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RESEARCH ARTICLE

Effects blended NPSB fertilizer on faba bean (*Vicia faba* L.) yield in selected districts of North Shewa zone, Oromia, central highlands of Ethiopia

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Abstract

The Faba bean (*Vicia Faba* L.) is a well-known legume crop in Ethiopia and the North Shoa district. In order to assess the impact of Faba bean varieties on blended NPSB fertilizer levels, an experiment was carried out in the districts of Girar Jarso and Degam in the main cropping season of 2022 on a farmer's training center and farmer's field, respectively. A randomized complete block design was used to set up a factorial combination of three improved varieties (Numan, Alloshe, and Gora) with one local variety, four NPSB fertilizer levels (0, 60, 120, and 180 kg ha^{-1}) and three replications. The findings showed that above ground biomass, grain yield, straw yield, harvest index, number of branches per plant, number of pods per plant, number of seeds per pod, days to flowering, days to maturity and plant height were significantly (P 0.001) affected by the main effects of NPSB and variety. At the NPSB rate of 120 kg ha^{-1} the maximum plant height of 45.58 cm, the number of pods per plant of 23.43, the number of seeds per pod of 63.23, the grain yield of 3527.17 kg ha^{-1} and the straw yield were all achieved. Additionally significantly (P 0.001) impacted by the fertilizer and variety interaction were the plant height, branch count, pod count, seed count, above-ground biomass, grain yield, straw yield, and harvest index. The highest grain yield (4060.33 kg ha^{-1}) and harvest index (60.50%) were obtained with rates of 120 kg NPSB ha^{-1} and the cultivar Alloshe. According to the partial budget analysis, Alloshe's use of 120 kg NPSB ha^{-1} produced the highest net return (196,787.8 birr ha^{-1}) and MRR (677.7%). Based on the findings of this study, it can be inferred that the production of Faba Beans in the study region is suitable for the Faba bean variety Alloshe and the NPSB rate of 120 kg ha^{-1}.

Keywords: Economic feasibility; NPSB; Variety; Fertilizer; Crop; Grain yield, Straw yield

Introduction

The faba bean (*Vicia faba* L.), one of the first cultivated edible legumes, was farmed by people in Israel (lower Galilee: Ahihud, Nahal Zippori, and Yiftah'el) 10,000 years ago. Before grain was grown in the area, it was a staple food (Caracuta et al. 2015; Brasier et al. 2023). Around 5,000 BC, shortly after it was domesticated, the crop is thought to have been transported from the Middle East to Ethiopia *via* Egypt (Duc et al. 2010; Westphal, 1974). Although the Central Asian and Mediterranean regions have been suggested as potential centers, its precise geographic origin is unknown (Norman, 1963). After the people's republic of China, the nation is the second largest producer of faba beans in the world (Temesgen et al. 2015; Kassa et al. 2021). In Ethiopia's highlands between 1800 and 3000 masl, where the soil and climate are thought to be conducive to the crop's superior growth and development, it is a significant pulse crop (Kubure et al. 2016; Dobocha et al. 2019). The nation is currently regarded as one of the centers for secondary faba bean diversity (Yohannes 2000).

According to Iannotti, et al., Faba Beans are a good source of dietary fiber, protein and essential amino acids. They are also easily digested and contain low amounts of anti-nutritional components. For the impoverished in Ethiopia who cannot afford animal protein, its edible seed serves as a necessary protein supplement to the cereal-based diet (Bakry et al. 2011). These characteristics make Faba Beans a potential source of high quality human diet protein. Due to its ability to fix nitrogen, it is also a viable crop for rotation with other key cereal crops grown in the country, such as teff, wheat, barley etc. (MoA 2014). The crop provides farmers with income as well as Ethiopia with foreign currency (Asnakech et al. 2016; Gemechu et al. 2016; Tewodros et al. 2015). However, its share in the country's pulse export is small (Newton et al., 2011).

Faba bean yield is typically lower than the world average despite its many benefits due to a variety of reasons, such as poor crop management techniques, a lack of high-yielding cultivars, stress brought on by harsh weather conditions, and insufficient soil fertility (Brink et al. 2006). Ethiopia's national average production of faba beans is 2.12 tons ha^{-1}, which is quite low when compared to Egypt's 3.47 tons ha^{-1} and the

United Kingdom's 3.83 tons ha^{-1}. The annual mean faba bean grain output, according to CSA, is 2.12 tons ha^{-1} which is relatively low when compared to the crop's potential yield of 4.4 tons ha^{-1} (Wondafrash et al. 2019).

The low yields of faba beans in Ethiopia are mostly caused by climatic, edaphic, biotic, insect and weed variables as well as poor agronomic techniques. The on-farm average yield of newly released faba bean varieties can reach 3.5 tons ha^{-1}, according to the national planning commission, demonstrating that there is a sizable yield difference between farmer managed and researcher managed plots.

According to, inadequate soil fertility management, a lack of better cultivars for the various agro ecological zones and early and improper field activities are the main contributors to the nation's low crop production. In addition to N and P deficiency, K, S, B and Cu deficiency have been found in important Ethiopian soils by soil fertility mapping. Additionally, it was discovered that the soils under study lacked essential soil nutrients like N, P, K, S and B. According to Fanuel, et al. each site experienced different nutritional inadequacies. Therefore, using a tailor made and balanced fertilizer application can aid in solving the issue.

Additionally, for the best tuber development and nitrogen fixation, legumes like kidney beans need particular Rhizobium strains (Redmon and Smith 2004). Nutritional imbalances and poor nodulation are the key issues with mung bean cultivation (Merkebu 2019). In order to increase yield and enhance soil quality, legumes should be infected with the proper bacteria (Thakur and Panwar 1995).

The standard prescription of 100 kg ha^{-1} DAP, which contains only 18 kg N and 46 kg P2O5 ha^{-1} is used by farmers in Ethiopia's central highlands. However, recent data on soil inventories from Ethio-SIS (the Ethiopian Soil Information System) revealed that, in addition to N and P, widespread nutrient deficiencies in many regions of Ethiopia also include K, S, B and Zn (Bezabih 2018). As a result, primary nutrient fertilizers have moved away from DAP and toward mixed formulations, which also include secondary and micronutrients. Therefore it is essential to maintain soil fertility and use plant nutrients in sufficient and balanced amounts in order to increase crop yield (Diacono et al. 2013).

So, this study was commenced with the following objectives:

- To evaluate the effects of blended (NPSB) fertilizer on yield and yield components of faba bean varieties,
- To estimate the partial budget analysis of NPSB fertilizer rate for faba bean production.

Materials and Methods

Description of the study area

The experiment was executed at the Farmer's Training Center (FTC) and farmer's fields in the GirarJarso and Degem districts of the North Shewa Zone during the 2022 main cropping season, from June to December, at specific sites in Kotichosafani and Anokare, respectively. In central Ethiopia, Koticho Safani is situated 6 kilometers south of the neighboring town of Fiche and 106 kilometers north of Addis Abeba. Its elevation above sea level (masl) is 2,784 meters and its coordinates are 9° 76' 67" north latitude and 38°C 73' 33" east longitude. The 8.19°C and 20.42°C, respectively, are the area's average minimum and highest temperatures. The pH value of the soil at the experimental site is 5.88 and it has a clayey texture with 16% sand, 66% clay and 18% silt. It also has a high organic matter level of 3%-5% (Dugassa 2018). Climate data from 2002 to 2018 showed that the region experienced 1126.65 mm of annual rainfall on average, most falling between April and September with peaks in July and August. Anokare is located in central Ethiopia 129 kilometers north of Addis Abeba and 5 kilometers east of the neighboring town of Hambiso. It is 3,086 masl and situated at 9° 81' 83" north latitude and 38° 63' 33" east longitude. In addition, clay soil and a pH of 6 characterize the region, which has typical temperatures that range from 8.17°C to 20.41°C. Data from the Ethiopian meteorological agency (2002–2018) show that the country experiences a mean annual rainfall of 883.18 mm, most of which falls between June and September during the growing season.

Planting material

A total of four accessions of Faba bean (*Vicia faba* L.) three released varieties and one local variety (for comparison purposes) was used as the planting material for this study. The Kulumsa Agricultural Research Center (KARC) and Sinana Agricultural Research Center (SARC) provided the released cultivars and Tab. 1 provides thorough descriptions of each.

Fertilizers materials

The blended NPSB fertilizers (18.9% of N, 37.7% of P2O5, 6.95% of S and 0.1% of B) were used for the experiment.

Table 1. Description of Faba bean varieties

S/N	Variety	Pedigree	Methods of development	Year of release	Growth habit	Adaptation area (masl)	Seed size	Productivity (ton/ha)		Breeder/ maintainer
								On station	On farmers field	
1	Numan	EH06007-2	Hybridization	2016	Indeterminate	1800-3000	Large	3.6-5.1	2.2-3.8	KARC
2	Alloshe	EH03043-1	Introduction	2017	Indeterminate	2300-2800	Large	4.4-5.0	3.5-4.1	SARC
3	Gora	EH01024-1-2	Hybridization	2012	Indeterminate	1900-2800	Large	3.0-5.0	2.0-4.4	KARC
4	Local									

Experimental design and field management

The treatments were set up in factorial four levels of NPSB (0, 60, 120, and 180 kg ha^{-1}) and four faba bean accessions using RCBD with three replications (Tab. 2). The accessions were hand drilled at both locations during the third week of June 2022 at a seed rate of 20 seeds per row. Each plot has four rows that are each 2 m long, with 0.4 m between rows and 0.1 m between plants. The data was gathered using two central rows. NPSB was applied to the soil in full doses at the time of sowing. The agronomic cultural practices were implemented in line with the recommendation adopted for the area.

Table 2. Shows the nutrient contents of NPSB kg ha^{-1}

S/N	Treatments	Total composition of the respective nutrients in the treatment (kg ha^{-1})			
	Fertilizer levels	N	P_2O_5	S	B
1	0 NPSB	0	0	0	0
2	60 NPSB	11.34	22.62	4.17	0.06
3	120 NPSB	22.68	45.24	8.34	0.12
4	180 NPSB	34.02	67.86	12.51	0.18

Data collection

The faba bean descriptors served as the foundation for collecting the following data on a plot or plant basis.

Crop phenology

Days to 50% Flowering (DF): The number of days taken by each accession from the day of sowing to the day on which 50% of the plants in the harvestable rows of a plot opened their first flower in the plot.

Days to 90% Maturity (DM): The number of days from sowing to the stage when 90% of the plants in a plot reach physiological maturity, *i.e.,* when the plants become yellow (showing signs of senescence).

Growth parameter

Plant Height (PH): The height of the plant measured in centimeters from the ground surface to the tip of the main guide from five plants randomly selected from each plot at physiological maturity and averaged.

The Number of Branches Per Plant (NBPPL): Numbers of branches per plant were counted on five randomly taken plants and the average was used.

Yield and yield components

The Number of Pods Per Plant (NPPPL): Is the numbers of fertile pods were counted from five randomly selected plants and averaged.

The Number of Seeds Per Pod (NSPP): Is the total number of seeds per plant divided by the total number of pods on the same plant and averaged over five plants taken randomly from each plot.

Above Ground Dry Biomass Yield (AGBM) (kg ha^{-1}): At maturity, the whole plants from each plot were harvested to determine the aboveground dry biomass yield after sun drying to a constant weight. The dry biomass was then converted into kg ha^{-1}.

Grain Yield (GY): The seed yield in grams per plot was measured and then converted to kilograms per hectare (Kg ha^{-1}) based on 10% seed moisture content.

Harvest Index (HI): The harvest index was calculated by dividing the grain yield per plot by the total above ground dry biomass yield per plot.

Thousand Seed Weight (TSW): The weight of a thousand seeds taken at random from each plot's harvested seed lots and measured at 10% seed moisture content and expressed in gram.

Straw yield (Kg ha^{-1}) straw yield was calculated as the difference between above ground biomass and grain yield.

Partial budget analysis

Utilizing the technique outlined in CIMMYT, the economic analysis was conducted using the market prices that were in effect at the time of planting and harvest. To account for the discrepancy between the experimental yield and the yield that farmers may anticipate from the same treatment, the actual yield of grain and straw was reduced by 10%. In Birr, all expenses and benefits were computed per hectare. The product of the field price and the mean yield for each treatment is known as the Gross Field Benefits (GFB) (ETB ha^{-1}).

Total Variable Cost (TVC) (ETB ha^{-1}) is the total of the NPSB and application expenses. Each variable had the following cost: In June 2022, the labor cost for applying NPSB was 7 persons ha^{-1}, or 150 ETB day-1, while the cost of blended NPSB was 36.00 ETB kg^{-1}. The costs of other inputs and production practices, such as the cost of seed and labor costs for land preparation, planting, weeding, harvesting and threshing, were considered the same for all treatments or plots. In December 2022, during harvest season, the open price of faba bean grain at Fiche market was an average of 54 ETB kg^{-1} while the price of straw was an average of 2 ETB kg$_{-1}$. The net benefit (NB) was calculated as the difference between the gross benefit and the Total Cost that Varies (TCV) using the formula NB=(GY x P)–TCV where GY x P=Gross Field Benefit (GFB), GY=adjusted grain yield ha^{-1} and P=field price per unit of the crop. The net income realized after paying a unit cost for fertilizer is referred to as the marginal rate of return. The marginal rate of return (MRR) was computed using the method for each pair of ranked treatments based on net income.

$$MRR (\%) = (\frac{NBb-NBa}{TVCb-TVC\ a}) \times 100$$

Where:

NBa: The immediate lower NB

NBb: The next higher NB

TVCa: The immediate lower

TVC and TVCb: The next highest TVC

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. Dominant treatment is any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits). The selected and discarded treatments using this technique were referred to as undominated and dominated treatments, respectively. Then the treatment with the highest net benefit and marginal rate of more than 100% was considered for the recommendation, as described by CIMMYT (1988).

Data analysis

To ascertain the variations among the accessions, Analysis of Variance (ANOVA) was conducted in accordance with Gomez and Gomez, et al. for each location independently. Replication was regarded as random, whereas accessions were treated as a fixed effect. To estimate the combined analysis of variance over locations, additional analyses were conducted for features that demonstrated statistically significant variations between the accessions as well as for those traits that demonstrated homogeneity of error variances. When the ANOVA indicated significant differences, the Duncan's Multiple Range Test (DMRT) at the 5% probability level was applied for mean comparison. Finally, statistical analysis was performed on computer using the R package.

Results and Discussion

Analysis of variance

Tab. 3 shows the analysis of variation for several traits pooled over sites in 2022. The calculated *chi-square* test (X^2) value is less than the equivalent tabular (X^2) value at the 5% level of significance for all traits, according to the results of the test of homogeneity for a variance error. According to Gomez and Gomez, et al., the homogenous variance hypothesis is therefore supported. As a result, pooled over locations were subjected to analysis of variance and other statistical tests. For the majority of the attributes, the combined main effects of blended NPSB fertilizer rate and varieties, as well as their interaction, were highly significant.

Table 3. Analysis of variance showed the effect of blended NPSB fertilizer rates on yield and yield components of faba bean varieties combined over locations

		Mean squares										
Source of variation	df	DF	DM	PH	NBPPL	NPPPL	NSPP	AGB	GY	SY	HI	TSW
Rep	2	34.04	43.29	24.11	0.25	11.61	12.5	945	989	3424	0.09	15881
Loc	1	240.67	263.34	1646.73	0.45	225.09	4110.8	24225	79	21540	0.16	349
Variety	3	103.00***	66.21***	178.48***	0.69***	349.75***	2674.00***	23052014***	15787096***	2962595***	1248.16***	1403720***
NPSB	3	44.92***	41.48***	42.62***	0.13***	113.29***	1198.30***	6261732***	3540919***	521000***	184.57***	15378*
Loc x Variety	3	0.33***	2.37^{ns}	39.59***	0.02^{ns}	12.25***	515.00***	8086*	83^{ns}	9608*	0.33	13229*
Loc x NPSB	3	0.2^{5***}	2.87^{ns}	9.09***	0.02^{ns}	49.39***	166.80***	19524***	80^{ns}	22025***	0.90 ***	2916^{ns}
Variety x NPSB	9	0.14**	1.51^{ns}	71.59***	0.33***	53.98***	599.00***	250285***	164329***	512153***	142.65***	8646^{ns}
Loc x Variety x NPSB	9	0.14**	3.23^{ns}	65.82***	0.01^{ns}	55.58***	299.70***	7816**	65^{ns}	8990**	0.29*	2576^{ns}
Residuals	62	0.04	1.84	0.3	0.02	0.77	0.6	2563	677	3156	0.13	4255
CV		0.36	0.96	1.25	9.96	4.18	1.49	0.84	0.81	2.01	0.69	8.51

*, **, *** and ns showed significant differences at 0.05, 0.01, 0.001 probability levels and non-significant differences, respectively.

Main effects

Crop phenology and plant height: Tab. 4 shows the main effect of variety and blended fertilizer levels on plant height, days to maturity and days to flowering. The local variety revealed much more days to maturity (141.54) than the Alloshe and Gora varieties, as well as significantly more days to flowering (58.75) than the other released varieties. This could be a result of genetic differences in phonological features between varieties. With the application of 180 kg ha-1, the longest days to flowering (58.50) and maturity (141.64) were noted. The varieties Numan and Gora had the shortest days to flowering (54.00) and maturity (138.00), respectively. The control was found to have the shortest days to flowering and maturity, with values of 55.38 and 138.54, respectively. The Numan variety was observed to have the tallest plants height (47.28) while a local variety had the smallest plants height (40.88). The control plot and the use of blended fertilizer at a rate of 120 kg ha^{-1} yielded the shortest (42.35) and tallest (45.58) plant heights, respectively.

Also included in Tab. 4 were yield and yield components. With values of 1.48, 6849.71, and 3322.75, respectively, the Numan variety outperformed the others in terms of the number of branches per plant, above-ground biomass and straw output. In terms of harvest index and grain yield, the Alloshe variety did better than the competition. The Gora variety outperformed all others for the trait thousand seed weight. Local variety, on the other hand, performed best in terms of the quantity of pods per plant and the quantity of seeds per pod.

Table 4. The main effect of varieties and blended NPSB fertilizer on mean values of yield and yield components of faba bean combined over locations

Treatment	Trait										
	DF	DM	PH	NBPPL	NPPPL	NSPP	AGB	GY	SY	HI	TSW
Variety											
Numan	54.00^{d}	141.46^{a}	47.28^{a}	1.48^{a}	19.38^{c}	48.08^{c}	6849.71^{a}	3526.96^{c}	3322.75^{a}	51.62^{c}	1024.67^{a}
Alloshe	57.92^{b}	139.96^{b}	44.50^{b}	1.10^{c}	20.15^{b}	50.73^{b}	6391.96^{b}	3793.71^{a}	2598.25^{c}	59.43^{a}	648.67^{c}
Gora	57.00^{c}	138.00^{c}	42.46^{c}	1.17^{bc}	18.00^{d}	45.40^{d}	6254.75^{c}	3555.25^{b}	2699.50^{b}	56.85^{b}	901.50^{b}
Local	58.75^{a}	141.54^{a}	40.88^{d}	1.19^{b}	26.6^{a}	68.73^{a}	4605.88^{d}	2020.96^{d}	2584.92^{c}	42.89^{d}	489.54^{d}
Blended NPSB (kg ha^{-1})											
0	55.38^{d}	138.54^{c}	42.35^{c}	1.28^{a}	21.65^{b}	53.23^{b}	5354.71^{d}	2707.71^{d}	2647.00^{c}	49.01^{d}	737.71^{c}
60	56.29^{c}	139.88^{b}	43.66^{b}	1.13^{b}	20.85^{c}	48.38^{c}	5928.71^{c}	3156.00^{c}	2772.71^{b}	52.58^{c}	752.92b^{c}
120	57.50^{b}	141.13^{a}	45.58^{a}	1.23^{a}	23.43^{a}	63.23^{a}	6289.92^{b}	3527.17^{a}	3001.79^{a}	53.99^{b}	780.58^{ab}
180	58.50^{a}	141.42^{a}	43.64^{b}	1.3	18.20^{d}	48.10^{c}	6528.96^{a}	3506.00^{b}	2783.92^{b}	55.65^{a}	793.17^{a}
Mean	56.92	140.24	43.81	1.24	21.03	53.23	6025.57	3224.22	2801.35	52.78	766.09
CV (%)	0.36	0.96	1.25	9.94	4.18	1.49	0.84	0.81	0.69	8.51	2.01

The plot treated with 120 kg ha^{-1} of NPSB application produced the highest yields of pods per plant, seeds per pod, grain yield, and straw yield, which increased by 13.14%, 6.28%, 12.56% and 13.60%, respectively, in comparison to the lowest yields. In comparison to plots that received the lowest values of NPSB, the 180 kg ha^{-1} NPSB level had produced the highest number of branches per plant, above ground biomass, harvest index, and thousand seed weight.

Interaction effects

Crop phenology and plant height: With 180 kg ha^{-1} NPSB on local cultivars, the greatest number of days to flowering (60.50 days) was noted. On the other hand, the Numan variety showed the shortest time to flowering (52.50 days) with 0 kg ha^{-1} NPSB (Tab. 5).

Table 5. Interaction effect of variety and blended NPSB fertilizer on days to flowering combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**

Numan	52.50^{k}	53.50^{j}	54.50^{i}	55.50^{h}
Alloshe	56.50^{g}	57.17^{f}	58.50^{c}	59.50^{b}
Gora	55.50^{h}	56.50^{g}	57.50^{e}	58.50^{c}
Local	57.00^{f}	58.00^{d}	59.50^{b}	60.50^{a}
Grand mean	56.92			
CV (%)	0.36			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05). With 60 kg ha^{-1} NPSB, the numan and local varieties yielded the tallest plants (49.90) and the shortest plants (38.83), respectively (Tab. 6).

Table 6. Interaction effect of variety and blended NPSB fertilizer on plant height combined over locations

Yield and yield components

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	47.10^{d}	49.90^{a}	42.60^{gh}	49.53^{a}
Alloshe	39.90^{i}	43.80^{f}	48.80^{b}	45.50^{e}
Gora	40.00^{i}	42.10^{h}	47.73^{c}	40.00^{i}
Local	42.40^{h}	38.83^{j}	43.20^{fg}	39.53^{i}
Grand mean	43.81			
CV (%)	1.25			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

The 180 kg NPSB ha^{-1} of the gora variety produced the most branches per plant (1.63 per plant). However, the Gora variety, which received control treatment, also had the fewest branches per plant (1.0) recorded (Tab. 7). On a 120 kg NPSB ha^{-1} applied to a local variety, the highest number of pods per plant (33.3) and number of seeds per pod (93.70) were obtained (Tabs. 8 and 9). While the gora and numan varieties, on 180 kg NPSB ha^{-1}, respectively, recorded the lowest numbers of pods per plant (16.7) and seeds per pod (36.4).

Table 7. Interaction effect of variety and blended NPSB fertilizer on number of branches per plant combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	1.77^{a}	1.50b^{c}	1.50b^{c}	1.17^{ef}
Alloshe	1.17^{ef}	1.00^{g}	1.06f^{g}	1.17^{ef}
Gora	1.00^{g}	1.03^{fg}	1.00^{g}	1.63^{ab}

Local	1.17^{ef}	1.00^{g}	1.37^{cd}	1.23^{de}
Grand mean	1.24			
CV (%)	9.94			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Table 8. Interaction effects of variety and blended NPSB fertilizer on number of pods per plant combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	23.9^{c}	19.4^{ef}	19.5^{ef}	14.7^{h}
Alloshe	19.2^{ef}	23.4^{c}	19.6^{e}	18.4^{f}
Gora	17.2^{g}	16.8^{g}	21.3^{d}	16.7^{g}
Local	26.3^{b}	23.8^{c}	33.3^{a}	23.9^{c}
Grand mean	21.03			
CV (%)	4. 18			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Table 9. Interaction effects of variety and blended NPSB fertilizer on number of seeds per pod combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	60.6^{d}	42.6^{l}	52.2^{g}	36.9^{n}
Alloshe	46.8^{i}	56.3^{e}	53.2^{f}	45.6^{j}
Gora	38.4^{m}	43.8^{k}	53.8^{f}	45.6^{j}
Local	67.1^{b}	50.8^{h}	93.7^{a}	63.3^{c}
Grand mean	53.23			
CV (%)	1.49			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

The application of 120 kg NPSB ha^{-1} of variety Numan resulted in the largest above-ground biomass (7403.00 kg ha^{-1}) ever recorded (Tab. 10). The highest grain production (4060.3 kg ha^{-1}) was achieved by using 120 kg ha^{-1} of combined NPSB fertilizer with the Alloshe variety (Tab. 11). While the control treatment using a local variety had the lowest grain yield (1228.33 kg ha-1). The applied 120 kg NPSB ha-1 on the Numan variety produced the maximum straw yield (3654.67 kg ha^{-1}) (Tab. 12). The Gora variety had the lowest straw production (2400.83 kg ha^{-1}), which was statistically comparable to the local variety's 180 kg ha^{-1} of applied NPSB. The 180 kg ha^{-1} of applied NPSB on the Alloshe variety produced a maximum harvest index of 60.65%, which was statistically equivalent to 120 kg NPSB ha^{-1} (Tab. 13).

Table 10. Interaction effects of variety and blended NPSB fertilizer on above-ground biomass combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	5902.50^{h}	7002.50^{c}	7403.00^{a}	7090.83^{b}
Alloshe	6006.50^{g}	6202.50^{f}	6703.83^{d}	6655.00^{d}

Gora	5504.83^{i}	6004.33^{g}	7003.17^{c}	6506.67^{e}
Local	4005.00^{m}	4505.50^{l}	5005.83^{j}	4907.17^{k}
Grand mean	6025.57			
CV (%)	0.84			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Table 11. Interaction effects of variety and blended NPSB fertilizer on grain yield combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	3200.5^{h}	3440.5^{f}	3748.33^{d}	3718.5^{d}
Alloshe	3400.50^{g}	3720.50^{d}	4060.33^{a}	3993.50^{b}
Gora	3001.50^{i}	3603.50^{e}	3805.50^{c}	3810.50^{c}
Local	1228.33^{l}	1859.50^{k}	2494.50^{j}	2501.50^{j}
Grand mean	3224.22			
CV (%)	0.81			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Table 12. Interaction effects of variety and blended NPSB fertilizer on straw yield combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	2702.00^{f}	3562.00^{b}	3654.67^{a}	3372.33^{c}
Alloshe	2606.00^{g}	2482.00^{h}	2643.00^{fg}	2661.50^{fg}
Gora	2503.33^{h}	2400.83^{i}	3197.67^{d}	2696.17^{f}
Local	2776.67^{e}	2646.00^{fg}	2511.33^{h}	2405.67^{i}
Grand mean	2801.35			
CV (%)	2.01			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Table 13. Interaction effects of variety and blended NPSB fertilizer on harvest index combined over locations

	Blended NPSB (kg ha^{-1})			
Variety	**0**	**60**	**120**	**180**
Numan	54.22^{e}	49.15^{i}	50.63^{g}	52.47^{f}
Alloshe	56.63^{d}	59.93^{b}	60.50^{a}	60.65^{a}
Gora	54.52^{e}	59.98^{b}	54.33^{e}	58.55^{c}
Local	30.67^{k}	41.27^{j}	49.82^{h}	50.95^{g}
Grand mean	52.78			
CV (%)	0.69			

Mean values followed by the same letters in each column and treatment showed no significant difference by DMRT (p=0.05)

Partial budget analysis

The partial budget analysis revealed that the Alloshe variety, which received 120 kg NPSB ha^{-1}, produced the maximum net benefit of 196,787.6 birr ha^{-1} with a marginal rate of return of 677.7 at that fertilizer rate (Tab. 14). However, the unfertilized treatment with local variety produced the lowest net benefits, 64,762 birr ha^{-1}. Therefore, the best and most economical way to produce Faba beans in the study area and other areas with comparable agro-ecological conditions would be to use 120 kg NPSB ha^{-1} with variety Alloshe.

Table 14. Summary of partial budget and marginal rate of return analysis for response of faba bean varieties to blended NPSB fertilizers in selected districts, central Ethiopia.

Treatment combination	Income (ETB ha^{-1})

Variety	Blended NPSB (Kg ha^{-1})	GY (Kg ha^{-1})	SY (Kg ha^{-1})	GY (ETB ha^{-1})	SY (ETB ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Numan	0	2881.8	2432.7	155,617.20	4,865.40	160,482.60	0	160,482.60	-
Numan	60	3097.8	3206.7	167,281.20	6,413.40	173,694.60	3,210	170,484.60	311.58
Numan	120	3374.7	3290.4	182,235.40	6,580.80	188,816.20	5,370	183,446.20	600. 1
Numan	180	3348	3109.5	180,792	6,219	187,011	7,530	179,481	D
Alloshe	0	3061.8	2344.5	165,337.20	4,689	170,026.20	0	170,026.20	-
Alloshe	60	3349.8	2234.7	180,889.20	4,469.40	185,358	3,210	182, 148.6	377.6
Alloshe	120	3655.5	2379.6	197,398.60	4,759.20	202, 157.8	5,370	196,787.80	677.7
Alloshe	180	3583.8	2540.7	193,525.40	5,081.40	198,606.60	7,530	191,076	D
Gora	0	2702.7	2252.7	145,945.80	4,505.40	150,451.20	0	150,451.20	-
Gora	60	3244.5	2160.9	175,203	4,321.80	179,524.80	3,210	176,314.80	805.7
Gora	120	3426.3	2878.2	185,020.20	5,756.40	190,776.60	5,370	185,406.60	420.9
Gora	180	3430.8	2424.6	185,263.20	4,849.20	190, 112.4	7,530	182,582.40	D
Local	0	1106.7	2499.3	59,763.40	4,998.60	64,762	0	64,762	-
Local	60	1674.9	2380.5	90,444.60	4,761	95,205.60	3,210	91,995.60	848.4
Local	120	2250	2255.4	121,500	4510.8	126,010.80	5,370	120,640.80	1326.2
Local	180	2252.7	2163.6	121,645.80	4,327.20	125,973	7,530	118,443	D

Where: GY: Grain Yield; GFB: Gross Field Benefit; TVC: Total Variable Costs; NB: Net Benefit, MRR: Marginal Rate of Return; ETB ha^{-1}: Ethiopian Birr per hectare; Cost of faba bean seed=49.00 ETB kg^{-1}; cost of NPSB=36.00 ETB kg^{-1}; labor cost for NPSB D=dominant treatments, application cost=7 persons ha^{-1}, each 150 ETB day^{-1}, price of straw=2 ETB kg^{-1}, market price of faba bean grain=54.00 ETB kg^{-1} in Fiche town at harvesting time in December 2022.

Discussion

Analysis of variance

The main and interaction effects of blended NPSB fertilizer rates on yield and yield components of faba bean varieties pooled over sites indicated extremely substantial variability for the majority of the parameters. This showed that the optimal crop varieties and fertilizers may be selected for the study location and other similar agro ecologies.

Main effects

Crop phenology and plant height: The main effects of varieties and blended fertilizers for traits including days to flowering, days to maturity, and plant height exhibited significant variations when combined across locations. The use of different levels of blended fertilizer for the various faba bean varieties can account for this variation. In a manner similar to this, Sharma, et al. demonstrated that higher dosages of N, P, K and S fertilizer significantly delayed days to 50% flowering, prolonged the growth period, and resulted in delayed flowering. According to this study, Arega, et al. (2019) also found that the number of days needed to reach physiological maturity increased as the blended NPKSB application rate increased from 0 to the ratio (61.5:69:60:10.5:0.15) NPKSB kg ha^{-1}. Because to the genetic differences amongst the types, the local variation is regarded as a dwarf variety in comparison to the other three newly released varieties. Similar to this, Shahzad, et al. reported that the crop's height can be influenced by environmental factors in addition to its genotype's genetic make-up. Talal and Munqez, et al. found that cultivars had a large impact on plant height. According to this finding, Rouhollah, et al. found that the high availability of nutrients, particularly nitrogen, affects growth and lengthens internodes by causing the plant to grow taller. A stronger root system and nutrient absorption were likely contributing factors to the promotion effect of greater phosphorus levels on plant height. According to this finding, Singh, et al. and Deshbhratar, et al. reported that the role of macronutrients, primarily nitrogen and phosphorus, in chlorophyll formation, the conversion of sugars and starches and nutrient movement within the plant boost vegetative growth, resulting in an increase in plant height for faba beans. The significant increase in plant height in response to the higher rates of NPSB application may be attributed to the increased availability of those nutrients for plant roots to absorb from the soil. This may have sufficiently enhanced vegetative growth by increasing cell division and elongation.

Yield and yield components

This study showed that, in comparison to the control plot, the application of various blended fertilizer quantities considerably affected various features. Meseret and Amin, et al. also showed that all applied P fertilizer rates significantly increased pods per plant over the control and a significantly higher number of pods per plant were recorded with P rates of 20 kg ha^{-1} over the other levels. Nikfarjam and Aminpanah, et al. noted that the application of P had a significant impact on the number of pods per plant. Similar to this, Kubure, et al. demonstrated that faba bean fertilization increased seed and biological yields over no fertilizer. These findings support the findings of Masood, et al., who said that grain yield of faba beans was significantly affected by different levels of phosphorus.

Interaction Effects

Crop phenology and plant height: Results of the interaction effects showed that delaying the faba bean's flowering by raising the NPSB rate. Additionally, N and P are important nutrients that help crops delay flowering and promote vegetative growth.

Yield and yield components

The interaction effects on the majority of the yield and yield components showed that the genetic components and the blended fertilizers both play a role in the variation in the traits. The effect of balanced fertilization, in which readily soluble minerals aid to stimulate the vegetative growth of the crop, may be the cause of the rise in the number of branches per plant. The genetic variability of varieties and the rising rate of mixed fertilizer rates also had an impact on the increases in the number of branches per plant. The genetic differences between varieties, which govern a crop's capacity to produce in a given year, are what caused the variation in the number of pods per plant and the number of seeds per pod that was discovered. Due to differences in fertilizer needs, the above-ground biomass of a faba bean increases with an increase in fertilizer rate up to a particular level for all types. This response may be explained by a suitable amount of fertilizer doses and their absorption in meristematic tissue, which may have benefited in branching and overall plant growth. Improved crop nutrition may also be a contributing element to the application of blended micronutrients (B) and macronutrients (N, P and S), which may encourage greater vegetative development of crops. By increasing the application of blended fertilizer at the rates advised for enhanced faba bean varieties, the crop's yield can be raised. This might be attributed to fertilizers' balanced nutrition (macro and micronutrients), which increased yield characteristics by encouraging greater uptake of all nutrients and greater photosynthetic translocation from source to sink. The considerable differences in straw production between cultivars may be caused by genetic variances. The difference in harvest index may be due to genetic variability and the synergistic effects of blended fertilizer.

Conclusion

The use of blended NPSB fertilizer has a considerable effect on the traits under examination. The Alloshe variety and a 120 kg ha^{-1} NPSB application produced the maximum grain and had the greatest harvest index. The partial budget analysis further demonstrated that combined applications of 120 kg ha^{-1} blended NPSB fertilizer rate with variety Alloshe offered a greater net benefit with the acceptable MRR range, while the lowest net returns were recorded with a 0 kg ha^{-1} blended NPSB rate with local variety. As a result, the study came to the conclusion that the production of faba beans in the study region and other locations with comparable agro ecologies can be suggested to apply 120 kg ha^{-1} of blended NPSB fertilizer with variety Alloshe. Overall, this study demonstrated that the wise application of blended NPSB and variety might raise faba bean production and revenue. It is recommended that the experiment be repeated using this and other improved faba bean varieties throughout numerous seasons at different sites as it was only carried out for one season at two locations in order to provide a full recommendation.

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Conflict of Interest

We announce that there is no conflict of interest.

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