



Growth and Yield of Fenugreek (*Trigonella foenum-graecum* L.) Varieties as Influenced by Application of NPS Fertilizer at Ginir, South-eastern Ethiopia

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Abstract: Shortage of improved varieties and soil nutrient depletion are the major production constraints of fenugreek in mid-altitude of Bale Zone in Ethiopia. Therefore, an on-farm experiment was conducted at Ginir, south-eastern Ethiopia, to assess the effect of NPS fertilizer rates on growth and, yield components and seed yield of fenugreek varieties. Factorial combinations of three fenugreek varieties (Burqa, Chala and Ebisa) and five rates of NPS (0, 50, 100, 150 and 200 kg NPS ha⁻¹) were laid out in a randomized complete block design (RCBD) with three replications. Analysis of variance showed that the main effects of varieties significantly influenced days to 50% flowering, days to 90% physiological maturity and thousand seed weight. The highest thousand seed weight (17.31 g) was recorded from variety Burqa. Variety Chala was the earliest to reach days to 50% flowering (63.27 days) while variety Burqa was the earliest (115 days) to reach 90% of physiological maturity. Similarly, the main effect of NPS showed significantly higher number of primary branches per plant (5.11), number of pod per plant (25.47) and biomass yield (7160 kg ha⁻¹) at 200 kg NPS ha⁻¹ while the highest thousand seed weight (18.44g) was obtained at 150 kg NPS ha⁻¹. The interaction of NPS fertilizer and varieties showed significant effect on plant height, number of seeds per pod and seed yield. The highest plant height (53.67cm) was recorded from Chala variety at 200 kg NPS fertilizer ha⁻¹ while the highest number of seeds per pod (11.89) was recorded from variety Burqa at 150 kg NPS fertilizer ha⁻¹. Similarly, the highest seed yield (1980 kg ha⁻¹) was recorded from variety Ebisa at 150 kg NPS fertilizer ha⁻¹. The economic analysis revealed that the highest net return of (42231.67 and 40361.9 ETB ha⁻¹) with marginal rate of return (566.84 and 542.5%) were recorded for varieties of Ebisa and Chala respectively, while variety Burqa resulted in the higher net benefit (39294.8 ETB ha⁻¹) with the highest marginal rate of return (166.24%) at 100 kg NPS ha⁻¹. Therefore, it can tentatively be concluded that application of 150 kg NPS ha⁻¹ Ebisa and Chala varieties and 100 kg NPS ha⁻¹ of variety Burqa to be the best treatment in the study area.

Keywords: Varieties, Economic Evaluation, Fenugreek, NPS Fertilizer, Seed Yield

1. Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is a multipurpose spice crop; every part of the plant is being used as leafy vegetable, fodder and condiment [1]. In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300 m.a.s.l.) characterized by subtropical climate of wet and dry seasons [2].

Nitrogen fertilization improved morphological parameters (plant height, number of branches, stem weight), yield components (thousand seed weight), and total protein content of fenugreek [3]. The deficiency of Phosphorus followed by N is the major constraint in pulse production since Phosphorus affects growth, nodule formation and development and N-fixation [4]. Sulphur (S) which has now emerged as the fourth important plant nutrient to crops.

Sulphur plays a vital role in plant metabolism. There is no information on the impact of different types of fertilizers except nitrogen and phosphorous on the yield and other traits of fenugreek at Bale Zone. Based on the EthioSIS (Ethiopian soil Information System) soil analysis report of 2014, Ginir area soil lacks S, Zn, Fe and B in addition to the N and P [5].

In Ginir, district of Bale Zone, fenugreek is one of the major seed spice crops produced for the purpose of both home consumption and market. However, its production constraints are poor soil fertility, especially nitrogen, phosphorous and Sulphur deficiency. Besides, lack of improved varieties, shortage of certified seeds, weeds, diseases like powdery mildew and root rot and insect pests such as aphids are also the limiting factors [6]. It is, therefore, necessary to improve fenugreek productivity through different fertilizer management and selection of varieties with high fertilizer use efficiency to make fenugreek production rewarding to farmers, and to satisfy the demand of fenugreek both in local and international market.

Therefore, the objectives of the study were:

1. to assess the effect of NPS fertilizer rates on growth, yield components and seed yield of fenugreek; and
2. to identify economically feasible rate/s of NPS fertilizer for fenugreek production

2. Materials and Methods

2.1. Description of Experimental Area

The experiment was conducted at Ginir mid altitude of Bale, Oromia Regional State, and South eastern Ethiopia during the main cropping season of 2017 to 2019. Ginir is located 519 km away from Addis Ababa to South eastern, 86 km away from the zonal capital town, Robe. It is located at 07° 15' N latitude and 40° 66' E longitude at 1972 m above sea level [7]. The area has bimodal rainfall patterns. Based on this there are two separate crop growing seasons locally called *bona* and *gana*. The main season *bona* extends from September to November and *gana* from March to May. The soil type is *Vertisols*. The major crops grown widely in the area are cereals (wheat, barley, maize and *tef*, pulses (chickpea, field pea, faba bean, and lentil), seed spices (black cumin, coriander and fenugreek) and vegetables (onion, garlic, potato and tomato) under rain fed and irrigation.

2.2. Experimental Materials

2.2.1. Planting Material

The fenugreek varieties Ebisa and Burqa which were released by Sinana Agricultural Research Centre (SARC) in 2006 and 2016 respectively and Chala which was released by Debrezeit Agricultural Research Center (DZARC) in 2005 were used in the experiment.

2.2.2. Fertilizer Material

The NPS (19% N, 38% P₂O₅ and 7% S) was used as the sources of fertilizer because these nutrients are the most production constraints of fenugreek in the study area.

2.3. Soil Sampling and Analysis

Before sowing, soil samples (0-30 cm depth) were collected diagonally from five spots from the entire experimental field and mixed to have one composite sample. The composite sample was air-dried, ground using a pestle and a mortar and allowed to pass through a 2-mm sieve. Working samples were obtained from submitted bulk samples were analysis for organic carbon, total N, available sulphur and cation exchange capacity (CEC), soil pH, available phosphorus and soil texture.

2.4. Treatments and Experimental Design

The treatments consisted of factorial combination of five rates of NPS fertilizer (0, 50, 100, 150 and 200 kg ha⁻¹) and the three fenugreek varieties (Ebisa, Burqa and Chala) in factorial combinations. The experiment was laid out in a randomized complete block design in three replications.

2.5. Experimental Procedure and Field Management

The experimental field was ploughed and disked by tractor and pulverized to a fine tilth by hand digging. Blocking and the required number of rows were marked in each plot according to the spacing proposed and rows were made to plant the seeds. The plots were leveled manually. The gross plot size of 2.1 m × 3 m (6.3 m²) which contain seven rows and the varieties were planted by spacing of 30 cm and 10 cm between rows and plants respectively. The four middle rows were used for data collection and one row was for destructive sampling. Two rows were left out as border rows to protect border effects.

2.6. Data Collected and Measurement

Phonological, yield components and yield data such as days to 50% of flowering, days to 90% maturity, plant height, number of primary branches per plants; number of pod per plant, number of seeds per pod, thousand seed weight, aboveground dry biomass yield, Seed yield and harvest index will be collected and subjected to analysis of variance (ANOVA) procedure using GenStat 16th edition software [8]. Comparisons among treatment means with significant difference for measured characters were done by using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

2.7. Economic Analysis

The economic analysis was carried out by using the methodology described in CIMMYT in which prevailing market prices for inputs at planting and for outputs at harvesting. The concepts used in the partial budget analysis were started from adjusted the yield downward by 10% for management difference and the mean seed yields for NPS treatment combinations were subjected to a discrete economic analysis using the procedure recommended by CIMMYT [9].

3. Results and Discussion

3.1. Soil Physico-chemical Properties of the Experimental Site

The physico-chemical properties of the soil were determined for composite soil (0-30 cm depth) samples collected before sowing (Table 1). Accordingly, the texture of the soil of the experimental site is dominated by the clay fraction. Thus, on the basis of particle size distribution, the soil contains 21% sand, 27% silt, and 52% clay.

The soil has a medium content of available phosphorus (10.23 ppm), according to the rating of Cottenie which indicates the requirement for application of another phosphorus fertilizer sources for crop growth and yield [10]. The results showed that, the soil had low organic carbon content (1.18%) indicating its low potential to supply nutrients especially S to plants through mineralization, since the major source of S (about 95%) is organic matter [11]. According to the rating of Lewis the level of available sulphur (21.42 ppm) is very low, suggesting a requirement

for N and S fertilizer application [12]. The pH of the experimental site is neutral (6.82) according to the rating of Murphy and Tekalign Tadesse [13] and [14]. According to FAO the suitable pH range for most crops is between 6.5 and 7.5 in which N availability is optimum [15].

According to Landon top soils having CEC greater than 40 cmol (+)/kg are rated as very high, 25-40 cmol (+)/kg as high, 15-25 cmol (+)/kg as medium, 5-15 cmol (+)/kg low and < 5 cmol (+)/kg of soil as very low [11]. According to this classification, the present study soil has very high CEC of 47.46 cmol (+)/kg soil indicating its very high capacity to retain the cation. Tekalign Tadesse classified soil total N availability of <0.05% as very low, 0.05- 0.12% as low, 0.12- 0.25% as medium and > 0.25% as high [14]. The present study soil total N was estimated to be 0.16% (medium) indicating that the nutrient is a limiting factor for optimum crop growth. Therefore, based on the current laboratory results, the soil of the experimental site is suitable for fenugreek growth and production.

Table 1. Selected soil physico-chemical properties of the experimental site before planting.

Properties	Result	Rating	References
1. Physical properties			-
Sand (%)	21		-
Silt (%)	27		-
Clay (%)	52		-
Textural Class	Clay		-
2. Chemical properties			
pH (1: 2.5 H ₂ O)	6.82	Neutral	Tekalign (1991)
Organic Carbon /OC/ (%)	1.18	Low	Tekalign (1991)
CEC (cmol kg ⁻¹)	47.46	very high	Roy <i>et al</i> (2006)
Total nitrogen /TN/ (%)	0.16	Medium	Tekalign (1991))
Available phosphorus /P/ (ppm)	10.23	Medium	Roy <i>et al</i> (2006)
Available sulfur /S/ (ppm)	21.42	Very low	Lewis (1999)

3.2. Crop Phenology and Growth Parameters

3.2.1. Days to 50% Flowering

Number of days to 50% flowering was highly significantly ($p < 0.01$) and significantly ($p < 0.05$) affected by the main effects of NPS rates and varieties of fenugreek, respectively while the interaction effect of NPS and varieties did not show significant effect on days to 50% flowering. As the rate of NPS increasing from zero to 200 kg ha⁻¹ the number of days required to reach 50% flowering was significantly from 65.89 days to 62.11 days (Table 2). This might be due to the fact that phosphorus enhances reproductive phase through fastened flowering. In agreement with this result, Gifole *et al.* reported that phosphorus application to haricot bean significantly reduced days to flowering [16].

In Fenugreek the days to 50% flowering were significantly influenced by varieties. Variety Chala had the shortest days (63.27 days) to reach days to 50% flowering while Burqa and Ebisa varieties took the longest days of 64.20 and 64.53 to flowering. This is due to their genetic difference in response to flowering. Nchimbi-Msolla and Tryphone reported significant differences in the number of days required to

reach 50% flowering among 20 common bean genotypes. The result is also in line with the finding of Abera, who reported that where chickpea applied with 20 kg P₂O₅ ha⁻¹ delayed days to flowering (52.67 days) [18].

3.2.2. Days to 90% Physiological Maturity

The analysis of variance showed that main effect of NPS and varieties highly significantly ($p < 0.01$) influenced the number of days required to reach physiological maturity. However, significant variation was not observed due to the interaction between varieties and NPS fertilizer. As the rate of NPS increasing; significantly the duration required to reach physiological maturity was decreased. Thus, plants with no application of the NPS fertilizer required the longest number of days (117.6 days) to reach physiological maturity, whereas those treated with the highest rate of NPS (200 kg ha⁻¹) required the lowest days (114.2 days) to reach physiological maturity (Table 2). The decreased number of days required to reach physiological maturity in response to increased rates of NPS fertilizer may be resulted to the enhanced availability of the nutrient in the soil and its increased uptake by the fenugreek plants, which might have

resulted in a more luxurious vegetative growth that resulted in delayed maturity.

This result is in line with that of Abera, who reported that days to 90% physiological maturity of chickpea was highly significantly ($p < 0.01$) affected by application of P fertilizer rate, where, the longest time to maturity (114 days) was recorded for the application of 20 kg P_2O_5 ha^{-1} [18]. Furthermore, Ibsa reported that days to maturity of chickpea was significantly ($p < 0.01$) extended by the applied soil fertility treatments (*Rhizobium* + 46 kg P_2O_5 ha^{-1}). He reported the shortest maturity time observed for the control, where, inoculation in combination with P application, resulted in the longest (104 days) growing period of chickpea

than the control (101 days) [19].

The results showed that variety Ebisa required significantly higher number of days (117 days) while variety Burqa required shortest days (115) to reach physiological maturity (Table 1). The difference might suggest distinction in genetic makeup of the cultivars of fenugreek. In agreement with this result, [20] reported a wide variability of fenugreek landraces for days to maturity with the maximum days required to reach physiological maturity on 166.3 days and the minimum days needed was 116 days. Similarly, million reported that with respect to maturity of fenugreek landraces in Ethiopia, six landraces and the commercial variety Chala (126 days) were the earlier to mature [21].

Table 2. Main effects of NPS fertilizer and varieties on days to 50% flowering, days to 90% maturity and number of primary branches of fenugreek.

Treatment	Days to 50% flowering	Days to 90% maturity	Number of primary branches per plant
Rate of NPS (kg ha^{-1})			
0	65.89 ^a	117.60 ^a	4.47 ^b
50	64.78 ^{ab}	117.40 ^a	4.51 ^b
100	63.89 ^{bc}	116.10 ^b	4.56 ^b
150	63.33 ^c	115.40 ^{bc}	4.69 ^b
200	62.11 ^d	114.20 ^c	5.11 ^a
LSD (0.05)	1.12	1.30	0.35
Variety			
Burqa	64.20 ^a	115.00 ^b	4.61
Chala	63.27 ^b	116.50 ^a	4.83
Ebisa	64.53 ^a	117.00 ^a	4.96
LSD (0.05)	0.87	1.01	NS
CV (%)	1.8	1.2	7.7

Means in columns with the same letter are not significantly different at 5% probability level; LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= non-significant.

3.2.3. Plant Height

The main effect of NPS fertilizer and varieties highly significantly ($p < 0.01$) influenced plant height. Similarly, the interaction between NPS fertilizer and varieties significantly ($P < 0.05$) influenced plant height. The highest plant height (53.67 cm) was recorded from variety Chala applied with 200 kg NPS ha^{-1} and it was statistically at par with same variety with the application of 150 kg NPS ha^{-1} while the lowest plant height (38.27 cm) was recorded from variety Ebisa without NPS fertilization (Table 3).

The increased plant height of fenugreek varieties with increased rate of NPS fertilizer might be due to the more availability of nutrients through chemical fertilizers application and more nitrogen fixation by bacteria. This might have helped in better absorption and subsequent utilization of nitrogen for synthesis of chlorophyll, as nitrogen is an integral part of chlorophyll results in higher photosynthesis there by producing more photosynthates leading to more plant height. It may also be due to the cumulative effect of P on the processes of cell division and balanced nutrition [22]. The result is in line with the findings of Alemu who reported an increase in plant height of fenugreek varieties at 50% flowering stage in response to P fertilization [23].

Table 3. The interaction effect of NPS and varieties on plant height (cm) of fenugreek.

Variety	NPS rate (kg ha^{-1})				
	0	50	100	150	200
Burqa	43.00 ^{efgh}	43.53 ^{defgh}	44.33 ^{def}	49.80 ^{ab}	44.80 ^{cde}
Chala	49.13 ^{bc}	47.80 ^{bcd}	47.73 ^{bcd}	49.87 ^{ab}	53.67 ^a
Ebisa	38.27 ⁱ	39.93 ^{thi}	45.13 ^{cde}	46.73 ^{bcd}	44.33 ^{defg}
LSD _{0.05} = 4.048 CV (%) = 5.3					

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; LSD=Least significance difference at 5% probability level; CV=Coefficient of variation.

3.2.4. Number of Primary Branches per Plant

The main effect of NPS was highly significant ($p < 0.01$) on the number of primary branches produced per plant while neither the main effect of varieties nor the interaction effect of NPS and varieties significantly influenced by number of primary branches per plant. The number of primary branches significantly increased with the increase in NPS rate from zero to 200 kg ha^{-1} . The highest number of primary branches per plant (5.11) was recorded from 200 kg NPS ha^{-1} fertilizer while the lowest number of primary branches per plant (4.47) was recorded from without application of NPS fertilizer (Table 2).

The increase in number of branches with increase in NPS

rate might be due to the fact that nitrogen found in the NPS fertilizer is responsible for crop branching. It also might be because of P_2O_5 involve in cell division activity, which is important for increasing plant height, number of branches and increased the plant dry weight [24]. Similarly, Data *et al.*; and Thapa and Maity reported that increased number of branches of fenugreek with increasing nitrogen levels up to 50 kg ha⁻¹ [25] and [26]. Likewise, Singh *et al.* reported that the numbers of primary and secondary branches of fenugreek were significantly influenced by application of Sulphur [27].

3.3. Yield Components and Yield

3.3.1. Number of Pods per Plant

The analysis of variance showed significant ($p < 0.05$) effect of NPS application on the number of pods per plant while the main effect of varieties and the interaction between NPS fertilizer and varieties of fenugreek did not show significant effect.

The highest number of pods per plant (25.47) was obtained from 200 kg NPS ha⁻¹, however; it was statistically at par with NPS rates of 150 and 100 kg ha⁻¹ while the lowest number of pod number per plant (20.22) was obtained from no application of NPS fertilizer (Table 5). This might be due to the effect of P in the processes of cell division and balanced nutrition that enhanced growth and improving the reproductive performance of the plants. It might also be due to adequate availability of N and P which might have facilitated the production of more primary and secondary branches and plant height, which might, in turn, have contributed for the production of higher number of total pods.

This result is in line with the findings Ramesh *et al.* reported that increasing phosphorus rate up to 50 kg P_2O_5 ha⁻¹ increased fenugreek pods per plant up to (38.40 [28]. Similarly, [29] have reported increased number of pods per plant of chickpea by seed inoculation and P fertilization. Zafar *et al.*, have also reported that phosphorus fertilization showed significant increase in number of pods per plant of lentil due to the cumulative effect of phosphorus in the processes of cell division and balanced nutrition [22].

3.3.2. Number of Seeds per Pod

The analysis of variance showed that the main effect of NPS was highly significant ($p < 0.01$) and the interaction between NPS and varieties significantly ($p < 0.05$) influenced the number of seeds per pod. However, there was no significant variation among the varieties of fenugreek in number of seeds per pod.

The highest number of seeds per pod (11.89) was recorded from Burqa variety at rate of 150 kg NPS ha⁻¹ fertilizer and it was statistically at par with variety Ebisa at the same rate of NPS (11.71). In contrast, the lowest number of seeds per pod (8.75) was obtained from Chala variety at no application of fertilizers (Table 4). The highest number of seeds per pod at the higher NPS rate might be because of the availability of major nutrients (NPS) in proportionate amount increases concentration of carbohydrates in seed which serve as a reservoir of carbohydrates which resulted in increased

number of seeds in each pod.

The present result is in agreement with that of Solomon, who reported that the number of seeds per pod of faba bean was significantly ($p < 0.01$) affected due to the application of phosphorus rate, where the highest number of seeds per pod (3.41) was obtained from faba bean with application of 69 kg P_2O_5 ha⁻¹ [30].

Table 4. The interaction effect of NPS fertilizer and varieties on number of seeds per pod of fenugreek.

Variety	NPS rate (kg ha ⁻¹)				
	0	50	100	150	200
Burqa	9.43 ^{bcd}	9.61 ^{bcd}	10.43 ^b	11.89 ^a	10.43 ^b
Chala	9.19 ^{cd}	9.91 ^{bc}	10.26 ^{bc}	9.87 ^{bc}	10.44 ^b
Ebisa	8.75 ^d	9.57 ^{bcd}	9.97 ^{bc}	11.71 ^a	10.01 ^{bc}
LSD _{0.05} V x NPS = 0.9891 CV (%) = 5.9					

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; LSD=Least significance difference at 5% probability level; CV=Coefficient of variation.

3.3.3. Thousand Seed Weight

The analysis of variance showed that the main effect of NPS was highly significant ($p < 0.01$) on thousand seed weight. Similarly, significant variation ($p < 0.05$) was observed due to fenugreek varieties. However, the interaction between NPS fertilizer and varieties did not significantly affect this parameter. The highest thousand seeds weight (18.44 g) was recorded from 150 kg NPS ha⁻¹ while the lowest thousand seed weight (15.56 g) was recorded from no application of NPS fertilizer (Table 5). These results indicated that NPS fertilizer application contributed to increase efficiency of major nutrients and, thus, led to higher seed weight and yield.

In agreement with this result, Malik *et al* reported that P fertilizer and seed inoculation to soybean had significant influence on thousand seed weight, with the highest rate at 90 kg P_2O_5 ha⁻¹ with *Rhizobium* inoculation which was statistically at par with 120 kg P_2O_5 ha⁻¹ with inoculation [31]. Similar result was reported by R  veyde *et al.* where thousand-seed weight was affected significantly ($p < 0.05$) by different doses of nitrogen and sulphur on fenugreek [32].

The variety Burqa scored significantly higher thousand seed weight (17.31 g) compared to Ebisa (16.74 g) and Chala (16.65 g). The reason for variation in thousand seed weight might be due to genetic characteristics of the varieties of fenugreek for this trait. This result is in agreement with the findings of Mustefa who reported that fenugreek cultivars are different in thousand seed weight [33].

3.3.4. Aboveground Biomass

The main effect of NPS was significant ($P < 0.05$) on the aboveground biomass. However, neither the main effect of varieties nor the interaction effect of NPS and varieties significantly influenced aboveground biomass. The highest biomass yield (7160 kg ha⁻¹) was obtained from 200 kg NPS ha⁻¹ and it was statistically at par with 150 kg NPS ha⁻¹ (7037 kg ha⁻¹) whereas the lowest biomass (6006 kg ha⁻¹) was recorded from no NPS application (Table 5). The increase in

biomass yield at maximum rate of NPS fertilizer may indicate that these nutrients play synergistic role in metabolism, chlorophyll formation, and photosynthesis of the plant which in turn increases the biological yield [34].

This result is in agreement with that of Alemu who reported that highest biomass yield (6508.9 kg ha⁻¹) of fenugreek was obtained from 26 kg P ha⁻¹ [23]. The result

was also in line with the findings of Yilmaz who pointed out that increasing phosphorus levels up to 75 kg P₂O₅ ha⁻¹ improved aboveground biomass of narbon vetch (*Vicia narbonensis* L.) at harvest by as much as 18.5% [35]. On the other hand, Rakesh *et al* have reported that increasing doses of S gradually increased biomass yield of mungbean [36].

Table 5. Main effect of NPS fertilizer and varieties on yield components of fenugreek.

Treatment	Number of pod plant ⁻¹	Thousand seed weight (g)	Above ground biomass (kg ha ⁻¹)	Harvest index (%)
NPS rate (kg ha ⁻¹)				
0	20.22b	15.56d	6006b	24.93
50	21.84 ^b	16.29 ^c	6420 ^{ab}	24.72
100	22.07 ^{ab}	16.46 ^c	6574 ^{ab}	25.27
150	22.47 ^{ab}	18.44 ^a	7037 ^a	27.29
200	25.47 ^a	17.76 ^b	7160 ^a	25.10
LSD (0.05)	3.255	0.658	695.3	NS
Variety				
Burqa	23.36	17.31 ^a	6889	25.86
Chala	22.72	16.65 ^b	6685	25.01
Ebisa	21.16	16.74 ^b	6344	25.51
LSD (0.05)	NS	0.510	NS	NS
CV (%)	15.0	4.1	10.8	10.3

Means in a column with the same letter (s) are not significantly different at 5% probability level; LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= non-significant.

3.3.5. Seed Yield

The main effect of NPS as well as that of variety was highly significant ($p < 0.01$) to influence the seed yield of the fenugreek varieties. The two factors also interacted highly significantly ($p < 0.01$) to influence the seed yield of the crop. The highest seed yield (1980 kg ha⁻¹) was recorded from variety Ebisa at rate of 150 kg NPS ha⁻¹ fertilizer and it was statistically at par with variety Burqa at rate of 200 kg NPS ha⁻¹ (1912 kg ha⁻¹) while the lowest seed yield (1284 kg ha⁻¹) was recorded from variety Chala without NPS fertilization (Table 6).

The yield increase with increased rate of NPS rate might be due to cumulative effect of more grain filling percentage and more number of seeds per pod due to the increased nutrient uptake by the plants might have stimulated the rate of various physiological processes like growth and assimilation of nutrients. In line with this result, Tolanur and Badnur reported the highest seed yield (2379 kg ha⁻¹) in chick pea by application of mineral and organic fertilization [37]. Similarly, Rūveyde *et al.* reported that the highest seed yields of fenugreek (831.0 kg ha⁻¹) were recorded by application of 90 kg N ha⁻¹, while the lowest values (503.0 kg ha⁻¹) was recorded from the control [32]. Habtegebriel *et al.* also reported that *Rhizobium* inoculation along with phosphorus application significantly influenced grain yield of faba bean, where inoculation and 40 kg P₂O₅ ha⁻¹ resulted in 62.5% increase in grain yield over the control [38]. Seed yield increased with the increase of sulphur doses in fenugreek. Likewise, many research results showed that the highest seed yields on fenugreek was obtained from the maximum sulphur applications [39, 40].

Table 6. The interaction effect of NPS fertilizer and varieties on seed yield (kg ha⁻¹) of fenugreek.

Variety	NPS rate (kg ha ⁻¹)				
	0	50	100	150	200
Burqa	1621 ^c	1618 ^c	1822 ^d	1833 ^{cd}	1912 ^{ab}
Chala	1284 ^s	1548 ^{ef}	1520 ^f	1897 ^{bc}	1625 ^d
Ebisa	1559 ^{ef}	1511 ^f	1597 ^c	1980 ^a	1812 ^d
LSD _{0.05} V x NPS = 68.41 CV (%) = 2.4					

Means followed by the same letter (s) within the table are not significantly different at 5% level of significance; LSD=Least significance difference at 5% probability level; CV=Coefficient of variation.

3.3.6. Harvest Index

The difference in harvest index was observed to be non-significant among varieties of fenugreek and NPS fertilizers. Similarly, significant variation was also not observed by the interactions of the two factors. The observed harvest index varies from 24.93 to 27.29% (Table 5). In line with this result Mehta *et al* reported that harvest index was not significantly affected with phosphorus levels in fenugreek [41]. However, contrary to the current result, Zafar *et al.* found that calculated values of harvest index showed an increasing trend in the harvest index values with application of P on lentil and minimum harvest index from the control plot [22]. Similarly, Ali reported that inoculation and phosphorus application exhibited significant effect on harvest index of chick pea [42].

3.4. Economic Evaluation

Partial budget analysis revealed that the highest net benefit (42231.67 and 40361.9 ETB ha⁻¹) with marginal rate of

return (566.84 and 542.5%) were recorded for varieties of Ebisa and Chala respectively, while variety Burqa resulted the higher net benefit (39294.8 ETB ha⁻¹) with highest marginal rate of return (166.24%) at 100 kg NPS ha⁻¹ (Table 7). The dominated treatments according to the dominance analysis were disregarded from further economic analysis. To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as a worthwhile preference to farmers, the marginal rates of return (MRR) need to be at least between 50% and 100% CIMMYT [9]. Thus, to draw farmers' recommendations from marginal analysis in this study, 100% return to the investment is

reasonable lowest acceptable rate of return.

Accordingly, application of 150 kg NPS ha⁻¹ with marginal rate of returns (566.84 and 542.5% MRR) for varieties of Ebisa and Chala respectively, were above the minimum acceptable rate of return. Similarly, application of 100 kg NPS ha⁻¹ with marginal rate of return (166.24%) for variety Burqa was also above the minimum acceptable rate of return (Table 7). Therefore, application of 150 kg NPS ha⁻¹ for varieties Chala and Ebisa and application of 100 kg NPS ha⁻¹ for variety Burqa were superior rewarding treatments and these fertilizer rates can be recommended for those varieties in Ginir and other areas with similar agro-ecology condition.

Table 7. Partial budget analysis result for NPS fertilizer rate on fenugreek varieties at Ginir in 2017/18-2019/20 main cropping season.

Variety	NPS rate (kg ha ⁻¹)	Average yield (kg ha ⁻¹)	Adjusted yield by 10% down (kg ha ⁻¹)	GFB (ETB ha ⁻¹)	TVC (ETB ha ⁻¹)	NB (ETB ha ⁻¹)	MRR (%)
Burqa	0	1620.83	1458.75	36468.7	0	36468.7	
Burqa	50	1618.06	1456.25	36406.3	1090	35316.3	D
Burqa	100	1821.99	1639.79	40994.8	1700	39294.8	166.24
Burqa	150	1832.87	1649.58	41239.6	2310	38929.6	D
Burqa	200	1912.5	1721.25	43031.3	2920	40111.3	66.92
Chala	0	1284.03	1155.63	28890.6	0	28890.6	D
Chala	50	1548.15	1393.34	34833.4	1090	33743.4	347.97
Chala	100	1520.14	1368.13	34203.2	1700	32503.2	D
Chala	150	1896.53	1706.88	42671.9	2310	40361.9	542.5
Chala	200	1625	1462.5	36562.5	2920	33642.5	D
Ebisa	0	1559.03	1403.13	35078.1	0	35078.1	228.73
Ebisa	50	1618.06	1456.25	36406.3	1090	35316.3	21.85
Ebisa	100	1597.22	1437.5	35937.5	1700	34237.5	D
Ebisa	150	1979.63	1781.67	44541.7	2310	42231.7	566.84
Ebisa	200	1811.57	1630.42	40760.4	2920	37840.4	D

Where GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha⁻¹ = Ethiopian Birr per hectare; D = dominated treatments; Cost of NPS 1220.00 Birr 100 kg⁻¹; Labour cost for NPS fertilizer application = 4 person day ha⁻¹, at 120 ETB per day; sale price of fenugreek seed 2500 Birr per 100 kg during harvest on farm.

4. Summary and Conclusion

The majority of tropical soils including that of Ethiopia have limited potential of producing high crop yields because of limitation of nutrients, particularly that of nitrogen, phosphorus and sulphur. Due to this fact, yield is usually below the genetic potential of crops. In case of fenugreek, the productivity is considerably lower than the world average due to lack of appropriate agronomic management practices particularly in relation to nutrients. One of the alternatives to address such problem is supplying well-balanced nutrients to meet the crop nutrient requirements. Therefore, an experiment was conducted with the objectives of assessing the effect of NPS fertilizer rates on growth, yield components and seed yield of fenugreek varieties under different NPS rates. The treatments consisted of factorial combinations of three varieties (Burqa, Chala and Ebisa) and five NPS application rates (0, 50, 100, 150 and 200 kg NPS ha⁻¹) in Randomized complete block design with three replications.

Analysis of variance revealed that days to 50% flowering, days to 90% physiological maturity, number of primary branch per plant, number of pod per plant, above ground biomass, thousand, and seed weight were significantly

affected due to main effect of NPS fertilizer. The maximum thousand seed weight was obtained by application of 150 kg NPS fertilizer ha⁻¹. On the other hand, the maximum number of primary branches per plant, number of pods per plant and biomass yield and the shortest days to flowering and maturity were recorded by the application of 200 kg NPS fertilizer ha⁻¹.

Days to 50% flowering, days to 90% physiological maturity and thousand seed weight were significantly affected by main effect of fenugreek varieties. The shortest days to reach days to 50% flowering (63.27 days) were recorded from variety Chala while variety Ebisa had the longest days to reach 50% flowering date. Variety Ebisa required significantly higher number of days while variety Burqa required shortest days to reach 90% physiological maturity and scored significantly higher thousand seed weight.

The interaction effects of variety and NPS fertilizer significantly affected plant height, number of seeds per pod and seed yield. Significantly the highest plant height (53.67 cm) was recorded from variety Chala applied with 200 kg NPS ha⁻¹ while the highest number of seeds per pod (11.89) and seed yield (1980 kg ha⁻¹) were recorded from varieties

Burqa and Ebisa, respectively, at rate of 150 kg NPS ha⁻¹ fertilizer application.

The results of this study have indicated that yield and yield components were significantly influenced by application of NPS except harvest index. The results generally demonstrated that NPS fertilizer significantly enhanced growth and yield of the tested fenugreek varieties. Variety and NPS fertilizer rates significantly affected number of seed per pod and seed yield gave desirable results at the rate of 150 kg NPS fertilizer ha⁻¹. The fenugreek varieties, Ebisa and Chala produced the highest seed yield at 150 kg NPS ha⁻¹ while variety Burqa at 200 kg NPS ha⁻¹.

The economic analysis also indicated that the highest net benefit/return (42231.67 ETB ha⁻¹) was recorded from variety Ebisa followed by net benefit (40361.9 ETB ha⁻¹) from variety Chala with marginal rate of return (566.84 and 542.5%) respectively, at application of 150 kg NPS ha⁻¹ while variety Burqa resulted higher net benefit (39294.8 ETB ha⁻¹) with the highest marginal rate of return (166.24%) at 100 kg NPS ha⁻¹ application. The lowest net return (28890.63 ETB ha⁻¹) was recorded from Chala variety without NPS fertilizer application.

In general, this study provided evidence that yield and economic returns of fenugreek varieties could be improved by application of NPS fertilizer at optimum rates. Among the varieties of fenugreek tested, variety Ebisa was superior on yield performance with the application of NPS fertilizer. Thus, it can be concluded from the result of present study that the application of 150 kg NPS ha⁻¹ to Ebisa and Chala varieties and 100 kg NPS ha⁻¹ to Burqa variety could be recommended to enhance the productivity of fenugreek in the study area.

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