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Evaluation of Different Grade Nps Fertilizers Effect on Soil Property and Agronomic Performance of Faba Bean in Nitisol of Central Ethiopia

Matias Dejene, Zeleke Obsa, Girma Chala and Mihretu Bedasa

Ethiopian Institute of Agricultural Research, Holeta Research Center,
Natural Resources Management Research Directorate, P.O. Box 31, Ethiopia

Abstract: Optimal application of different essential nutrient sources is crucial in the production of faba bean to exploit its potential productivity with sustainable soil fertility maintenance of crop lands with diverse nutrient sources and rates. The research activity was implemented in Welmera and Ejere districts for two successive cropping seasons since 2019 to determine the optimum and economical application rates of different grade NPS fertilizers for faba bean production. Three different grade NPS fertilizers were evaluated with different application rates among which one of them (NPS-19N-38P_2O_5-7S) used as standard check since it was widely used in the current crop production system of the country. Different crop and soil related data was collected to determine the optimum rate and types of fertilizer accordingly there was no significant yield difference were observed between different grade NPS fertilizers, whereas the partial budget economic analysis and agronomic nutrient use efficiency results indicated that use of 80 % recommended rate of P from 13.3N-36P_2O_5-13.7S grade fertilizer got the highest result with greater net benefit, marginal rate of return and highest value to cost ratio related to other treatments with better performance in agronomic nutrient use efficiency related to other treatments.

Key words: Different Grade · NPS · Soil Productivity · Faba Bean · Fertilizer Rate · Phosphorus

INTRODUCTION

Rapid declines in soil fertility are associated with huge demands for food due to increasing population, extensive nutrient mining of agricultural areas with allied shifts of produce to cities, and intensification of agricultural activities without proper regard for long-term maintenance of fertility by application of appropriate fertilizers, recycling of organic wastes, liming to combat acidification, fallowing, rotations and prevention of large scale soil erosion aggravates the issue of sub-Saharan African countries malnutrition, these declining soil fertility is among the most constraining factor challenging food production and hence food self-sufficiency in Ethiopia [1]. Application of balanced nutrition is the key role in enhancing nutrient use efficiency of applied nutrients for maintaining soil productivity and production. For the past several decades, farmers in Ethiopia used limited types of nutrients (N and P) in the form of urea and DAP to increase crop production. However, recently acquired soil inventory data revealed that the deficiencies of other nutrients such as sulphur, boron and zinc (on about 92, 65, 53 % of the studied areas, respectively) is widespread in Ethiopian soils in addition to N and P nutrient deficiencies [2]. To alleviate the problems in this regard, the Ethiopian Soil Information System (EthioSIS), introduced different formula of blended fertilizers for evaluation in the production system of the country.

Since 2009, the country has been testing different types of new fertilizer products including blend fertilizers for their potential to improve yield and quality for food and nutrition security. As known that faba bean is a major source of protein, ensuring nutritional security and income for farming families in the highlands of Ethiopia, which have important role in enriching the soil fertility by fixing atmospheric nitrogen. It is a crop that makes significant contribution to an integrated management of soil fertility and sustainable farming systems. It stands

Corresponding Author: Matias Dejene, Ethiopian Institute of Agricultural Research, Holeta Research Center, Natural Resources Management Research Directorate, P.O. Box: 31, Ethiopia.

first in area coverage as well as total production of pulse crops produced in Ethiopia [3] CSA. Thus, this study was initiated to evaluate faba bean response to application of different grade NPS fertilizer products in combination with Urea in their Welmera and Ejere districts of the central Ethiopian highlands. Therefore, the aim of this study was to evaluate the effect of different grade NPS blended fertilizers on yield and quality improvement of faba bean crop on Nitisol of central Ethiopia and to determine economically feasible optimal rate of the different grade NPS fertilizer in improving yield of faba bean production.

MATERIALS AND METHODS

Description of the Study Area: This field trial was conducted in Welmera and Ejere districts farmers field which are located in the central highlands of Ethiopia at DMS latitude 9° 03'32''N, longitude 38° 25'62''E, Alt 2438 masl for Welmera district and at latitude of 9° 02'76''N Longitude 38° 25'56''E, Alt 2258 masl for Ejere districts specifically known Sademo and Chiri PA respectively (Table 1) they have Clay soil textural class with Nitisol genetic classification. The experiments were carried out on farmers' fields and research stations for two consecutive cropping seasons during 2019 and 2020 in different parts of the country during the main rainy seasons. The study locations are among major areas for the production of the test crops.

Treatments and Experimental Design: Nine treatments consisting of negative control, positive controls and different rates of different grade NPS fertilizers (Table 2) were evaluated. For the recommended NP (positive controls), NPS (19N-38P_2O_5-7S) were used as P sources. The treatments were arranged in randomized completed block design (RCBD) and were replicated three times at each location. Nutrient composition of the different NPS grade fertilizers and the total amount of each nutrient applied per hectare for each treatment is indicated in Table 2. All NPS fertilizers treatment were applied at planting with band application the amount of urea or N applied with NPS fertilizers were sufficient to full fill its requirement for most treatments with few exceptions. The small amount of N remaining to full fill the faba bean N requirement was applied from Urea fertilizer at planting. The seed rate used for faba bean, was 175 kg ha^{-1}, was used for faba bean. The plot size used was 4 m x 3 m or 12m^2 plot area. All other agronomic and crop management practices were applied as per the recommendation of the faba bean.

Data Collection: Plant height, dry biomass and grain yield of faba bean and thousand seed weight was also collected following the standard data collection procedures.

Soil Sampling and Analysis: Composite surface soil samples (0-20 cm) were collected from the experimental sites before treatment application as well as after harvesting to see the initial soil physicochemical properties and treatment effect on some selected soil chemical properties. The soil samples were air dried and ground by using mortar and pestle to pass 2 mm sieve. Soil texture, soil pH, exchangeable acidity, organic carbon, total N, available P and sulphur were determined at respective agricultural research soil Laboratories following standard lab procedures.

The determination of soil particle size distribution was carried out using the hydrometer method [4] as described by Dewis and Freitas. Soil pH was measured using digital pH meter in 1:2.5 soil to solution ratio with H_2O [5], The exchangeable acidity was determined by extracting the soil samples with KCl solution and titrating with sodium hydroxide as described by McLean [6]. The organic carbon was determined following wet digestion methods as described by Walkley [7] and Nelson and Sommers [8] whereas the Kjeldahl procedure was used for the determination of total N as described by Bremner and Mulvaney [9]. The available P was determined by Bray II method [10]. Available Sulfur was determined by using Turbidi metric method [11] as described by Chesnin and Yien. Accordingly, the soil analysis result taken before planting at each experimental site indicated that the value of pH, Exchangeable acidity, available phosphorus, total nitrogen, organic carbon and available Sulfur (Table 3) as followed ratings.

The soil pH was categorized as moderately acid for all of the experimental sites according to Tekalegn, ratings. The organic carbon contents were low for all experimental sites (Table 3). The total N was found in the medium rating range except for HARC on station and Ejere where it was in the high rating range [12]. The available phosphorus of the experimental sites was found in the low rating according to Tekaligns' rating and hence positive responses was expected from different rates of phosphorus application. According to EthioSIS [2] of soil sulphurs rating the values observed in this study lies in the low range.

Data Analysis: The collected plant height, dry biomass and grain yield for all the test crops and thousand seed weight were subjected to analysis of variance using SAS

Table 1: Geographic, soil and climate information for the study site of response of faba bean to different grade NPS fertilizer trial

Locations	Latitude	Longitude	Altitude	Annual total rainfall (mm)	Annual average min. and max. Temp. (°C)	Soil textural class
Wolmera (Sademo)	9° 03'32''N	38° 25'62''E	2438m	1100	6.9 °C and 23.2 °C	Clay
Ejere (Chiri)	9° 02'76''N	38° 25'56''E	2258m	1040	6.7 0C and 22.9 0C	Clay

Moti improved faba bean variety was used as test crop for this experiment with planting space of 40 cm and 10cm between rows and plant respectively

Table 2: Treatment's setup of different grade NPS fertilizer and total amount of each nutrient applied (kg. ha^{-1}) for faba bean

No.	Treatments	N	P_2O_5	S
T1	Control (no fertilizer)	0	0	0
T2	100 % recommended rate of P from DAP (positive control 1)	18	46	0
T3	100 % recommended rate of P from 19N-38P_2O_5-7S (positive control 2)	18	46	8.47
T4	80 % recommended rate of P from 12N-42P_2O_5-10S	18	36.8	8.76
T5	100 % recommended rate of P from 12N-42P_2O_5-10S	18	46	10.95
T6	120 % recommended rate of P from 12N-42P_2O_5-10S	18	55.2	13.14
T7	80 % recommended rate of P from 13.3N-36P_2O_5-13.7S	18	36.8	14.0
T8	100 % recommended rate of P from 13.3N-36P_2O_5-13.7S	18	46	17.5
T9	120 % recommended rate of P from 13.3N-36P_2O_5-13.7S	18	55.2	21.0

The recommended rate of P_2O_5 were 46 kg ha^{-1} for faba bean, Nitrogen (N) was uniformly applied at the rate of 18 kg ha^{-1}, except for the negative control

Table 3: Mean values of soil chemical properties sampled from the experimental sites before treatment application

	Locations			
Soil parameters	HARC	Welmera	Ejere	Rating
pH (1:2.5 soil: H_2O)	5.62	5.47	5.74	Moderately acid
Exchangeable acidity	0.863	0.927	0.765	
OC (%)	1.36	1.34	1.42	Low to moderate
Total N (%)	0.16	0.24	0.23	Low to Moderate
Available P (ppm)	11.68	9.68	10.42	Moderate
Available S (unit)	2.38	2.36	2.44	Low

HARC = Holeta Agricultural Research Center

software version 9.2 [13]. The dependent variables were subjected to mean separation using LSD (least significant difference) procedure when differences were found statistically significant. Partial budget analysis for yields was computed using CIMMYT procedure to determine economically profitable rates of different grade NPS fertilizers [14]. The prices of NPS, DAP and Urea were ETB 16, 16 and 14 kg^{-1}, respectively. The grain prices of wheat and rape seed were ETB 22 and 35 kg^{-1}. The average grain yields were adjusted down by 10% to reflect the real farmer's condition.

RESULTS AND DISCUSSION

Soil Analysis Result at Harvest: The soil analysis result of organic carbon, total nitrogen and available phosphorus content for the experimental locations are indicated (Table 4 and 5). There were some differences in the analysis results of the soil parameters among the treatments including for different grade NPS fertilizer rates. However, the differences found were inconsistent and cannot be attributable to the different level of phosphorus and sulphur nutrient variations regardless of the differences in experimental location.

Effects of Different Grade NPS Application on Faba Bean Performances: All the three parameters (plant height, grain yield and dry biomass) of faba bean were non-significantly ($P>0.05$) affected by different grade NPS fertilizer rates application in 2019, 2020 cropping seasons and combined over years (Table 5 and 6).

Numerically, over years higher mean values (3038 and 6275 kg ha^{-1}) of grain and dry biomass yield of faba bean were obtained with application of 80% recommended rate of P from 13.3N-36P_2O_5-13.7S as compared to other treatments (Table 6). The different grade NPS fertilizers and their rates evaluated in this experiment did not significantly affect the faba bean plant growth and yield parameters. Therefore, application of any of the different grade NPS fertilizers evaluated in this experiment can alternately be used considering the accessibility and cost of the fertilizer products to be incurred.

Table 4: After harvest soil chemical properties as affected by different grade NPS fertilizer rates for both crops at Welmera, HARC and Ejere

	pH		Organic Carbon (%)		Total Nitrogen (%)		Available P (ppm)		Available S (ppm)	
Treatments	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
T1	5.52	5.34	1.38	1.34	0.18	0.16	9.92	10.62	2.32	2.28
T2	5.47	5.25	1.34	1.32	0.19	0.18	11. 48	10.12	2.34	2.25
T3	5.26	5.42	1.40	1.28	0.26	0.22	12.75	9.96	2.38	2.32
T4	5.43	5.22	1.34	1.37	0.24	0.24	10.62	8.98	2.36	2.30
T5	5.44	5.36	1.38	1.32	0.19	0.23	12.02	10.02	2.44	2.42
T6	5.46	5.18	1.32	1.30	0.29	0.26	13.92	11.06	2.41	2.36
T7	5.34	5.40	1.36	1.28	0.22	0.25	11..86	10.34	2.48	2.32
T8	5.41	5.38	1.38	1.41	0.24	0.22	12.72	11.38	2.46	2.38
T9	5.38	5.44	1.42	1.38	0.26	0.24	12.88	12.2	2.42	2.33
Grand Mean	5.41	5.33	1.37	1.33	0.23	0.22	12.12	10.52	2.40	2.33

Where:

T1. Negative control (no input)

T2. 100% of recommended rate of P from NP source (positive control-1)

T3. 100% of recommended rate of P from 19N-38 P_2O_5-7S (positive control-2)

T4. 80% of recommended rate of P from 12N-42 P_2O_5-10S

T5. 100% of recommended rate of P from 12N-42 P_2O_5-10S

T6. 120% of recommended rate of P from 12N-42 P_2O_5-10S

T7. 80% of recommended rate of P from 13.3N-36 P_2O_5-13.7S

T8. 100% of recommended rate of P from 13.3N-36 P_2O_5-13.7S

T9. 120% of recommended rate of P from 13.3N-36 P_2O_5-13.7S

Table 5: Results of analysis of variance for faba bean crops as affected by application of different grade NPS fertilizer

	Faba Bean								
	Plant height (cm)			Grain yield (kg/ha)			Biomass yield (kg/ha)		
Source	DF	MS	P	DF	MS	P	DF	MS	P
Rep	2	27.105		2	145748		2	927511	
Trt	8	63.563	0.826	8	486326	0.1473	8	1779546	0.2274
Error	124	118.153		124	314054		124	1322765	

where: abbreviations in ANOVA table described as Trt is treatment; DF degree of freedom; MS mean square

Table 6: Effects of differently graded NPS fertilizer on plant height, grain yield and dry biomass yield faba bean in 2019, 2020 and combined over years in Holeta

	Plant height (cm)			Grain yield (kg ha^{-1})			Dry biomass (kg ha^{-1})		
Treatments	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
1. Negative control (0 input)	131	130	131	2196	2742	2524	5882	4778	5219
2. 100% of rec. rate of P from NP ($^+$ve cont'l-1)	141	133	136	2833	2698	2752	7243	5185	6008
3. 100% of rec. rate of P from 19N-38P_2O_5-7S($^+$Ve cont'l 2)	139	133	135	2791	3087	2969	6965	5722	6219
4. 80% of rec. rate of P from 12N-42P_2O_5-10S	139	128	133	2481	2875	2717	6201	4981	5469
5. 100% of rec. rate of P from 12N-42P_2O_5-10S	136	134	135	2529	2482	2501	6814	5148	5814
6. 120% of rec. rate of P from 12N-42P_2O_5-10S	137	131	133	2627	2725	2686	6861	5222	5878
7. 80% of rec. rate of P from 13.3N-36P_2O_5-13.7S	141	130	134	2945	3100	3038	7215	5648	6275
8. 100% of rec. rate of P from 13.3N-36P_2O_5-13.7S	135	132	133	2535	2831	2713	6369	5259	5703
9. 120% of rec. rate of P from 13.3N-36P_2O_5-13.7S	139	137	137	2606	2647	2631	6403	5056	5594
LSD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.6	5.99	8.1	21.1	20.61	20.56	12.2	18.54	19.8

NS=non-significant difference at 5% probability level

Table 7: Agronomic Nutrient use efficiency of Faba bean crop as affected by different application rates of varied NPS fertilizers

Treatments	GYD	F.Rt	AUE
1. Negative control (0 input)	2524	0	0
2. 100% of rec. rate of P from NP (+Ve Con't)	2752	64	3.56
3. 100% of rec. rate of P from 19N-38 P_2O_5-7S	2969	72	6.18
4. 80% of rec. rate of P from 12N-42 P_2O_5-10S	2717	59.6	3.24
5. 100% of rec. rate of P from 12N-42 P_2O_5-10S	2501	74.9	-0.31
6. 120% of rec. rate of P from 12N-42 P_2O_5-10S	2686	85.2	1.90
7. 80% of rec. rate of P from 13.3N-36 P_2O_5-13.7S	3038	68.5	7.50
8. 100% of rec. rate of P from 13.3N-36 P_2O_5-13.7S	2713	81.5	2.32
9. 120% of rec. rate of P from 13.3N-36 P_2O_5-13.7S	2631	94.1	1.14

where: fertilizer (F.Rt) rate include sum of all the amounts of N, P and S rates which was used for each treatments; AUE agronomic nutrient use efficiency and GYD mean grain yield

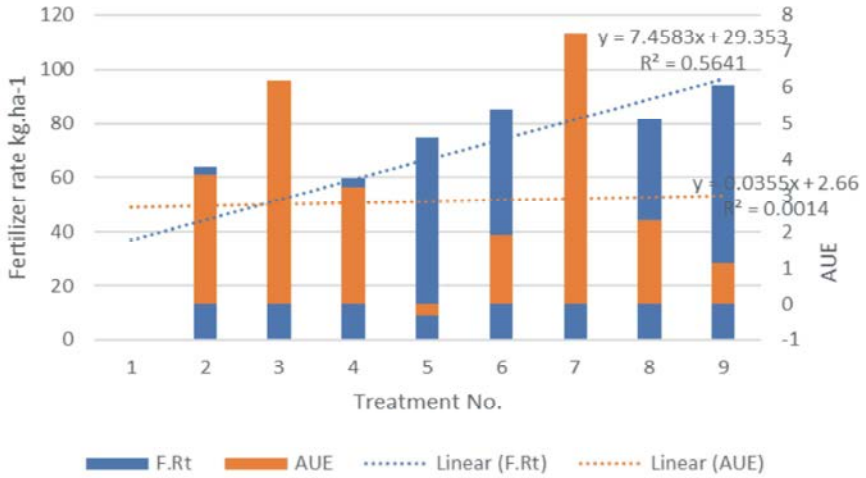

Fig. 1: Agronomic nutrient use efficiency of faba bean crop as affected by different grade NPS fertilizer rates

Effects of Different Grade NPS Application on Faba Bean AUE: As the agronomic nutrient use efficiency result showed (Figure 1) the highest AUE resulted from treatment number 7 which is 80% of recommended rate of P from 13.3N-36P_2O_5-13.7S with 7.5 followed by treatment number 3 which contains 100% of recommended fertilizer rate of Phosphorus from 19N-38 P_2O_5-7S sources of fertilizer with 6.18 AUE the list result was obtained from treatment number 5 which receives 100% of recommended rate (i.e 46 kg P_2O_5 ha^{-1}) of P from 12N-42 P_2O_5-10S grade NPS fertilizer with -0.31 agronomic nutrient use efficiency. The highest nutrient use efficiency happens at the lower parts of the crop yield response curve, where inputs of fertilizer are at their lowest, while the fertilizer efficiency increases crops yields and improves profitability. It's also critical to balance the input supply and plant density of faba bean specially phosphorus supply as an essential nutrient to get sustainable productivity [15, 16]. Therefore, there should be a balance between optimal nutrient use efficiency and optimal crop productivity [17, 18].

Economic Aanalysis (Partial Budget): Although the statistical analysis of variance of biological yield was not significantly affected by the uses of different grade NPS fertilizer the results of the partial budget analysis of faba bean for different treatments are presented in Table 7. Higher net benefit of EB 63851.2 ha^{-1} with the marginal rate of return of 4857.07 % and value to cost ratio of EB 36.08 per unit of investment of faba bean was obtained with application of 80% of recommended rate of P from 13.3N-36P_2O_5-13.7S fertilizer for faba bean. The second higher net benefit EB 62193.6 ha^{-1} with marginal rate of return of 27493.2 % and value to cost ratio of EB 32.11 per unit of investment of faba bean was obtained with application of 100% of recommended rate of P from 19N-38P_2O_5-7S fertilizer rate or Positive control treatment. Therefore, the application of 36.8 kg P_2O_5 Ha^{-1} from 13.3N-36P_2O_5-13.7S and 18 kg N ha^{-1} from both NPS and Urea fertilizers followed by NPS positive control or 46 kg P_2O_5 Ha^{-1} and 18 kg N ha^{-1} from 19N-38P_2O_5-7S fertilizer was found to be economically sound for production of faba bean in Welmera and Ejere districts of central Ethiopia.

Table 7: Partial budget analysis for evaluation of different grade NPS fertilizers effect on performance of faba bean

Treatments	NPS Ct.	Urea Ct.	Grain yield (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Gross field benefit (EB ha^{-1})	TVC (EB ha^{-1})	Net benefit (EB ha^{-1})	Value to cost ratio	MRR (%)
T1	0.0	0.0	2524	2271.6	54518.4	0.0	54518.4		
T2	1600.0	0.0	2752	2476.8	59443.2	1600.0	57843.2	36.15	207.8
T4	1401.9	227.8	2717	2445.3	58687.2	1629.7	57057.5	35.01	D
T7	1635.6	134.0	3038	2734.2	65620.8	1769.6	63851.2	36.08	4857.07
T5	1752.4	147.8	2501	2250.9	54021.6	1900.2	52121.4	27.43	D
T3	1936.8	0.0	2969	2672.1	64130.4	1936.8	62193.6	32.11	27493.2
T8	2044.4	30.6	2713	2441.7	58600.8	2075.0	56525.8	27.24	D
T6	2102.9	67.8	2686	2417.4	58017.6	2170.7	55846.9	25.73	D
T9	2453.3	0.0	2631	2367.9	56829.6	2453.3	54376.3	22.16	D

CONCLUSIONS AND RECOMMENDATION

Based on the agronomically optimum yield performance and economic benefits obtained from the application of different grade NPS fertilizer rates, the following conclusion can be made.

For faba bean production, the different grade NPS fertilizers and their rates evaluated did not significantly affect growth and yield parameters of the crop when compared to an already existing P source fertilizer recommendation rate. Therefore, unless there exist special comparative advantage of better on market availability and market price of the different grade NPS fertilizers, the previously used P source fertilizer (DAP) is more promising to use in the study locations. Base on the study result of this experiment, further evaluation or validation of the promising treatments on relatively larger plots in similar agro ecological zones but also out of the current study areas is of paramount important to increase the level of confidence for their wider applicability. The increase in world population and the potential of the food system to meet future demand for food and maintain the sustainable soil productivity has brought into focus, the use of pulse with appropriate input to boost crop yield. The integrated nutrient management could be the way to sustain the major crop production with sustainable soil fertility maintenance and secure the world food demand.

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