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ORIGINAL ARTICLE

Growth and Yield Response of Fenugreek *(Trigonella foenum-graecum* L.*)* Genotypes to Phosphorus Application at Adea District, Ethiopia

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ABSTRACT

Fenugreek (*Trigonella foenum-graecum* L.) is an important legume crop which has huge potential for human nutrition and animal feeds. However, its productivity is considerably lower due to production constraints such as poor agronomic practices and low yielding varieties. A field experiment was conducted during August to December 2018 to evaluate the response of fenugreek genotypes to phosphorus (P) application in terms of growth, yield attributes and seed yield at Adea district, central highland of Ethiopia. The experiment consisted of six genotypes (Bishoftu, Chala, Ebbisa, Hunda, 28605 and 28606) combined with four P levels (0, 9, 17and 26 kg P ha^{-1}) of P. The treatments were arranged in factorial fashion and laid out in completely randomized block design with three replications. The results revealed that most growth and yield attributes, biological yield and harvest index were significantly influenced by genotype. Among the tested genotypes Chala variety was highest in biological yield, harvest index and apparent recovery. Phosphorus application also significantly affected growth, yield components and biological yield. Nodule number and dry weight, P agronomic use efficiency and seed yield were those parameters influenced by interaction effect of genotype and P application. The combination of Chala variety with 17 kg P ha^{-1} was promising combination that generated highest seed yield followed by same variety with 9 kg P ha^{-1}. Therefore, Chala variety combined with 17 kg P ha^{-1} rate can be recommended for farmers in the study area. However, in order to give comprehensive recommendation in the study area and areas of similar agro-ecology the study should be re confirmed over the year and location.

Keywords: Fenugreek, Genotype, Growth, Phosphorus, Seed yield

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is the annual herbaceous legume crop that parts of the plant is used as leafy vegetable, fodder and condiment (Khiriya *et al.*, 2003). Nursing mothers consumes fenugreek for the maintenance of breast milk. Infants after the age of 4-6 months are also fed with extracts of fenugreek seed (Engles *et al.*, 1991). Farmers in some parts of Ethiopia such as Hararghe as 'Lafiso' and Harari people as 'Hulbat Meraq' used as their best dish (Jemal, 1998).

Feysal (2006) reported that Ethiopia is recognized as the original homeland of *Trigonella foenum-graecum* subspecies Mediterranean, ecotype Abyssinian with its distribution extending to neighbor countries. Study reported presence of fenugreek genetic variability as well as the production and distribution in Ethiopia as nearly similar to those of other cool season food legumes (DZARC, 2004). According to the CSA (2017/18) estimation, out of the total cultivated land in Ethiopia, fenugreek occupies 32,587 ha with productions and productivity of 43637.39 ton and 1.33 ton ha^{-1}, respectively, in 2017/2018. In Ethiopia, Oromia Region State shared most of the production with productivity of 1.31 t ha^{-1}.

The productivity of fenugreek both nationally and regionally during 2017/2018 cropping season was too low as compared to its potential yield (1.8 ton ha^{-1}) reported by MoA (2014). One of the primary production constraints of fenugreek is poor soil fertility like P deficiency. According to Fairhurst *et al.* (1999) P deficiency is one of the largest constraints to crop production, owing to low native content of P coupled with high P fixation capacity of many tropical soils. The soil fertility map made over 124 Woradas of Oromia showed that most soils lack NPK (EthioSIS, 2014).

Phosphorus is the most important yield-limiting elements that required by legume crops (Fageria *et al.*, 2010). In plant metabolism it plays an important role via cellular energy transfer and being key structural component of nucleic acids coenzymes and proteins

(Blackshaw *et al*., 2004). Godara (2015) has been found that P application increases NPK contents and significantly increases seed and straw yields. According to Chiezey (2001) legume crops require adequate P supply as long as P has consistently increased grain yield on P deficient soils via production and retention of more pods plant^{-1}.

Research on phosphorus fertilizer practices for the fenugreek crop is given little attention in Ethiopia. Previously in Ethiopia only a few agronomic trials have been done on planting dates, seeding rate and some N and P fertilizer trials (DZARC, 2007). Accordingly, a blanket recommendation of 26 P ha^{-1} is being used across the country regardless of the type of variety, soil type and other factors. According to Khiriya *et al.* (2001) P fertilizer at a rate of 17 P ha^{-1} resulted in the highest seed yield of fenugreek and recommended for production in India. However, P requirement of plants vary with varieties, soil type, environmental conditions and availability of other nutrients.

Site and/or variety specific phosphorus fertilizer recommendation for many crops including fenugreek is lacking in Ethiopia. Furthermore, comparison of fenugreek accessions and varieties potential in terms of growth, yield attributes and seed yield in response to P application was not under taken under Ethiopia condition. However, reports indicate that some variety development efforts have been made in few research centers in the country (DZARC, 2004). Therefore, majority of the farmers use inappropriate/smaller doses of P fertilizer and some of the farmers do not use P fertilizer at all. In view of filling such gap, this research work was conducted with the objective of growth, yield attributes and seed yield response of fenugreek genotypes to phosphorus application.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Debre Zeit Agricultural Research Centre (DZARC) Horticulture research station in 2018 cropping season. The research center is found at 47 km away to South East of Addis Ababa, Ethiopia. It is located at 8o 44′ N latitude, 38o 58′ E longitudes at 1900 m.a.s.l. altitude. The area received an annual rainfall of 690 mm during the cropping season, which was higher than the mean annual rainfall (558.18 mm) of the ten years. Mean maximum and minimum temperature of 26.84 oC and 11.01 oC, respectively, were recorded at the station during the season.

Description of genetic materials

A total of 6 genotypes were used in the study. Among them four improved varieties (Bishoftu, Chala, Ebbisa and Hunda) from DZARC and two conserved accessions (28605 and 28606) from Ethiopia biodiversity Institute (EBI) were collected (Table 1). The accession collected from farmer was chosen in experiment to compare their potential with improved varieties as long as currently some farmers are cultivating unimproved genotypes. In addition all genotypes were cultivating under almost similar agro ecology. The passport description depicted as the accessions were under cultivation though the potential of these accessions were not assessed earlier.

Table 1. Improved fenugreek varieties and accession used in the experiment

S. No	Name	Releasing/collecting Research Center*	Release/collection year	Yield ton ha^{-1}	Recommended agro-ecology
1	Bishoftu	DZARC/EIAR	2017	1.19	Mid and high altitude
2	Chala (FG -47-01)	DZARC/EIAR	2005	0.9-1.65	Mid and high altitude
3	Ebbisa	SARC/OARI	2012	1.38	Mid and high altitude
4	Hunda - 01 (FG-18)	SARC/OARI	2006	1.22	Mid and high altitude
5	28605	EBI	2016	-	1954 m.a.s.l.
6	28606	EBI	2016	-	1966 m.a.s.l.

*DZARC = Debre Zeit Agricultural Research Center, EIAR=Ethiopian Institute of Agricultural Research, SARC=South Agricultural Research Center, OARI=Oromia Agricultural Research Institute. EBI=Ethiopia Biodiversity Institute. Source: (Ministry of Agriculture and Natural Resources, 2016)

Treatments and Experimental design

The experiment consisted of 24 treatment combinations of six fenugreek genotypes (four improved varieties and two accessions) with four levels of Phosphorus fertilizer rates (0, 9, 17 and 26 kg P ha^{-1}). It was laid out in Randomized Complete Block Design (RCBD) arranged factorial with three replications.

Physico-chemical analysis of soil

Before planting soil samples from depth of 0-20 cm were collected randomly in zigzag pattern from the entire experimental site and composited for determination of selected physico-chemical properties of the soil. Soil nitrogen was determined by Kjeldahl method (Jackson, 1958) and available P was estimated by Olsen's method (Olsen *et al.*, 1954). The content of K in the solution was estimated by Flame photometer and organic carbon was estimated by Walkley and Black method (Walkley and Black, 1934). CEC was determined by ammonium acetate method (Scollenberger and Simon, 1945), soil pH in1:2.5 soil-water ratios using an electrodes pH meter and particle size distribution by hydrometer method (Day, 1965) were determined at soil laboratory of DZARC.

Soil Physical and Chemical Properties

The result depicted that the experimental soil was a constituent of clay, silt and sand. CEC (21.8), pH (7.32), organic carbon (1.41), organic matter (2.43), total N (0.09), available P (9.04 ppm) and K (1.01meq/100 g soil) (Table 2). Based on Tekalign (1991) the analysis of the collected sample indicated that the soil is clay, neutral in reaction (pH 7.32), low both in organic carbon (1.41) and organic matter (2.43). Furthermore, the soil test showed low in total N (0.09). According to Marx (1996) soil test result of P less than 10 ppm categorized as low and the experimental site had low available P (9.04 ppm) and high K (1.01meq/100 g soil).

Table 2. Phsico-chemical characteristics of the experimental soil

Soil depth	Ph (1:2.5)	Total N	Available P (mg/kg)	K (mg/kg)	CEC (meq/100 g soil)	OC %	OM %	Soil texture Clay %	Silt %	Sand %	Class
0-20	7.32	0.09	9.04	1.01	21.8	1.41	2.43	56	28	16	Clay

Seed sowing and fertilizer application

Seeds were sown in 5 rows at each plot (24 plots) in which 0.5 m and 1 m distances were maintained between plots and blocks, respectively. The P fertilizer was applied as triple superphosphate (TSP). Treatments were randomly assigned to the experimental plots at each replication. At sowing P fertilizer was banded into the soil along rows depending on the treatment and also a recommended dose of nitrogen (20 kg N ha^{-1}) in the form of urea was uniformly applied to all the plots (Dogra and Dudeja, 1993). Thinning was done manually after germination with maintaining of healthy vigorous seedling at the spacing of 10 cm x 30 cm in 3 m^2 area of single plot sizes. The middle three rows were considered for recording of data. Six plants were taken randomly and tagged from each plot for recording observations on growth and yield parameters; finally seed and haulm samples were collected from each plot and plant tissue analysis (seed and haulm P concentrations) were undertaken for some selected physiological parameters.

Data Collection

Crop phenology

Days to 50 % flowering: Recorded by counting the number of days taken from date of sowing to 50% plants flower in each plot.

Days to maturity: Days to maturity of plants were recorded by counting the number of days from sowing to 50% of the plants in each plot physiologically matured which is explained by yellowing of straw.

Growth and nodulation attributes

Plant height: The height of six randomly taken plants was measured from the ground to the tip of the plant. The average was worked out and expressed as plant height in cm.

Root length and dry weight: Six plants gently uprooted and tap roots were measured from basal part to the tip, averaged and expressed as root length in cm after the shoot part was removed. The root (without dried nodules) was then oven dried at 70°C to constant weight, averaged and expressed in g per plant.

Nodule number and nodule dry weight per plant: At mid flowering six random plants were taken from destructive row of each plot and roots were carefully uprooted with the bulk of root mass and nodules using a spade. The nodules were separated from the soil, washed and the total number of nodules was determined by counting. After drying, the nodules from each plot weighed and averaged to record the dry weight of nodules per plant in milligram.

Yield and yield attributes

Pod length: Six pods from six plants selected randomly from each plot at physiological maturity were measured from the base to the tip of the pod and their mean was recorded.

Number of pod per plant: The pods of six randomly selected plants from each plot at the time of physiological maturity were counted and average was recorded as pods per plant.

Seed per pod: Seed of six randomly selected pods from six plants were counted and averaged to compute seed number per pod.

Weight of 1000- seeds (g): 1000 seeds were counted in samples drawn from the finally cleared seed and weighed.

Seed yield (t ha^{-1}): After threshing and winnowing, clean seeds obtained from individual net plot (1.8 m^2) were weighed separately and this weight was converted into t ha^{-1}.

$$\text{Adjusted seed yield} = \frac{(100 - Mc) * \text{unadjusted yield}}{100 - AM}$$

where, AM; adjusted moisture (10%), Mc= moisture content of fenugreek seeds at the time of measurement.

Biological yield (t ha^{-1}): The weight of thoroughly sun dried harvested produce of each net plot was recorded separately before threshing as biological yield, then it was converted into t ha^{-1}.

Harvest index: The ratio of economic yield (seed yield) to the biological yield was computed.

$$\text{Harvest index} = \frac{\text{Economic yield } (t\,ha^{-1})}{\text{Biological yield } (t\,ha^{-1})}$$

Phosphorus agronomic use efficiency and apparent recovery

P AUE (kg kg^{-1})

$$= \frac{\text{Grain yield of fertilized plot} - \text{Grain yield of unfertiled plot}}{\text{P applied}}$$

P AR (kg kg^{-1})

$$= \frac{\text{Total P plant of fertiliized plot} - \text{Total P plant of control plot}}{\text{P applied}}$$

where P is Phosphorus, AUE is agronomic use efficiency, AR is apparent recovery

Data analysis

The collected data were subjected to analysis of variance (ANOVA) using GLM procedure of SAS version 9.0 and after the significance determined test of mean separation was done using Duncan's Multiple Range Test (DMRT) at 5 % probability level using SAS.

RESULTS AND DISCUSSION

Crop phenology and growth attributes

Days to flowering and days to maturity

Days to 50% flowering was significantly affected due to genotype (P<0.001) and P application (P<0.01). However, the interaction effect of these two factors had no significant difference on days to 50% flowering. Further, maturity was significantly (P< 0.01) affected only by genotype (Table 3).

Among genotypes, accession 28605, varieties Chala and Hunda showed long delays to 50% flowering as compared to accession 28606 and Ebbisa variety. Variety Bishoftu was earlier to flower of all genotypes tested (Table 3). With regard to maturity, accession 28605 and variety Ebbisa were earlier matured than Hunda, Chala varieties and accession 28606 (Table 3). Accession 28605 was the late in terms of flowering, but took less number of days to mature. This may be due to genetic potential which expressed as it took less time in grain filling period. The other reason might be due to the existence of difference in genetic makeup that genotype can be classified as early and late flowering. The variation in crop phenology among genotypes can be an indicator for the possibility of significant improvement by selection.

In line with the current result, Feysal (2006) and Alemu (2009) found significant variation in flowering time among fenugreek genotypes. In against to this experiment Alemu (2009) reported that Chala variety flowered earlier than Hunda variety. A high degree of genotypic variation in phenology of fenugreek reported by Provorov *et al.* (1996). Further, reports showed that days taken for maturity varied significantly due to varieties (Sharanya, 2017).

With regard to P application, 26 kg ha^{-1} resulted in earlier flowering as compared to control and 9 kg ha^{-1} (Table 3). The result showed that application of P at rates of 17 and 26 kg ha^{-1} had similar impact on days to flowering. This shows that P application at a rate of 17 kg ha^{-1} is enough to enhance flowering of fenugreek varieties at the study area. The earlier flowering at higher rates could be due to the reason that phosphorus increases cytokinins synthesis (Horgan and Wareing, 1980). Additionally, it increases supply of photo-assimilates for flower formation through hastening physiological activity (Marschner, 1995). Abel *et al.* (2002) reported as phosphorus significantly influences plant growth and metabolism on account of being a component of DNA and RNA that exerts regulatory functions on cell division. However, the current result is in contrary to Sheoran *et al.* (2000) who observed no significant effect of P for floral initiation.

Plant height, root length and root dry matter

Plant height

Plant height was significantly (P<0.01) influenced by P application only. Both genotype and interaction effect had no significant influence on plant height (Table 4). Taller plants were seen at 17 kg P ha^{-1} as compared to control and 9 kg P ha^{-1} (Table 4). The higher plant height recorded might be due to the contribution of phosphorus to plant growth attributes such as increasing of inter nodal length and greater dry matter accumulation. The result is in agreement with, Khiriya *et al.* (2001) who revealed that higher application of phosphorus increased plant height significantly over the lower doses at all stages of crop growth.

Root length and dry matter

Root dry weight significantly (P<0.001) affected due to main effects genotype and P application. However, the interaction effect of these two factors had no significant difference on root dry weight. Additionally, root length was significantly (P<0.001) affected only by P application (Table 4).

The highest root dry weight was produced by variety Bishoftu as compared to all of tested genotypes. The other five genotypes were produced similarly root dry weight (Table 4). Differential root dry weight potential showed existence of genetic variation among fenugreek genotypes in root traits. Trindade and Araújo (2014) suggested selection of cultivars with greater root growth as a strategy to increase phosphorus uptake and grain yield especially where the availability of phosphorus in the soil is very low.

Table 3. Days to 50% flowering and maturity of fenugreek as influenced by genotype and P

Genotype (G)	Days to 50% flowering	Days to maturity
Bishoftu	46.83^{c}	93.33^{ab}
Chala	50.83^{a}	96.66^{a}
Ebbisa	48.58^{b}	90.50^{b}
Hunda	50.66^{a}	95.08^{a}
28605	51.16^{a}	90.16^{b}
28606	48.50^{b}	94.20^{a}
MS	36.61***	79.34**
EMS	3.11	17.17
P (kg ha^{-1})		
0	50.38^{a}	95.05
9	49.77^{a}	94.11
17	49.27^{ab}	92.72
26	48.27^{b}	91.44
MS	14.34**	45.07
EMS	3.11	17.17
CV (%)	3.56	4.43
G*P (MS)	0.92ns	1.64ns

P=Phosphorus, MS=Mean Square, EMS=Error mean square, CV (%) = Coefficient of variation, ns; non-significant. Means in the same column followed by the same letter(s) are not significantly different at 5 % probability level by DMRT

In case of P application the recorded data showed increment of phosphorus fertilizer statistically resulted in higher root biomass in sequential order from control to 26 kg P ha-1. Application of 9 kg ha-1, 17 kg ha-1 and 26 kg ha-1 increased root dry weight by 18.7%, 35.9% and 70.3% respectively, as compared to the control treatment (Table 4). With regard of root length the application of 17 kg ha-1and 26 kg ha-1 resulted in similar root length in which both rates were higher as compared to control and 9 kg ha-1. The result showed that application of P at rates of 17 and 26 kg ha-1 had similar impact on root length. The application of 17 kg ha-1increased root length by 17.6% over the control (Table 4). This is due to the fact that phosphorus has a positive and direct effect on a dry matter, root development and proliferation (Srivastava and Ahlawat, 1995). In line to this result Trindade and Araújo (2014) noted that the higher dose of phosphorus promoted mass of tap root, higher root dry weight and length of roots.

Nodule number and nodule dry weight

Nodule number and nodule dry weight per plant was significantly (P<0.01) affected due to genotype, P application and interaction effect of these two factors (Table 5). Higher nodule number was obtained at combined effect of variety Ebbisa with 26 kg ha^{-1} and variety Bishoftu with 26 kg ha^{-1} (Table 5). The lowest nodule number was recorded from accession 28606 with no P application. The nodule number showed successive improvement as P level increased from control to 26 kg ha^{-1} with Ebbisa, Bishoftu and Hunda varieties (Table 5). With regard to nodule dry weight; variety Ebbisa with 26 kg ha^{-1} and Bishoftu with 26 kg ha^{-1} produced the highest nodule dry weight numerically. Accession 28606 produced numerically lower nodule dry weight particularly as planted without phosphorus (Table 5). Higher nodulation due to increased phosphorus fertilizer might be due to symbiotic nitrogen fixation requires higher phosphorus for the maximum activity in reduction of atmospheric nitrogen by nitrogenase system. The other reason might be due to genetic factors that the genotype nature to nodulation as long as non nodulating and nodulating genotype existed, irrespective of agronomic practices available (Provorov and Simarov, 1990). This result is in agreement with Abbasi *et al.* (2010) who stated increasing in phosphorus application increased the total of root nodules and dry weight. Increased nodulation due to application of 40 to 60 kg P_2O_5 ha^{-1} has been reported (Bhunia*et al.*, 2006).

Yield and yield attributes

Pod length and number of pod per plant

Pod length showed significant variation due to genotype and P application (Table 6). Among genotypes variety Ebbisa and accession, 28606 produced longer pod lengths, while variety Chala produced statistically similar pod length (Table 6). This might lead to the reason of genetic variation as suggested by Fageria *et al.* (2006) the variation exists among legume genotypes for pod length greatly controlled genetically. The observation is in harmony with the results of Sharanya (2017) who stated variety has significant effect on length of pods.

The three rates of P application (9 kg P ha^{-1}, 17 kg P ha^{-1} and 26 kg P ha^{-1}) resulted in longest pod similarly. The shortest pod length was recorded at control (Table 6). The application of 9 kg ha^{-1}, 17 kg ha^{-1} and 26 kg ha^{-1} had similar impact on pod length. Thus, the application of 9 kg ha^{-1} is enough for pod length improvement. The increased pod length might be due to higher phosphorus availability in the soil which enables the root to transfer phosphorus toward sink and more transfer of photosynthates towards sink (pod) from sources as compared to control plot. Similarly Khiriya and Singh (2003) documented that the highest pod height from higher dose of P than control treatment.

Pod number per plant was significantly affected due to genotype (P< 0.05) and P application (P<0.001) (Table 6). Of genotypes, Chala variety produced higher pod number per plant as compared to Ebbisa and 28605 genotypes (Table 7). Variety Chala generated statistically similar number of pod per plant with Bishoftu, Hunda and 28606 genotypes (Table 6).

Table 4. Plant height and root components as influenced by genotype and P application

Genotype (G)	Plant height (cm)	Root dry weight per plant (g)	Root length (cm)
Bishoftu	29.9	0.99[a]	15.06
Chala	28.8	0.80[b]	16.23
Ebbisa	29.28	0.84[b]	15.31
Hunda	28.78	0.84[b]	15.51
28605	28.91	0.81[b]	14.86
28606	30.26	0.78[b]	16.03
MS	4.69ns	0.067*	3.46ns
EMS	10.13	0.02	3.46
P (kg ha^{-1})			
0	27.36[c]	0.64[d]	13.78[b]
9	28.68[bc]	0.76[c]	14.93[b]
17	31.41[a]	0.87[b]	16.21[a]
26	29.83[ab]	1.09[a]	17.08[a]
MS	53.1**	0.65**	36.67***
EMS	10.13	0.02	3.46
CV(%)	10.85	16.84	12
G*P (MS)	3.45ns	0.03ns	1.81ns

P= Phosphorus, MS= Mean Square, EMS=Error Mean Square, CV(%)=Coefficient of variation, ns= non significant, Means in the same column followed by the same letter (s) are not significantly different at 5% probability level by DMRT

An increase in number of pods per plant was 32.63 %, 20.5 % higher in Chala as compared to variety Ebbisa and accession 28605, respectively. Fageria *et al.* (2006) reported that variation exists among legume genotypes for number of pods per plant which is controlled genetically. Similarly, Feysal (2006) reported high genotypic variation in number of pods per plant for fenugreek.

The application of 26 kg ha^{-1} resulted in maximum pod per plant as compared to other P levels. The control and 9 kg ha^{-1} resulted in statistically similar pod per plant (Table 6). An increment of pod per plant in 26 kg ha^{-1} and 17 kg ha^{-1} over control were 41.18 % and 30.72%, respectively (Table 6). The increased in number of pod with increased P rate might be due to role of phosphorus to various enzymatic activities which enhanced flowering and pod formation (Nehara*et al*., 2006). Phosphorus has consistently increased grain yield of legumes on phosphorus deficient soils as it also encourages production and retention of more pods per plant (Chiezey, 2001). In line to this Shweta *et al.* (2014) indicated that high application of phosphorus gave higher number of pods per plant.

Seed per pod and thousand seed weight

The analysis of variance showed that seed per pod significantly affected due to main effects of genotype (P<0.001) and P application (P<0.05) only (Table 6). Variety Bishoftu produced the highest seed per pod over all genotypes tested in this experiment (Table 6). The variation exists might be due to genetic factor. The result is in agreement to Chowdhury *et al.* (2014) who reported variation of seed per podamong fenugreek genotypes. The application of 17 kg P ha^{-1} and 26 kg P ha^{-1} resulted statistically similar, which were higher seed per pod over control treatment. Control plot showed great reduction of seed per pod by 6.7 % as compared to 17 kg P ha^{-1} application (Table 6). Increment might be due to P aids in seed development in legumes through making seed production more uniform, resistant to plant disease, improves flower formation and seed quality (Kumar *et al*., 2000). This finding is in close conformity with the results reported by Tunçtürk, (2011) who showed seeds per pod increased significantly with increasing dose of P.

The recorded data indicated that weight of thousand seeds significantly affected by genotype and P application. But was not significantly affected by interaction of these two factors (Table 6). Accession 28606 and variety Ebbisa resulted in higher and lower seed weight numerically (Table 6). The fundamental difference in seed weight might be due to genetic facts. The result is in corroborate with Sharanya (2017) who reported as genotypes of fenugreek showed significant effect on weight of seed. Regarding to P application, higher seed weight was recorded at 26 kg P ha^{-1} as compared to control (Table 6). The higher seed weight recorded over the control could be due to the fact that P application may improve the seed weight of the plant through higher uptake of P during seed formation. This result is in agreement with the result of Shweta *et al.* (2014) who noted that seed weight increased with the applied P.

Seed yield

Seed yield showed significant variation due to genotype, P application and interaction (P<0.01) effect of two factors (Table 7). The combined effect of Chala variety with 17 kg ha^{-1} resulted in significantly higher seed yield followed by the same variety combined with both 9 and 26 kg ha^{-1}. Accession 28605 combined with both control plot and 9 kg ha^{-1} as well as Ebbisa variety combined with control plot were those treatments generated lower seed yield statistically (Table 7). Seed yield of a crop is a function of yield attributes such as number of pods per plant, number of seeds per pod and 1000-seed weight that increasing in growth due to enhanced nutrient uptake and utilization which have direct and positive effect on seed, straw and biological yields of fenugreek. The increment in seed yield due to increase in plant growth attributes and yield components were reported (Dubey *et al.,* 2012). Higher dose of phosphorus helped in increase in the number of pod per plant and filled pods. This might be due to higher response of genotype to applied P as long as the initial soil available P was low (Table 2). The existence of capable genotype to respond and produce higher grain yield might be a reason. Our finding confirmed with Khiriya *et al.,* (2001) who stated as significant increase in seed yield of fenugreek up to 17 kg ha^{-1}.

Table 5. Nodule number and dry weight of fenugreek as affected by interaction effect of genotype and P application

	Nodule number per plant				Nodule dry weight per plant(mg)			
	P (kg ha^{-1})				P (kg ha^{-1})			
Genotype	0	9	17	26	0	9	17	26
Bishoftu	14.9hi	18.3fg	24.6cd	34.3a	19.7e-g	22.4^{ef}	33.3^{cd}	47.8^{a}
Chala	10.8^{jk}	14.6^{hi}	15.9^{hi}	24.0^{c-e}	17.8^{f-i}	19.3^{f-h}	43.5^{ab}	28.2^{de}
Ebbisa	18.7^{f}	23.0^{de}	31.5^{b}	35.2^{a}	12.5^{g-j}	19.1^{f-h}	44.8^{ab}	50.1^{a}
Hunda	14.4^{i}	19.0^{f}	21.7^{e}	25.9^{c}	10.5^{h-j}	15.0^{f-j}	16.2^{f-i}	46.5^{ab}
28605	9.5^{k}	11.2^{j}	22.1^{e}	16.3^{gh}	8.9^{ij}	17.2^{f-i}	21.8^{ef}	38.3^{bc}
28606	7.2^{l}	9.6^{jk}	13.6^{i}	15.0^{hi}	6.5^{j}	14.0^{f-j}	15.0^{f-j}	15.6^{f-i}
MS		23.06**				196.86***		
EMS		1.91				7.59		
CV (%)		7.35				11.3		

MS=Mean Square, EMS=Error mean square, CV (%) ; Coefficient of variation. Means followed by the same letter(s) are not significantly different at 5 % probability level by DMRT

Table 6. Yield attributes of fenugreek as influenced by genotype and P application

Genotype(G)	Pod length (cm)	Number of pod plant^{-1}	Seed pod^{-1}	Thousand seed weight (gm)
Bishoftu	12.34^{cd}	18.65^{ab}	14.63^{a}	14.77^{cd}
Chala	13.22^{ab}	20.32^{a}	12.45^{b}	17.33^{ab}
Ebbisa	12.26^{a}	15.32^{c}	13.10^{b}	13.76^{d}
Hunda	12.90^{bc}	19.72^{ab}	12.44^{b}	16.95^{ab}
28605	12.73^{b-d}	16.85^{bc}	12.80^{b}	15.74^{bc}
28606	13.57^{a}	19.09^{ab}	12.83^{b}	18.44^{a}
MS	3.06***	42.77*	8.01***	36.2***
EMS	0.45	13.35	0.57	3.82
P (kg ha^{-1})				
0	12.11^{b}	15.49^{c}	12.61^{c}	15.15^{b}
9	12.85^{a}	16.73^{c}	12.90^{bc}	15.90^{ab}
17	13.11^{a}	19.21^{b}	13.46^{a}	16.38^{ab}
26	13.26^{a}	21.87^{a}	13.19^{ab}	17.24^{a}
MS	4.69***	143.51***	2.41*	13.89*
EMS	0.45	13.35	0.57	3.82
CV (%)	5.21	19.93	5.8	12.08
G*P (MS)	0.32ns	6.34ns	0.15ns	0.36ns

P=Phosphorus, MS=Mean Square, EMS=Error mean square, CV (%) = Coefficient of variation, ns; non-significant. Means in the same column followed by the same letter(s) are not significantly different at 5 % probability level by DMRT

Biological yield and harvest index

The analysis of variance showed that biological yield was significantly affected (P<0.01) due to main effects of genotype and P application but not showed significant difference at interaction (Table 8). Chala variety produced highest biological yield over all tested genotypes. The remaining five genotypes produced statistically similar biological yield (Table 8). The vigorous growth performance observed (higher branching habit) and yield attributes (higher pod per plant) and higher grain yield finally made this variety to higher biological yield. Moreover, the intrinsic potential of the variety towards generating of total above ground yield might be one of the reasons being superior. This is in corroborate with the result of Muhammad *et al.* (2017) who reported as mung bean genotypes differed significantly for biological yield. The application of 17 kg ha^{-1} and 26 kg ha^{-1} resulted in similar biological yield that were higher than the control treatment (Table 8). The improvement of biological yield at applied phosphorus over control could be due to the phosphorus beneficial effect for vigorous growth, bumper yield and better quality, ensures timely and uniform maturity, enormous nodule and extensive root formation in legume crops. The result supported with the findings of Methal*et al.* (2012) who stated the application of 40 kg P_2O_5 ha^{-1} gave significantly higher biological yields.

The main effect of genotype significantly (P<0.01) affected harvest index (HI). However P application and the interaction effect of genotype and P application had no significant influence on HI (Table 8). The higher HI was recorded by Chala variety as compared to Hunda, Ebbisa varieties and accession 28605. Chala variety was similar in harvest index with accession 28606 and

Bishoftu variety (Table 8). It may be attributed to the fact that higher seed yield produced due to its genetic potential resulted in higher harvest index. Since harvest index frequently expressed efficiency of grain production in crop plants, visible variation was occurred among genotypes in harvest index that can be potentially important for improvement programs in fenugreek. This result is in conformity with the result of Muhammad *et al.* (2017) who stated harvest index differed significantly due to genotypes.

Table 8. Seed yield of fenugreek as influenced by interaction effect of genotype and P

Genotype	Seed yield (t ha^{-1})			
	P (kg ha^{-1})			
	0	9	17	26
Bishoftu	1.16^{e-g}	1.17^{ef}	1.32^{cd}	1.22^{de}
Chala	1.29^{cd}	1.48^{b}	1.62^{a}	1.52^{b}
Ebbisa	0.88^{j}	1.00^{i}	1.01^{i}	1.03^{hi}
Hunda	1.04^{hi}	1.14^{e-h}	1.15^{e-g}	1.16^{ef}
28605	0.82^{j}	0.89^{j}	1.06^{f-i}	1.07^{f-i}
28606	1.11^{e-i}	1.14^{e-h}	1.35^{c}	1.15^{e-g}
Mean	1.05	1.13	1.25	1.19
CV (%)		5.11		
MS		0.009**		
EMS		0.003		

P=Phosphorus, MS=Mean square, EMS=Error mean square, CV (%) = Coefficient of variation, Means followed by the same letter(s) are not significantly different at 5 % probability level by DMRT

Phosphorus agronomic use efficiency

Phosphorus agronomic use efficiency (PAE) was significantly (P<0.01) affected by genotype, P application and interaction effect of these two factors (Table 9). Across combined effect, Chala variety with 9 kg ha^{-1} was the treatment observed with the highest agronomic efficiency. Agronomic efficiency recorded at Chala with 9 kg ha^{-1} was not statistically different from same variety with 17 kg ha^{-1}. The lower agronomic efficiency was recorded at combined effect of accession 28606 with both 9 kg ha^{-1} and 26 kg ha^{-1} as well as others those statistically at par (Table 9). The agronomic efficiency more than two fold observed in combined effect of 9 kg ha^{-1} with Chala variety, as compared to 26 kg ha^{-1} with same variety. This implies that the agronomic use efficiency declined in the interaction effect of genotypes with high dose of P. The variation might be due to the intrinsic factors which depend up on the nutrient absorption power (internal requirement) of the genotype and their utilization at the biochemical level. In agreement to this result, agronomic efficiency of phosphorus was more than threefold from the low level of phosphorus fertilization as compared to high level, when phosphorus applied from organic and inorganic sources (Salam *et al.*, 2014).

Table 7. Yields of fenugreek as influenced by genotype and P application.

Genotype(G)	Biological yield (t ha^{-1})	Harvest index
Bishoftu	4.87^{b}	0.25^{ab}
Chala	5.62^{a}	0.27^{a}
Ebbisa	4.43^{b}	0.22^{bc}
Hunda	4.88^{b}	0.23^{bc}
28605	4.65^{b}	0.20^{c}
28606	4.94^{b}	0.24^{ab}
MS	1.91**	0.0053**
EMS	0.44	0.0012
P (kg ha^{-1})		
0	4.49^{b}	0.23
9	4.76^{ab}	0.24
17	5.19^{a}	0.24
26	5.15^{a}	0.23
MS	2.00**	0.00014ns
EMS	0.44	0.0012
CV (%)	13.5	14.6
G*P	0.32ns	0.0012ns

P=Phosphorus, MS=Mean square, EMS=Error mean square, CV (%) = Coefficient of variation, ns; non-significant. Means in the same column followed by the same letter(s) are not significantly different at 5 % probability level by DMRT.

Table 9. P agronomic use efficiency as affected by interaction effect of genotype and P

	Agronomic use efficiency (kg kg^{-1})			
	P (kg ha^{-1})			
Genotype	0	9	17	26
Bishoftu	-	2.16^{fg}	9.10^{c-e}	2.35^{fg}
Chala	-	20.79^{a}	18.78^{ab}	8.98^{c-e}
Ebbisa	-	14.20^{bc}	7.86^{de}	5.95^{d-g}
Hunda	-	10.47^{cd}	5.39^{d-g}	4.6^{e-g}
28605	-	7.24^{d-g}	13.70^{bc}	9.32^{c-e}
28606	-	2.88^{fg}	13.74^{bc}	2.01^{g}
MS			50.01**	
EMS			6.29	
CV (%)			28.32	

P=Phosphorus, MS=Mean square, EMS=Error mean square, CV (%) = Coefficient of variation. Means followed by the same letter(s) are not significantly different at 5 % probability level by DMRT.

Phosphorus apparent recovery

The analysis of variance showed that apparent recovery was significantly (P<0.01) affected by main effects of genotype and P application (Fig. 1). Among genotypes Chala variety was the genotype that recorded highest apparent recovery over all the tested genotype. Three of genotypes namely accessions 28605 and 28606 and variety Bishoftu were recorded the lowest and statistically similar (Fig. 1A).The differences in apparent recovery could be related to the differences in root characteristics as well as longer growing period (Marschner, 1995). As to present investigation in other crop apparent recovery was significantly affected by variety (Alemayehu, 2014). In response to P application 9 kg ha^{-1} and 17 kg ha^{-1} recorded higher and statistically similar apparent recovery (Fig. 1B). The lower apparent recovery was recorded at 26 kg ha^{-1}. These higher and lowervalues showed that level of P application affected apparent recovery to various extents. The reason could be supported by evidence of Salam *et al.* (2014) depending up on the nutrient absorption power of the crops and their utilization at the biochemical levels, crops may vary in the recovery of the nutrients. In agree to this result Alemayehu (2014) stated that apparent recovery was significantly affected by P application.

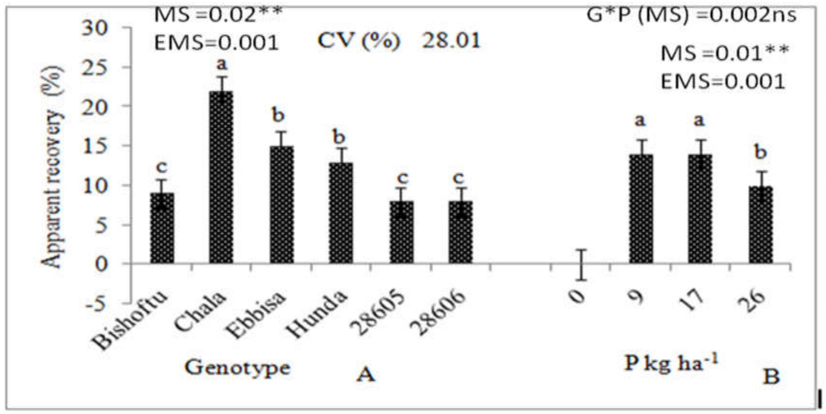

Figure 1. Apparent recovery as influenced by genotype (A) and P application (B). CV (%) = Coefficient of variation, Means with different letter on the figure are statistically different, G=Genotype, P=Phosphorus, MS=Mean square, EMS=Error mean square.

Correlation Studies for Some Selected Related Traits

Correlation coefficient (r) was calculated for different response variables which help to show how the growth characters, yield components and seed yield affect each other. Many measurements in this study were significantly correlated with each other (Table 10). Seed per pod significantly correlated with number of nodule per plant and nodule dry weight at r= 0.54* and 0.55* respectively. This indicated that increase in nodule number per plant and nodule dry weight result in increasing of seed per pod which in turn resulted in increased seed yield of fenugreek. Positive and statistically significant correlation was observed between seed yield and pod length r=0.49*, seed yield and pod per plant r=0.61**, seed yield and thousand seed weight r=0.54**, seed yield and biological yield r=0.78**, seed yield and harvest index r=0.77**. Thus, the overall increment of seed yield is due to the cumulative effect of growth and yield components as observed in correlation analysis.

Table 10. Pearson correlations among some selected growth attributes, yield attributes and yields of fenugreek genotypes under P application.

	PH	NNP	NDW	PL	NPP	SPP	TSW
PH	1						
NNP	0.41*	1					
NDW	0.38	0.85**	1				
PL	0.55**	-0.01	0.11	1			
NPP	0.41	0.29	0.42	0.66*	1		
SPP	0.38	0.54*	0.55*	0.13	0.21	1	
TSW	0.32	-0.26	-0.12	0.85**	0.66**	-0.28	1
SY	0.33	0.03	0.04	0.49*	0.61**	0.06	0.54**
BY	0.29	0.15	0.27	0.60**	0.70**	0.06	0.60**
HI	0.22	-0.09	-0.22	0.19	0.29	0.02	0.27

where; PH; plant height, NNP; number of nodule per plant, NDW; nodule dry weight, PL; pod length; NPP; number of pod per plant, SP; seed per pod; TSW; thousand seed weight, SY; seed yield, BY; biological yield, HI; harvest index.

CONCLUSION

The result showed that phenology, root dry weight, yield attributes, biological yield, harvest index and apparent recovery were significantly influenced by genotype of fenugreek. Among tested genotypes Chala variety was highest in biological yield, harvest index and apparent recovery. However, the variety was late to mature by about 7 days as compared to Ebbisa variety and accession 28605. Phosphorus application significantly affected growth and yield attributes biological yield and apparent recovery. Nodule number and dry weight as well as seed yield and agronomic use efficiency were those parameters influenced by interaction effect of genotype and P application. The combination of Chala variety with 17 kg P ha^{-1} was promising combination that generated highest seed yield followed by same variety with 9 kg P ha^{-1}. In general, the results of the present investigation have indicated considerable fenugreek genotypic variation in terms of growth, yield characters and seed yield under levels of P application. Therefore, Chala variety combined with 17 kg ha^{-1} rate of P can be recommended for farmers producing fenugreek in the study area. However, in order to give comprehensive recommendation in the study area and areas of similar agro-ecology the study should be re confirmed over the year and location.

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