizer. This result agrees with [28]; [29] reported that nitrogen supply for common bean delayed days to flowering by extending the vegetative growth. Days to physiological maturity was significantly (p<0.01) influenced by the main effect of varieties (p<0.05) and blended NPSB fertilizer application, but not by interaction effect (Appendix 1). The highest number of days required to physiological maturity (85.5 days) was recorded for the variety Nassir; while the lowest days to reach physiological maturity (81.7 days) was recorded for variety Hawassa- Dume followed by Ibado (82.6 days). The longest days (85.2) to physiological maturity were recorded due to the application of 200 kg ha^{-1} of NPSB fertilizer rate while the earliest days to physiological maturity (81.56 days**)** were recorded with the application of 50 kg ha^{-1} of NPSB fertilizer rate (Table 3). 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 is in line with the results of [33] who reported that nitrogen promoted vegetative growth and thereby delaying plant maturity of onion. This indicates 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. This result is further corroborated with the finding of [33] who reported delayed physiological maturity due to nitrogen fertilization of up to 80 kg ha^{-1} in common bean.

Table 3: Days to flowering and physiological maturity of haricot bean as influenced by the main effects of varieties and blended NPSB fertilizer application.

Treatments	Days to flowering	Days to physiological maturity
NSPB fertilizer rate (kg ha-1)		
0	46 [c]	82. 1[bc]
50	46.3 [bc]	81. 6[c]
100	46.5[abc]	82. 9[abc]
150	47 [ab]	84. 7[ab]
200	47.1 [a]	85. 2[a]
LSD @0.05	0.7	2.6
Varieties		
Hawassa- Dume	45.46[b]	81.733[b]
Ibado	44.3[c]	82.600[b]
Nassir	50 [a]	85.533[a]
LSD @0.05	0.6	2
CV (%)	1.58	3.3

Means within a column followed by the same letters are not significantly different at 5% least significant difference (LSD); CV=Coefficient of Variation. NPSB=Nitrogen, phosphorus, sulfur, boron.

3.3. Growth parameters

3.3.1. Number of primary branches plant^{-1}

The analysis of variance showed that the primary branches were significantly ($P<0.05$) influenced due to the main effect of variety; while the interaction did not significantly influence the number of primary branches (Appendix 1). Variety Hawassa dume recorded the highest number of primary branches per plant (4.9); while the lowest number of primary branches (4.3) was recorded for variety Nassir. This difference might be due to genetic differences in the production of several primary branches among the varieties (Table 4). The blended NPSB rate had significantly ($P<0.01$) affected the number of primary branches per plant (Appendix 1). Increasing rates of blended NPSB fertilizer from 0 to 200kg ha^{-1} showed a progressive increase in the number of primary branches per plant. Thus, the highest number of primary branches per plant (5.2) was recorded at the highest rate of NPSB application (200 kg ha^{-1}) and it was statistically at par with NPSB rates of 150 kg ha^{-1}; while the lowest number of primary branches per plant (3.8) was recorded from the control (Table 4). The increase in the number of primary branches per plant in response to the increased rate of blended NPSB application indicates higher vegetative growth of the plants under higher N, P, S, and B availability. This result is in line with [34] reported a significantly higher number of branches per plant of common bean with 75 kg P ha^{-1} over the control. The increment in the number of branches with an increased rate of P might also be due to the importance of P for cell division, leading to the increase in plant height and number of branches [35]. Also, in line with [36] reported that the number of branches per plant increased significantly with the increase of N up to 120 kg ha^{-1} on common bean. The increased primary branches observed under blended fertilizer might also be attributed to a readily available form of S that enhanced uptake of nutrients even at the initial stage of crop growth.

3.3.2. Plant height

Analysis of variance showed a highly significant (p<0.01) difference among varieties for plant height at physiological maturity (Appendix 1). The tallest plant (0.54cm) was recorded for variety Nassir while the shortest (0.49cm) was recorded for Ibado (Table 4). The variation in plant height between haricot bean varieties might be attributed to their inherent genetic characters. This result agrees with [37] who reported that plant height difference within common bean varieties. The plant height was also significantly (P<0.01) affected due to the main effect of blended NPSB fertilizer application (Appendix 1). The NPSB rate of 150 kg ha^{-1} gave the highest plant height (0.5cm) but it was statistically the same result were recorded with the rates of 200, 100, 50 kg ha^{-1} and higher than the control (Table 4). This might be due to the positive effect of blended fertilizer nutrients. However, the interaction effect between varieties and blended NPSB fertilizer application rates was not significant.

Table 4: Number of primary branches/plants, and plant height of haricot bean as influenced by the main effects of varieties and blended NPSB fertilizer application.

Treatment	No of primary branches/plant	Plant height
NSPB fertilizer rate (kg ha^{-1})		
0	3.8^{d}	0.46^{b}
50	4.1^{cd}	0.5^{a}
100	4.5^{bc}	0.5^{a}
150	4.9^{ab}	0.5^{a}
200	5.22^{a}	0.5^{a}
LSD @0.05	0.6	0.03
Varieties		
Hawassa- Dume	4.9^{a}	0.5^{b}
Ibado	4.38^{b}	0.49^{b}
Nassir	4.3^{b}	0.54^{a}
LSD @0.05	0.49	0.029
CV (%)	14.5	7.5

Means within a column followed by the same letter are not significantly different at 5% LSD (0.05) least significant difference, CV=Coefficient of Variation. NPSB=Nitrogen, phosphorus, sulfur, boron.

3.3.3. Leaf area index

The leaf area index during the mid-flowering stage was significantly (P<0.05) affected by the interaction effects of haricot bean varieties and blended NPSB fertilizer application rate (and Appendix 1). The highest leaf area index (3.00) was recorded from variety Ibado with 50 kg ha^{-1} NPSB fertilizer; and it was statistically at par with NPSB rates of 150 kg ha^{-1} with variety Nasir and 200 kg ha^{-1} Hawassa- Dume (Table 5). While the lowest leaf area index (1.5) was recorded for the variety Nassir with no fertilizer application**.** The present study revealed that blended fertilizer had a positive impact on the leaf area index of haricot bean varieties. This result is in line with [38] who reported that the leaf area index of common bean increased significantly from 1.6 to 3.1 due to increasing fertilizer rate from zero to 120 kg N ha^{-1}.

Table 5: Leaf area index of haricot bean as affected by the interaction effect of variety and blended NPSB fertilizer rates.

Variety	NPSB Fertilizer rates (kg ha^{-1})				
	0	50	100	150	200
Hawassa Dume	1.9^{e}	2^{cde}	1.9^{cde}	2^{cde}	2.7^{abc}
Ibado	2.2^{bcde}	3^{a}	2.3^{bcd}	2.3^{abcd}	2.3^{abcd}
Nasir	1.5^{e}	2.1^{cde}	2^{cde}	2.8^{ab}	2.4^{abcd}
Lsd(0.05)	0.7				
Cv(%)	16.79				

Means with the same letters are not significantly different at 5% least significant difference (LSD); CV=Coefficient of Variation; NPSB=Nitrogen, phosphorus, sulfur, boron.

3.4. Yield and yield components

3.4.1. Number of pods per plant

The analysis of variance showed a significant ($P<0.001$) difference in the number of pods per plant due to the interaction effects of varieties and blended NPSB fertilizer application rates ($P<0.01$). The application of 200 kg ha^{-1} blended NPSB fertilizer rate for variety Nassir recorded the highest number of pods per plant (34.3) followed by Hawassa- Dume (28.3); whereas the lowest number of pods per plant was recorded for variety Hawassa- Dume with 50 kg ha^{-1} NPSB fertilizer (12.7) (Table 6). The increase in the number of pods per plant with the increased NPSB rates might be due to adequate availability of N, P, S, and B which might have facilitated the production of primary branches and plant height which might, in turn, have contributed to the production of higher number of total pods. This result is in conformity with [39] who reported that the significant effect of N fertilizers on pod production per plant of french bean with the maximum number of pods per plant (25.49). The variation in the number of pods per plant among the varieties might be related to the genotypic variation of the cultivars in producing pods. In line with the results of the present study, different authors reported significant variations in the number of pods per plant for common bean varieties [38, 39].

Table 6: Number of pods per plant of haricot bean as affected by the interaction effect of variety and blended NPSB fertilizer rates.

	NPSB Fertilizer rates (kg ha^{-1})				
Variety	0	50	100	150	200
Hawassa Dume	23.4^{cdef}	12.733^{g}	18.067^{gef}	24.533^{cde}	28.267^{abc}
Ibado		26.6^{bcd}			
Nasir	13.6^{g}		31.867^{ab}	19.533^{defg}	16.4^{fg}
Lsd(0.05)		25.93^{bcd}			
Cv(%)	21.8^{cdef}		21.66^{cdef}	28.46^{abc}	34.267^{a}
	7.31				
	19.0				

Means within a column followed by the same letter are not significantly different at 5% LSD (0.05) least significant difference, CV=Coefficient of Variation. NPSB=Nitrogen, phosphorus, sulfur, boron.

3.4.2. Number of seeds per pod

The number of seeds per pod was significantly ($p<0.001$) affected due to varieties, but not significantly affected due to the interaction of varieties with blended NPSB fertilizer rates (Appendix 2). The maximum number of seeds per pod (4.7) was recorded from the variety Hawassa-Dume; while the lowest number (3.2) was recorded from variety Ibado (Table 7). The significant difference among the varieties for seed number pod-1 might be attributed to their genetic difference than the management. [40] reported that the number of seeds per pod of different common bean genotypes varies in the range of 3.1 to 6 and attributed the difference mainly due to the genetic variation of cultivars. Also, the effects of blended NPSB fertilizer application rate were significant ($P<0.01$) on the number of seeds per pod (Appendix 2). The highest number of seeds per pod (4.4) was recorded with the application of 200 kg-1 NPSB fertilizer rate; while the least was (3.8) recorded from the control (Table7).

3.4.3. Hundred seed weight

Hundred seed weight was significantly ($P<0.001$) affected due to the main effects of varieties. However main effects of fertilizer application rates and interaction effect were not significant (Appendix 2). Maximum (74.2g) and minimum (30.8g) hundred seed weight were recorded on variety Ibado and Nassir, respectively (Table 7). This result is in conformity with the finding of [41] who reported significant differences in hundred seed weight among common 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, [42] stated that the number of seeds per pod and weights of hundred seeds were strongly controlled genetically in field bean (*Pisum ativim*). The higher 100 seed weight for variety Ibado is associated with the size of the seed by [38] who explained that the larger the seed the higher its seed weight.

3.4.4. Above-ground dry biomass yield

The above-ground dry biomass yield of haricot bean was significantly ($P<0.001$) affected due to blended NPSB fertilizer application rates. However, the interaction effect between haricot bean varieties and blended NPSB application rates was not significant (Appendix 2). The maximum above-ground dry biomass (5462.5 kg ha^{-1}) was recorded from 150 kg ha^{-1} while the minimum (3245.83 kg ha^{-1}) and (3182.83 kg ha^{-1}) from the control and 50 kg ha^{-1} respectively (Table 6). Above-ground dry biomass was significantly ($p<0.05$) influenced by the main effect of varieties (Appendix 2). The highest above-ground dry biomass (4819.67 kg ha^{-1}) was recorded for the variety Ibado; while the lowest (3872.83 kg ha^{-1}) was recorded for the variety Hawasa- Dume (Table 7). The increase in biomass yield of varieties across blended NPSB rates could be attributed to the fact that the enhanced availability of N, P, and S significantly increased plant height, the number of pods per plant, and to the overall vegetative growth of the plants that contributed to higher aboveground dry biomass yield. This result was in line with that of [43] who reported that total dry matter production per plant increased significantly from12.0 to 16.03g due to increased nitrogen application from 40 to 120 kg N ha^{-1} on French bean (*P. Vulgaris*). The increment in dry matter yield with the application of blended NPSB fertilizer might also be due to the adequate supply of P from the NPSB that could be attributed to an increase in the number of branches per plant, which increased photosynthetic area and the number of pods per plant.

3.4.5. Grain yield

Grain yield was significantly ($p<0.01$) affected by blended NPSB fertilizer application rates and haricot bean varieties. However, no significant effect was noted due to interaction between varieties with blended NPSB fertilizer rates (Appendix 2). Due to the main effects of varieties maximum (2048.6 kg ha^{-1}) and minimum (1434.3 kg ha^{-1}) grain yield was obtained from variety Hawassa-Dume and Nassir, respectively (Table 7). The significant difference among the varieties could be associated with the difference reported for yield components such as the number of primary branches per plant, number of seeds per pod, and plant height. Accordingly, high yielding variety Hawassa-Dume produced a maximum number of primary branches per plant, and the number of seeds per pod compared to the low yielding varieties Nassir and Ibado. This result agreed with the finding of [43] who reported significant differences in grain yield among common bean varieties for a different rate of NP fertilizer application. Also, [41] reported that the highest and lowest seed yield from the variety Hawassa-Dume and Ibado, respectively due to the response of Phosphorus fertilizer. Grain yield increased from control (no fertilizer application) to the high dose of NPSB fertilizer rates. Maximum grain yield (2199.8 kg ha^{-1}) was recorded when was applied (200 kg NPSB ha^{-1}); which was statistically the same results were recorded with fertilizer rates of 150 and 100 kg NPSB ha^{-1}, but the minimum grain yield (980.7kg ha^{-1}) was obtained from the control treatment (Table 7). 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.

3.4.6. Harvest index

The analysis of variance showed that harvest index was significantly ($p<0.05$) affected due to haricot bean varieties and blended NPSB fertilizer application rate. However, the ANOVA showed no significant effect of interaction between haricot bean varieties with blended NPSB application rates (Appendix 2). The maximum harvest index (56%) was recorded from Hawassa-Dume while the minimum harvest index (35.3%) was recorded from Nassir followed by Ibado(39.3%) which attributed to their genetic difference(Table 7). The result suggested that the applied blended fertilizer leads to more vegetative growth than translocation of the sink in variety Nassir and Ibado as compared to Hawassa-Dume that might have resulted in self-shading thereby reducing the yield. A significant difference in harvest index among varieties was documented by [41]. The increment in harvest index with rates of fertilizer agrees with the findings of [44] who also reported improvement in harvest index values of 31.60, 31.99, and 33.86% due to increasing N level zero to 60 and 120 kg ha^{-1} N ha-1 respectively.

Table 7: Number of seeds per pod, hundred seed weight(g), above-ground dry biomass, grain yield, and harvest index of haricot bean as influenced by the main effects of varieties and blended NPSB fertilizer application.

Treatments	Number of seeds per pod	Hundred seed weight(g)	Above-ground dry biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
NSPBfertilizer					
0	3.8^{b}	44.556	3245.83^{c}	980.7^{c}	29.11^{b}
50	4.1^{ab}	47.556	3182.83^{c}	1611.1^{b}	52.5^{a}
100	4.2^{a}	44.889	4955.83^{ab}	2195.9^{a}	47.63^{a}
150	4.3^{a}	45.222	5462.5^{a}	1895.8^{ab}	37.36^{ab}
200	4.4^{a}	47.444	4385.83^{b}	2199.8^{a}	51.22^{a}
LSD @0.05	0.29	NS	957.22	509.93	16.39
Varieties					
Hawassa dume	4.7^{a}	32.800^{b}	3872.83^{b}	2048.6^{a}	56.07^{a}
Ibado	3.2^{b}	74.200^{a}	4819.67^{a}	1847$^{\mathbf{a}}$	39.33^{b}
Nassir	4.6^{a}	30.8^{b}	4047^{b}	1434.3$^{\mathbf{b}}$	35.3^{b}
LSD @0.05	0.2	2.681	741.46	394.99	12.69
CV%	7.2	7.8	23.3	24.46	38.9

Means within a column followed by the same letter are not significantly different at 5% least significant difference (LSD); CV=Coefficient of Variation; NPSB=Nitrogen, phosphorus, sulfur, boron.

3.5. 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 852.3%. According to [27], most situations indicated that the minimum rates of return acceptable to farmers were between 50 and 100%. In the present study, the treatment that had between 50 and 100% marginal rate of return was recommended for the farmers, 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 highest 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 [27]. The partial budget analysis indicated that planting of the variety Hawassa- Dume produced the highest net benefit (28635.3-birr ha^{-1}) compared to other cultivars. Further, compared to other NPSB rates, the highest net benefit (25127.93-birr ha^{-1}) with an acceptable marginal rate of return was obtained when NPSB was applied at the rates of 100 kg ha^{-1} (Tables 8). Therefore, the production of the Hawassa-Dume variety with the application of 100 kg NPSB ha^{-1} was the most economical as compared to Nassir and Ibado varieties.

Table 8: Partial budget analysis of haricot bean varieties and blended NPSB fertilizer rates in kg ha^{-1}

Treatments	Total variable cost (birr ha-^{1})	Net benefit (birr ha^{-1})	MRR (%)
Varieties			
Nasir	2626.19	11716.81	-
Ibado	2750.07	15719	3230.7%
Hawassa dume	2769.7	28635.3	65798.77
Fertilizer rates			
0	1000	11454	-
50	1980	18480	716.9
100	2760	25127.93	852.3d
150	3540	20536.66	
200	4320	23617.46	394.97

3.6. Correlation analysis

Number of seeds per pod showed a positive and a highly significant ($P<0.001$) relationship with days to flowering ($r = 0.58$). The number of primary branches per plant, plant height had a significant ($P<0.05$) relationship with grain yield ($r = 0.31$). Leaf area index ($r = 0.36$) and number of pods $plant^{-1}$ ($r = 0.37$) respectively. Negative and highly significant ($p<0.001$) relationship was observed between 100 seed weight and number seeds/pod ($r = -0.87$) which agrees with the findings of Kindie [45]. Grain yield had a postive relationship with harvest index ($r = 0.79$) and significant ($P<0.05$) relationship with above-ground dry biomass. It is also clearly observed that the increment in grain yield under this experiment due to NPSB blended fertilizer application has resulted from improvement in total dry matter accumulation, the number of primary branches per plant and number of seeds per pod which is supported by the positive and significant relationship of grain yield with total dry matter accumulation ($r = 0.36$) (Table 9)

Table 9: Correlation analysis

	DF	DPM	NPBP	PH	LAI	NPP	NSP	HSW	AGBM	GY	HI
DF	1	0.4	-	0.45	-	0.34	0.58*	-	-	-	-
DPM		1	0.09^{n}	0.56	0.19	0.23^{n}	0.28^{n}	-	0.26^{nsss}	-	-
NPBP			1	0.25^{n}	0.19	0.13^{n}	0.26^{n}	-	0.19^{ns}	0.31	0.25^{n}
PH				1.	0.36	0.37	0.46	-	0.25^{ns}	0.26	0.19^{n}
LAI					1	0.41	-	0.31	0.28^{ns}	0.28	-
NPP						1	0.23^{n}	-	0.14^{ns}	0.21	0.05
NSP							1	-	-0.11^{ns}	0.12	0.18^{n}
HSW								1	0.32*	0.14	-
AGBM									1	0.36	-
GY										1	0.79*
HI											1

DF=days to flowering DPM= days to physiological maturity PH= plant height LAI= leaf area index NPP= number of pods/plants NSP= number of seeds /pods HSW= 100 seed weight AGBM= above-ground dry biomass GY= grain yield HI= harvest index

4. Conclusion and Recommendation

According to the present study results the main effect of NPSB fertilizer rates was significantly affected on days to flowering, days to physiological maturity, number of primary branches per plant, plant height, number of seed per pod, leaf area index, above-ground dry biomass, grain yield, and harvest index. Significantly the highest days to flowering (47.11), days to physiological maturity (85.1), number of primary branches per plant (5.22), plant height (53.1cm), number of seed per pod (4.38), and grain yield (2199 kg ha-1) were recorded at the highest rate of 200 kg ha-1 NPSB blended fertilizer rate; however, it was statistically at par with treatment 100 kg NPSB ha-1. Whereas the highest above-ground dry biomass (5462.5 kg ha-1) was recorded at 150 kg ha-1 NPSB blended fertilizer rate. Varieties were also significantly affected in many primary branches per plant, plant height, number of seeds per pod, grain yield ha-1, and harvest index. Among the varieties Hawassa-Dume gave significantly the highest number of primary branches per plant (4.92), plant height (50cm), number of seed per pod (4.67), grain yield ha-1 (20486 kg ha-1), and harvest index (56%). The interaction of NPSB blended fertilizer rates and varieties had a non-significant effect on almost all parameters except leaf area Index and the number of pods per plant. The highest number of pods per plant (34.267) for variety Nassir and followed by (28.267) for Hawassa-dume were recorded with the application of 200 kg ha-1 NPSB fertilizer rate. Leaf area index for variety Ibado (3.04) with 50 kg ha-1 NPSB fertilizer rate and for Hawassa-Dume (2.7) with 200 kg ha-1 NPSB rate were recorded. The partial budget analysis revealed that the highest net benefit obtained

(28635.3birr ha-1) and (25127.93-birr ha-1) from variety Hawasa-Dume and 100 kg ha-1 NPSB fertilizer rate respectively.

Therefore, the production of Hawassa-Dume variety with 100 kg ha-1 NPSB fertilizer rate is most productive and economically proftable and can be recommended for the study area.

5. Author Contributions

Ermias. E. was involved in the entire field work, data collection and proposal development, Desta. A. data analysis, writing, and computerization.

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6. Competing Interests

The authors have not declared any conflict of interests

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7. Appendices

Appendix 1:- ANOVA for Days to Emergence, Days to flowering, Days to physiological maturity, Primary branches per plant, Plant height, Leaf area index, and. number of pods per plant

Table 10

Source of variation		Mean squares					
		DF	NSPP	100 SW	AGDBIM	GY	
Replication	2	0.067315ns	19.466ns	524051.67	1132089.799*	556.8^{ns}	
Fertilizer	2	0.371213**	18.9222^{NS}	9302970.00***	2317398.122**		905.29*
Variety	2	10.52297**	9003.8**	3809602.9*	1470771.07**		1820.5*
F ×V	8	0.0944283^{NS}	19.855^{NS}	898476.35^{NS}	201221.88^{NS}		148.8^{NS}

Appendix 2:- ANOVA for, number of seed per pod, 100 seed weight, above ground dry biomass, grain yield, and harvest index

Table 11

Source of variation	DF	Mean squares					
		DPH	PB	PH	LA	NPPP	
Replication	2	0.06^{NS}	0.82^{NS}	0.2948^{NS}	0.000295^{NS}	0.738746*	17.227^{NS}
Fertilizer	4	1.92*	22.92*	2.92**	0.008183**	0.64627**	58.7457*
Variety	2	140.6**	59.48**	1.682*	0.0109**	0.379046^{NS}	121.51**
F ×V	8	0.32^{NS}	5.07^{NS}	0.3178^{NS}	0.002763^{NS}	0.38558*	151.6924**