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Response of Blended NPS Fertilizer Rates on Growth, Yield Attributes and Yield of Faba Bean (*Vicia faba* L.) in Acidic Red Soil Under Limed Condition in Bore, Southern Ethiopia

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Abstract: The main factors limiting yield for faba bean production in the research area include low soil fertility, which is constituted of low accessible P, total N, and S. Five doses of NPS (0, 50, 100, 150, and 200 kg/ha) were used in a field experiment in Bore at the station of the Bore Agricultural Research Centre. The experiment used a randomized full block design with three replications. The study's objectives were to determine economically viable blended NPS rates that boost faba bean productivity as well as to evaluate the impact of blended NPS rates on the yield and yield characteristics of several faba bean varieties. On all investigated parameters, with the exception of days to flowering and harvest index, the results demonstrated a substantial impact of different quantities of blended fertilizer. The maximum value was achieved with 200 kg/ha NPS, with plant height (167.5 cm), days to physiological maturity (197.0), and total biomass (10666 kg ha-1). The greatest value, 150 kg/ha, was achieved by the number of pods per plant (19.62), seeds per pod (3.13), grain production (4278 kg ha-1), and agronomic efficiency (1466%). The best net benefit (105955.8 Birr ha-1) and highest marginal rate of return (993.22%) were both achieved with the application of 150 kg NPS. Therefore, based on soil result and economic analysis production faba bean with the application of 150 kg NPS ha^{-1} was most productive for economical production and can be recommended for highlands of Guji Zone.

Keywords: Blended Fertilizer, Faba Bean, Gebelcho, Nitrogen, Phosphorus, Sulphur

1. Introduction

One of the earliest crops in existence, the faba bean (Vicia faba L.), was probably domesticated in the late Neolithic [23]. It is primarily grown in nine major agro-ecological regions, including the Mediterranean Basin, the Nile Valley, Ethiopia, Central Asia, East Asia, Oceania, Latin America, Northern Europe, and North America [4]. It is the third most significant cool-season food legume in the world after chickpea and field pea.

In Ethiopia, subsistence farmers primarily grow faba beans from June through September [32]. This region supplied 3.53% (or 443, 074.68 ha) of the grain crop area, which was faba bean. The production of pulses made up 9.88%, or 2.672 million tons, of the grain production, and the production of faba beans made up 31.4%, or 0.84 million tons, of the pulses [7].

According to [3] one of the most significant chemical factors influencing soil productivity in the Ethiopian highlands is soil acidity. Due to nutrient deficiencies and the toxicity of aluminum (Al), manganese (Mn), and hydrogen (H) ions to plant physiological processes, soil acidity has a negative impact on soil biodiversity and crop growth [1]. Drew, E. A, Denton et al. [10] Observed that below pH 5.5 (measured in calcium chloride), the quantity of rhizobia is typically less than 100 per gram of soil. Low pH also impacts the population and survival of rhizobia in the soil. Similar to this, Drew, E. A. et al. [10] revealed that field pea fields with pH (CaCl2) less than 4.5 have rhizobia counts of less than 10 per gram of soil.

Despite the potential for using fertilizers to increase yields and farm income, many smallholder farmers lack the resources to do so. The soil fertility mapping research in Ethiopia has revealed that major Ethiopian soils had insufficient levels of K, S, Zn, B, and Cu in addition to N and P, and as a result, they advise using balanced and personalized fertilizers [14]. This highlights the significance of creating alternative methods to supplement the usual N and P fertilizers with NPS that contains S in order to meet the requirement for nutrients in plants.

Thus, the goals of this study were to determine economically viable blended NPS rates that would boost faba bean productivity in southern Ethiopia as well as to evaluate the impact of blended NPS rates on faba bean yield and yield features.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at the Bore Agricultural Research Center, Guji Zone of Southern Oromia, one of the recently created Research Centers of the Oromia Agricultural Research Institute (OARI), for three years in a row during the main cropping season. The site of the Bore Agricultural Research Center lies just off the main road that leads to Addis Abeba via the town of Hawassa, some 8 km north of the town of Bore. The experimental location is located at a height of 2728 m above sea level, between the latitudes of 06°23'55"N and 06°24'15"N and the longitudes of 38°34'45"E and 38°35'5"E. The study area corresponds to the highlands of the Guji Zone, which are known for their heavy rainfall and bimodal rainfall distribution. The second rainy season begins in late November and lasts until the beginning of March, while the first rainy season lasts from April to October. Nitosols (red basaltic soils) and Orthic Aerosols are the two main types of soil. The soil has a clay loam texture and a pH of roughly 5.11, making it very acidic.

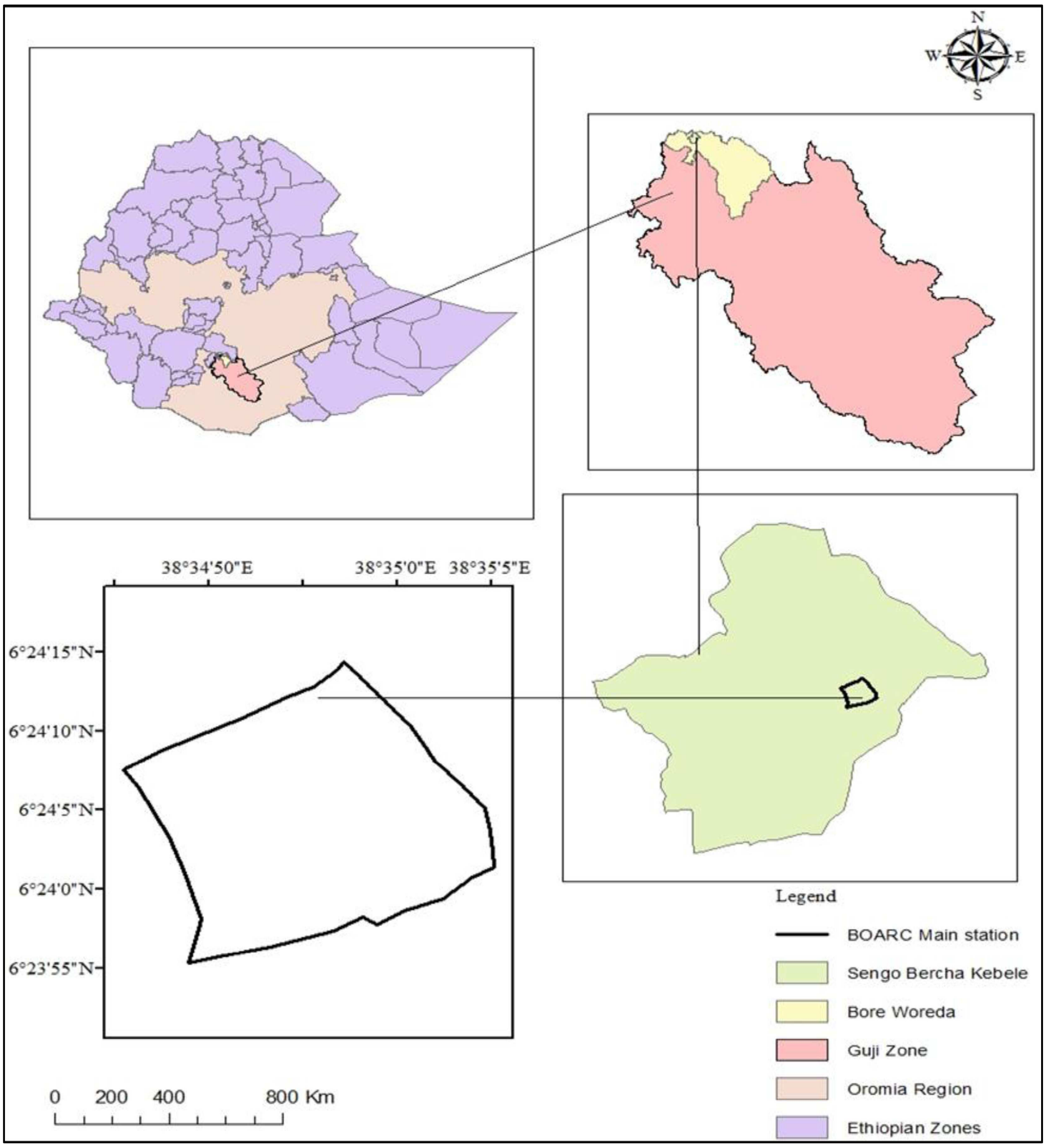

Figure 1. *Description of study area.*

2.2. An Explanation of the Research Materials

The Holeta Agricultural Research Center provided the Gabelcho faba bean cultivar. The kind was introduced in 2006. It has been advised at altitudes between 1900 and 3000 meters above sea level for regions receiving 700-1000 mm of precipitation per year and matures in 103–167 days. On the fields of research stations and farmers, it yields 2500-4400 kg ha-1 and 2000-3000 kg ha 1, respectively. It was chosen due to its greater performance and ability to adapt in the environment.

2.3. Analyzing and Sampling Soil

Pre-planting soil samples were randomly collected in a zigzag pattern from the experimental plots and then analyzed at the soil and water analysis lab of Horticoop Ethiopia (Horticultural) PLC for specific physicochemical properties, primarily textural analysis (sand silt and clay), soil pH, total nitrogen (N), available sulphur (S), organic carbon (OC), available phosphorus (P), and cation exchange capacity (CEC). The Boycous Hydrometer Method was used to determine the soil texture class [2]. Wet digestion was used to measure organic carbon (OC) [31], and organic matter was computed by multiplying the organic carbon percentage by a factor of 1.724. The Kjeldhal technique was used to determine the total nitrogen [18]. With a typical glass electrode pH meter and 1:2.5 soil-water suspensions, the soil pH was determined potentiometrically [30]. Leaching the soil with neutral 1N ammonium acetate allowed for the measurement of Cation Exchangeable Capacity (CEC) [12]. Using a spectrophotometer, available phosphorus was measured according to Olsen's method [26]. Turbidimetric analysis was used to measure the amount of available sulfur (S) [11].

The total nitrogen, phosphorus and sulphur balance were determined according to the following formula:

$$TNB = QNS - QNH \tag{1}$$

$$TPB = QPS - QPH \tag{2}$$

$$TSB = QSS - QSH \tag{3}$$

where TNB: total nitrogen balance, QNS: quantity of nitrogen before sowing, and QNH: quantity of nitrogen at harvest, TPB: total phosphorus balance, QPS: quantity of phosphorus before sowing, QPH: quantity of phosphorus at harvest, TSB: total Sulphur balance, QSS: quantity of sulphur before sowing and QSH: quantity of sulphur at harvest.

2.4. Medications and Experimental Planning

Five blended NPS fertilizer rates (0, 50, 100, 150, and 200 kg ha^{-1}) were used as the treatments. The experiment used a factorial combination of three replications of each treatment in a randomized complete block design (RCBD) design. The plot's overall dimensions were 4 m x 3 m. Blocks and plots were separated by 1.5 m and 1.0 m, respectively. Each plot contained 8 rows that were 40 cm apart. Three plants (30 cm) were planted on either end of each row, with the outermost row on each side of the plot seen as a border. Destructive sampling was performed on one row that was next to the border rows on each side. The net pot size was (2.4 m x 3.4 m = 8.16 m^2) as a result. 30 days prior to planting, 3.84 t ha^{-1} of lime was applied and worked in. Crop management procedures like weeding, thinning, and plant protection techniques were carried out as needed.

Table 1. *Treatments for the experiment's rate of fertilizer and their nutrient content (kg ha^{-1}).*

No	Blended NPS Fertilizer rate (kg ha^{-1})	N	P_2O_5	S
1	0 kg NPS	0	0	0
2	50 kg NPS	9.5	19	3.5
3	100 kg NPS	19	38	7
4	150 kg NPS	28.5	57	10.5
5	200 kg NPS	38	76	14

2.5. Measurements and Data Collection

2.5.1. Growth and Phenological Parameters

Days to flowering: Counted as the number of days from planting and the time when 50% of plants in a net plot produced flowers.

Days to physiological maturity (DTM) were calculated as the number of days from planting to the point at which 90% or more of the plants in a plot had mature pods in their upper parts, with pods in their bottom portions turning yellow. When determining physiological maturity, leaves' yellowness and drying were utilized as indicators.

Plant height was calculated as the mean of the heights (in centimeters) of 10 randomly selected plants from the net plot area between the time of physiological maturity and the apex of each plant.

2.5.2. Yield and Attributes of Yield

Number of pods per plant: At harvest, 10 randomly selected plants from the net plot area were counted for pods, and the average number of pods per plant was noted.

This information was gathered from 10 randomly selected pods from each net plot during harvest.

Test weight (g): 100 randomly selected seeds from each net plot area's total yield were weighed to get the test weight (g), which was then adjusted for 10% moisture content.

Total above-ground dry biomass (kg ha-1): Ten plants were chosen at random when they reached physiological maturity, and the leaves were taken separately before being shaded to prevent loss of biomass. At maturity, the harvestable net plots at the crown were manually harvested for the residual biomass. The leftover biomass harvested at maturity, along with the leaves harvested at physiological maturity, were mixed and air-dried in the sun until they reached a consistent weight. To calculate the above-ground dry biomass yield, the findings were converted to plot basis. The aboveground dry biomass yield per plot was then quantified in kilograms per hectare and expressed as kg ha-1.

Grain yield (kg ha-1): To calculate seed yield, the four central rows were threshed. The seed yield was then adjusted to a 10% moisture level. The average yield was then reported in kilograms per hectare after yield per plot was translated to that basis.

Harvest Index (HI): This was calculated as the difference between the total above-ground dry biomass (kg plot-1) and the seed yield (kg plot-1).

2.6. Agronomic Efficiency

Agronomic efficiency was determined as the yield gain per applied unit of nutrient. Agronomic efficiency for fertilizer application rates 1, 2, and 3 is calculated using the formulas AE1 = Y1-Y0/F1*100, AE2 = Y2-Y0/F2*100, AE3 = Y3-Y0/F*100, and AE4 = Y4-Y0/F4*100. where Yo = Yield derived from control plot, Fertlizer1 = 50 kg NPS ha-1, Fertlizer2 = 100 kg NPS ha-1, Fertlizer3 = kg NPS ha-1, and Fertlizer4 = 200 kg NPS ha-1 Y1 = Yield from 50 kg NPS per hectare, application Y2 = Yield obtained from application of 100 kg NPS ha-1; Y3 = Yield received from application of 150 kg NPS ha-1; Y4 = Yield obtained from application of 150 kg NPS ha^{-1}.

2.7. Analyzing Statistical Data

According to the General Linear Model (GLM) of Gen Stat 18th edition (GenStat, 2012), all measured parameters were subjected to analysis of variance (ANOVA) suited to a factorial experiment in RCBD, and interpretations were produced in accordance with the method outlined by Gomez and Gomez (1984). When the ANOVA revealed significant differences, the Least Significant Difference (LSD) test at the 5% level of probability was utilized for mean comparison.

2.8. Economic Analysis

Following the process outlined by [6] economic was carried out using partial budget analysis, using the going market rates for inputs at planting and for outputs at harvest. The hectare base in Birr was used to calculate all costs and benefits. The mean grain yield for each treatment, the field price of common bean grain, and the gross field benefit (GFB) ha-1 (the sum of field price and mean yield for each treatment) were the concepts employed in the partial budget analysis.

The difference between the gross benefit and the overall cost was used to compute the net benefit (NB). The average production achieved from the experimental plot was decreased by 10% to match the anticipated yield of the farmers treated similarly. Prices for different varieties of grain (in Birr kg-1), such as Gebelcho, were collected from the local market. Using the modified yield, the total sale from one hectare was calculated. Other expenses like the price of fertilizer (3500 Birr per kilogram of blended NPS) and the cost of applying it were taken into account as expenses that differ from treatment to treatment.

3. Results and Discussion

3.1. Physico-Chemical Properties of Experimental Soil

Physical and Chemical Features of the Test Site Clay loam was present in the soil at the experimental site, and its pH value was 5.11 (Table 2). Thus, the soil reaction is observed in strongly acidic to moderately acidic environments, as determined by [20]. Fertilizer application and faba bean planting both raised the pH of the test site's soil. This suggests that the planting of faba beans with and without fertilizer under limed altered the way the soil reacted (Table 2). Crop rotation and N-P addition considerably raised the pH of the soil, according to [29]. According to [11] assessment, the total nitrogen percentage (0.29%) obtained through laboratory testing was optimal. A soil's total nitrogen content (TN) can be categorized as very low (0.1%), low (0.1-0.5), optimal (0.15-0.3), high (0.3-0.5), or very high (>0.5) according to [11]. This classification determined that the soils from the study had upper range total nitrogen content. having a low total nitrogen content (Table 2). The overall nitrogen concentration of the site increased from 3.33% to 6.45% after faba bean planting, both with and without fertilizer application. This may be because the faba bean fixes nitrogen biologically. Legumes in crop rotation boost soil fertility, particularly soil N content, according to [17] and [19]. Cottenie (1980) reported that the experimental site's available P level was just 7.85 mg kg-1 (Table 2). The minimal amount of phosphorus that is readily available may be due to fixation in such acidic soils. Faba bean planting under limed was improved. Phosphorus availability was compared to levels of fertilizer application before and after planting. The soil's ability to store and exchange cations is known as its cation exchange capacity. It acts as a buffer against variations in pH, the availability of nutrients, calcium levels, and soil structure. The findings revealed that the experimental soil's CEC ranged from 24.61 to 27.86 meq/100 g (Tables 2), which corresponds to soils that [20] evaluated as moderate to high.

This soil has a high organic matter content for crop production, a medium degree of nutrient holding capacity, a water holding capacity, and is less prone to leaching losses of Mg^{2+} and K^+. According to [20] the total carbon content of the soil was found to be between 3.04 and 3.16%, which is considered to be high. Thus, according to [11], the soil's OM content was optimal, falling between 5.24 and 5.45%. According to Karltun's (2013) classification of nutrients, soils with sulfur concentrations of >100, 80-100, 20-80, 10-20, and 10 mg/kg fall into the categories of very high, high, medium, low, and very low, respectively. The experimental soil therefore included a medium amount of accessible S, 21.65 to 31.27 mg kg^{-1} (Table 2).

Table 2. *Selected physico-chemical characteristics of the experimental soil before and after faba bean harvest.*

Soil parameters	Soil result at Pre-plant	Post-harvest result of treatments (Blended NPS Fertilizer rate (kg ha^{-1})				
		0 kg	50 kg	100 kg	150 kg	200 kg
pH (1:2.5)	5.11	5.74	4.84	4.92	5.09	5.22
OC (%)	3.04	3.08	3.24	2.77	3.10	3.16
OM (%)	5.24	5.31	5.59	4.78	5.34	5.45
TN (%)	0.29	0.30	0.31	0.30	0.30	0.31
C: N (%)	10.48	10.27	10.45	9.23	10.33	10.19
P (ppm)	7.85	9.29	7.13	11.19	7.56	7.34
S (ppm)	21.65	28.21	12.86	23.64	22.8	31.27
CEC (meq)	24.61	25.6	26.57	25.73	25.36	27.86

3.2. Faba Bean Phenology, Growth, Yield, and Yield Components

Days to flowering, Days to Physiological Maturity, Plant Height, Number of Pods Per Plant, and Harvest Index were not significant (P 0.05) among Fertilizer Rates Application, according to the analysis of variance.

3.2.1. Physiological Maturity

According to the analysis of variance, blended NPS application had a substantial impact on how many days faba beans needed to reach physiological maturity. The number of days needed to reach physiological maturity significantly increased with an increase in blended NPS application rate from 0 to 200 kg ha-1. The variety with the highest mixed NPS treatment rate (200 kg ha-1) required the most days to reach physiological maturity (197 days). The findings showed that days to maturity were often extended in response to higher levels of blended NPS, which is likely due to nitrogen's role in promoting vegetative development. This suggests that the nutrients ingested by plant roots from the soil were used to promote greater cell division and the synthesis of carbohydrates, which will primarily be partitioned to the plants' vegetative sinks, giving rise to plants with lush leaf growth [21].

3.2.2. Plant Girth

The blended NPS rates had a highly significant (P 0.05) impact on plant height at physiological maturity, according to the analysis of variance. According to the data presented in the table below, not all rates of blended NPS fertilizer application resulted in the same plant height. For instance, the highest height (167.5 cm) was achieved when 200 kg ha-1 of blended NPS was applied, but this was not the case when 100 kg ha-1 (166.9 cm) or 100 kg ha-1 (165.2 cm) of NPS were applied. The plant height was generally the smallest for the unfertilized condition (Table 4). The maximal vegetative development of the plants under higher N, P, and S availability may be the cause of the rise in plant height in response to the increased blended NPS application rate. Sulphur boosted the development of chlorophyll and encouraged vegetative growth, phosphorus builds strong roots, and nitrogen aids in the formation of chlorophyll (Halvin et al., 2003). This outcome is consistent with [15] report that phosphorus application in faba bean on acidic Nitisols of the Central Highlands of Ethiopia significantly increased plant height. In a row [8] also noted that phosphorus application up to 40 kg P ha-1 greatly increased faba bean plant height at Bore in addition to this.

3.2.3. Amount of Seeds in Each Pod

The results of the analysis of variance revealed that the main effects of blended NPS application rates and the interaction impact of variety and blended NPS application rates were not statistically significant, indicating that the characteristic is more strongly influenced by hereditary factors than by management. According to [9], a crucial factor that has a direct impact on maximizing the potential for yield recovery in leguminous crops is the quantity of seeds per pod. When a single genotype is taken into consideration, it is likely that the quantity of seeds pod-1 greatly differed between several genotypes and was less affected by outside influences like fertilizer. [33] noted notable variability in the quantity of seeds per pod among genotypes of common beans, which is consistent with the findings of this study.

3.2.4. Yield of Above-Ground Dry Biomass

The application of NPS fertilizer had a significant (P0.05) impact on the output of above-ground dry biomass. As the rate of blended NPS increased, the results generally revealed an increase in biomass production. The application of the maximum rate of NPS fertilizer (200 kg NPS ha-1) followed by 100 kg NPS ha-1 resulted in the largest above-ground dry biomass yield (10666 kg ha-1) while the control NPS rate produced the lowest biomass yield (4045 kg ha-1) (Table 4). The aboveground dry biomass yield was unaffected by increasing the rate of treatment from nil to 50 and 100 kg NPS ha-1. But when fertilizer application rates were increased even further to 150 and 200 kg NPS ha-1, the yield of aboveground dry biomass increased noticeably. Although there was statistical parity between the aboveground dry biomass yields produced in response to the application of 150 and 200 kg NPS ha-1 (Table 4). The fact that the aboveground dry biomass yield significantly increased as the rate of NPS fertilizer application was increased shows that the study area's soil actually lacks natively available N, P, and S due to possible fixation, necessitating the application of external N, P, and S fertilizer. The results of [15], who found that phosphorus administration in faba bean on acidic Nitisols of central Ethiopia's highlands, resulted in a substantial linear response of aboveground dry biomass output. In agreement with this finding, other researchers found that the total aboveground dry biomass yield of faba beans considerably increased in acidic

Nitisols with poor soil phosphorus availability when phosphorus fertilizer was applied [16].

3.2.5. Crop Yield

Blended NPS fertilizer rate had a substantial (P0.05) negative impact on seed production. Statistics showed statistical parity between the seed yields at 150 and 200 kg NPS kg ha-1 (Table 4). The 150 kg NPS ha-1 treatment produced the maximum grain production (4278 kg ha-1) while the control produced the lowest yield (2914 kg ha-1) and was therefore substantially less effective than all other treatments (Table 4). It was therefore reasonable to conclude that the highest yield was already being achieved at the NPS application rate of 150 kg per acre and that no further increase in NPS application would be required.

Table 3. Effects of NPS levels on faba bean development, yield, and yield characteristics at Bore.

Fertilizer rate (NPS kg ha^{-1})	DF	DM	PH (cm)	NPP	SPP	GY (kg/ha)	AGBY	HI (%)
0	65.67	192.7^{c}	161.0^{c}	15.30^{c}	2.83^{b}	2914^{c}	7239^{d}	40.25
50	65.33	193.0^{ba}	162.3^{bc}	15.38^{bc}	2.88b	3293^{b}	8327^{c}	39.55
100	64.67	193.7^{ba}	166.9^{ab}	17.92^{ab}	2.67^{c}	3545^{b}	9349^{b}	37.92
150	64.33	193.7^{ba}	165.2^{ab}	19.62^{a}	3.13^{a}	4278^{a}	10477^{a}	40.83
200	64.67	197.0^{a}	167.5^{a}	19.25^{ab}	2.92^{b}	4080^{a}	10666^{a}	38.25
Mean	64.93	194.08	164.58	17.51	2.88	3622	9211.6	40.25
CV	1.5	1.4	19.49	14.1	3	21.8	7.64	24.6
LSD	NS	1.73	13.43	5.19	0.17	1743.36	9023.45	NS

Means within the same column followed by the same letter(s) are not significantly different at 5% level of significance; DF=Days to flowering, DM=Days to physiological maturity, PH=Plant height, NPP= Number of pods per plant, SPP=Number of seed per pod, GY=Grain yield, AGBY=above ground biomass yield, HI=Harvest index, LSD = Least Significant difference; NS= Not significant; CV= Coefficient of Variation.

The outcome may be explained by the fact that adding NPS fertilizer to soils that are naturally low in NPS or that have been depleted boosts crop growth and yield (Mullins, 2001). The highest seed yield may have been achieved as a result of effective, assimilative partitioning of photosynthates from source to sink in the post-flowering stage, which was caused by higher levels of S, its availability along with major nutrients, and higher crop uptake. This outcome is consistent with that of [8] who noted that NPS administration at a rate of 200 kg NPS ha-1 resulted in increased production and the number of pods per plant when compared to unfertilized plots.

3.3. Agronomic Efficiency

The yield of grain that may be harvested per kilogram of applied nutrients is known as agronomic efficiency. The NPS rates have a large and considerable impact on agronomic efficiency (AE). The application of 150 kg NPS ha-1 resulted in the highest agronomic efficiency (1466%), followed by that of 50 kg NPS ha-1, and the lowest value (504%) was noted for 100 kg NPS ha-1. It is possible that the difference between the rate of growth in seed yield and the rate of rise in NPS supply is what causes the improvement in agronomic efficiency at lower rates of NPS application and its decline at higher rates. This finding is supported by the findings of [16] and [34] who found that as P supply increased, agronomic efficiency decreased.

Table 4. Average faba bean agronomic performance as affected by NPS rate in a limed environment.

Treatment Description	GY (kg ha^{-1})	AE (%)
0 NPS kg ha^{-1}	2914	-
50 kg NPS kg ha^{-1}	3293	758
100 NPS kg ha^{-1}	3545	504
150 NPS kg ha^{-1}	4278	1466
200 NPS kg ha^{-1}	4080	-396

GY=grain yield, AE=agronomic efficiency

3.4. Economic Analysis

The agronomic data must be pertinent to the farmers' particular agro-ecological settings, and the recommendations must be evaluated in a way that is consistent with the farmers' objectives and socio-economic situation [6].

Due to faba bean, application of blended NPS fertilizer, and interaction of variety with application of blended NPS fertilizer, the net benefit was calculated. The economic analysis showed that applying 150 kg of NPS each year produced the largest net benefit (105955.8 Birr ha-1), which was followed by a net benefit of 97288 ETB ha-1, which had a marginal rate of return of 993.22%. Fertilizer application of 200 kg NPS ha-1 resulted in a negative MRR of (-247.65%). The lowest net benefit, on the other hand, was obtained with no fertilizer treatment (75755.4 Birr ha-1; Table 5). The minimum acceptable marginal rate of return must be 100% in order to use the marginal rate of return (MRR) as a foundation for fertilizer recommendations [6]. In line with this outcome, [34] found that applying 150 NPS kg ha-1 to common beans at a 5 cm intra row spacing resulted in the maximum net benefit (46148 ETB ha^{-1}) and marginal rate of return (861.2%). Therefore, the most productive method for producing faba beans economically was to apply 150 kg NPS per hectare.

3.5. Nutrient Balance in the Soil After Cultivation

The results show that, at the end of the experiment, the total nitrogen, phosphorus and sulphur balance in the cultivation soil of most treatments are negative. Indeed, initial nitrogen, phosphorus and phosphorus in the soil were 0.29 ppm, 7.85 ppm and 21.65 ppm of soil respectively. However, at the end of the experiment, the result noted that increase in the initial amount of nutrients in the soil. Thus, the higher amount of total N (0.31) and available S (31.27) at harvest were obtained from 200 kg NPS ha^{-1} respectively. Similarly, the higher amount of total phosphorus (11.19 ppm) at harvest was obtained from 100 kg NPS ha^{-1}. The N and S balance in the crop soils of almost all treatments are positive except 50 kg NPS kg ha^{-1}. Amazing positive P balance was resulted from no and application of 50 kg NPS kg ha^{-1}. This result is further corroborated with the finding of [35] who reported the soil nitrogen balance was generally positive with an increase of 0.326 g N kg^{-1} of soil, which represents a nitrogen input from the mung bean contributing to the improvement of the soil nitrogen status in Burkina Faso.

Table 5. *Total nitrogen, phosphorus and Sulphur balance in the soil.*

Treatment combination	Initial nutrient	Final Nutrient (ppm)			Nutrient Balance (ppm)		
		Final N	Final P	Final S	NB	PB	SB
0kg NPS ha^{-1}	N = 0.29	0.30	9.29	28.21	0.01	1.44	6.56
50kg NPS ha^{-1}	P = 7.85	0.31	7.13	12.86	0.02	-0.72	-8.79
100kg NPS ha^{-1}	S = 21.65	0.30	11.19	23.64	0.01	3.34	1.99
150kg NPS ha^{-1}		0.30	7.56	22.80	0.01	-0.29	1.15
200kg NPS ha^{-1}		0.31	7.34	31.27	0.02	-0.51	9.62

N=nitrogen, P=phosphorus, S=sulphur, NB=Nitrogen balance, PB=phosphorus balance, SB=sulphur balance

Table 6. *Summary of a partial budget study for the effects of faba bean yield and NPS fertilizer application rates.*

Treatment Description	GY (kg ha^{-1})	AGY (kg ha^{-1})	GB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0 NPS kg ha^{-1}	2914	2622.6	76055.4	300	75755.4	
50 kg NPS kg ha^{-1}	3293	2963.7	85947.3	2200	83747.3	420.63
100 NPS kg ha^{-1}	3545	3190.5	92524.5	3950	88574.5	275.84
150 NPS kg ha^{-1}	4278	3850.2	111655.8	5700	105955.8	993.22
200 NPS kg ha^{-1}	4080	3672	106488	9200	97288	-247.65

GY=Grain Yield, ADGY=Adjusted grain yield, GB=gross benefit, NB=Net benefit, MRR=marginal rate of return

4. Conclusion

The two main causes of decreased faba bean productivity are declining soil fertility and low pH (acidity), particularly in highland regions like Bore where frequent rains and chilly temperatures predominate throughout the main growing season. Although the use of mineral fertilizers has had a significant influence on plant growth, soil management techniques that improve nutrient usage efficiency are equally essential for the effective use of applied fertilizers. Liming, the application of manure and crop residues, the rate, observance of the right time and mode of application, cropping patterns, and erosion control techniques are among the management strategies that affect the availability and efficiency of nutrients such as P.

Application of blended NPS fertilizer increased faba bean grain yield compared to control. Therefore, the application of 150 kg NPS ha-1 on faba bean in Bore and other highlands of Guji Zone could be advised given the agronomic responses (agronomic efficiency) and economic analyses. To ascertain the required values of N, P, and S for optimum faba bean yield, more research involving other components is necessary.

References

[1] Achalu Chimdi. 2014. Assessment of Acid Saturation on Soils Collected from Cultivated Lands of East Wollega Zone, Ethiopia. Science, Technology and Arts Research Journal, 3 (4): 42-48.

[2] Anderson, J. M. and Ingram, J. S. I. 1993. Tropical soil biology and fertility. A handbook of methods. 2nd Edition pp. 93-95. CAB International U.K.

[3] Birhanu Angumas, Enyew Adgo and Mekuria Argaw. 2014. Impact of land use types on soil acidity in the highlands of Ethiopia: The case of Fagetalekoma district. Academia Journal of Environmental Science, 2 (8): 124-132.

[4] Bond, D. A., Laws, D. A., Hawtin, G. C., Saxena, M. C. and Stephens, J. S. 1985. Faba bean (Vicia faba L.). pp. 199-265. In: Summerfield, R. J. and Roberts, E. H. (Eds.). Grain Legume Crops. William Collins Sons Co. Ltd., London, UK.

[5] Chilot, Y., T. Agajie, Getachew Agegnehu, Getnet Abebe and Gemechu Keneni. 2002. Crop-livestock farming systems of the highlands of Welmera Wereda: the case of Welmera Goro bench-mark site. pp. 147-174. Towards farmers‟ participatory research: In: Proceedings of Client Oriented Research Evaluation Workshop, Holetta Research Center, Holetta, Ethiopia.

[6] CIMMYT (1988). Agronomic data to farmers' recommendations: an economics training manual. Completely revised edition. Mexico. 27-18-6.

[7] CSA (Central Statistical Agency). 2019. Federal Democratic Republic Of Ethiopia, Agricultural Sample Survey, Volume I Report on Area and Production of Major Crops. Statistical Bulletin 532, Addis Ababa, Ethiopia 12 p.

[8] Demissie A., Nigussie D., and JJ Sharma., 2017. Response of Faba bean (Vicia faba L.) to Rhizobium Inoculation and Application of Mineral Phosphorus Fertilizer in Bore Highlands, Guji Zone, Southern Ethiopia.

[9] 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.

[10] Drew, E. A, Denton, M. D, Sadras, V. O, and Ballard, R. A. 2012 a. Agronomic and environmental drives of population size and symbiotic performance of Rhizobium leguminosarumbv. viciaein Mediterranean-type environments. Crop & Pasture Science, 63: 467-477.

[11] EthioSIS (Ethiopia Soil Information System). 2014. Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Ethiopia.

[12] FAO (Food and Agricultural Organization). 2008. Food and Agricultural Organization. Fertilizer and Plant Nutrition Bulletin. FAO, Rome, Italy.

[13] Gemechu Ejigu and Solomon Tulu, 2021. Effect of NPS Fertilizer Rate and Intra Row Spacing on Growth and Yield of Common Bean (Phaseolus vulgaris L.) at Metu, South western Ethiopia. International Journal of Agriculture Innovations and Research Volume 10, Issue 2, ISSN (Online) 2319-1473.

[14] Getachew Agegnew and Resene Fessehaie. 2006. Response of Faba bean to phosphorus fertilizer and weed control on Nitisols of Ethiopian Highlands. *Italian Journal of Science/Review Agronomy*, 2: 281-290.

[15] Getachew Agengew and Angaw Tsige. 2006. The role of Phosphorus fertilization on growth and yield of faba bean on acidic *Nitisol* of central Ethiopia. *Ethiopian Journal of Science*, 29 (2): 177-182.

[16] Girma, A., Demelash, A. and Ayele, T., 2014. The Response of Haricot bean varieties to different rates of Phosphorus at Arbaminch, southern Ethiopia. ARPN Journal of Agricultural and Biological Science, 9 (10), pp. 344-350.

[17] Holford ICR and Crocker GJ (1997). A comparison of chickpeas and pasture legumes for sustaining yields and nitrogen status of subsequent wheat. Australian Journal of Agricultural Research 48: 305-315.

[18] Jackson, M. L. 1958. Soil chemical analysis Prentice-Hall. Inc. Sixth printing Department of Soil Science, University of Wiscosin, Madison. P. 496.

[19] Kumar VDK, Dart PJ and Sastry PVS (1983). Residual effect of pigeon pea (Cajanus cajan) on yield and nitrogen response of maize. Experimental Agriculture 19: 131-141.

[20] Landon, J. R., 1991. Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p. OR John Wiley & Sons Inc., New York.

[21] Marschner, P. 2012. *Marschner's Mineral Nutrition of Higher Plants. 3rd Edition*, Academic Press, San Diego, ISBN: 9780123849052, P. 651.

[22] Mehlich, A. 1984. Mehlich-3 Soil Test Extractant: A Modification of Mehlich-2 Extractant. *Communications in Soil Science and Plant Analysis*, 15 (12): 1409- 1416.

[23] Metayer N. 2004. Vicia faba breeding for sustainable agriculture in Europe. Gie feverole.

[24] Mullins, G. 2001. Phosphorus, Agriculture and the Environment. Virginia Cooperative Extension, Virginia state university. No: 424-029.

[25] Mussa Jarso, Dereje Gorfu and Gemechu Keneni. 2008. Procedures of Faba Bean Improvement through Hybridization. Technical Manual No. 21, Ethiopian Institute of Agricultural Research. pp 48.

[26] Olsen, S. R., Cole, C. W., Watanabe, F. S. and Dean, L. A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *Soil Sci*ence, 96: 308- 12.

[27] Singh, A. K., Chandra, N., Bharati, R. C. and Dimree, S. K. 2010. Effect of seed size and seeding depth on Fava bean (Vicia fava L.) productivity. Environmental Ecology, 28 (3): 1722-1527.

[28] Street K., Ismail A. and Rukhkyan N. 2008. Regeneration guidelines: faba bean. In: Dulloo M. E., Thormann I., Jorge M. A. and Hanson J., editors. Crop specific regeneration guidelines (CD-ROM]. CGIAR System-wide Genetic Resource Programme, Rome, Italy. 9 pp.

[29] Tolera A, Daba F and Friesen DK (2009). Effects of Crop rotation and N-P Fertilizer Rate on Grain Yield and related characteristics of Maize and Soil Fertility at Bako Western Oromia, Ethiopia. East African Journal of Science 3: 70-79.

[30] Van Reewijk, L. P. 1992. *Procedures for Soil Analysis (3rd edition)*. International Soil Reference Center, Wageningen, Netherlands, 371p.

[31] Walkley, A. and Black, C. A. 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sciences*, 37: 29-34.

[32] Yirga Weldua, Mitiku Haileb and Kiros Habtegebrie. 2012. Effect of zinc and phosphorus fertilizers application on yield and yield components of faba bean (Vicia faba L.) grown in calcaric cambisol of semi-arid northern Ethiopia. Journal of Soil Science and Environmental Management, 3 (12): 320-326.

[33] 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.*

[34] Gemechu Ejigu and Solomon Tulu 2023. Effect of NPS Fertilizer Rate and Intra Row Spacing on Growth and Yield of Common Bean (Phaseolus vulgaris L.) at Metu, South western Ethiopia. International Journal of Agriculture Innovations and Research Volume 10, Issue 2, ISSN (Online) 2319-1473.

[35] Rasmata Nana, Ma¨ıga Oumar, Nerbe´wende´ Sawadogo, and Mohamed Loure. 2023 Agrophysiological Performance of Mungbean Accessions (Vigna radiata (L.) R. Wilczek) and Nitrogen Balance under Mungbean in Burkina Faso. International Journal of Agronomy.