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Evaluations of faba bean (*Vicia faba* L.) Genotypes for agronomic traits and crude protein content across seven faba bean growing are of Ethiopia

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Abstract: **Faba bean (*Vicia faba* L.) is an important cool season protein-rich food and feed legume belongs to the Fabaceae family. Twelve faba bean genotypes were evaluated in 2018/2019 cropping season across seven environments in Ethiopia using randomized complete block design with four replications. The combined analysis of variance showed highly significance difference among genotypes, environments, and genotype by environment interaction effects (P<0.01) for seed yield, seed protein content, plant height, number of pods per plant, thousand seed weight, days to 50% flowering and days to maturity except for number of seeds per pod which showed non-significance difference for interaction between genotypes and environments. The significant interaction among environment or genotype by environment interaction revealed that the environments were different and genotypes responded differently across environments so that developing environment-specific or general adaptable varieties is crucial. The mean grain yield of environments ranged from 950.5 kg ha-1 at Adet to 4509.3 kg ha-1 at Holetta. The highest yield was obtained from standard check Tumsa variety (3171.8 kg ha-1) followed by G8 (EH 09017-5) and G6 (EH 010058-2) with mean grain yield 3125.3 kg ha-1 and 3081.4 kg ha-1, respectively whereas, the lowest yield was obtained from G7 (EH 09012-1), 2653.3 kg ha-1. In addition to high yielding potential G8 is early matured genotype across the test locations and thus provides opportunities for early mature faba bean production across the test environments. The relative means of genotypes across environments are adequate indicators of genotypic performance only in the absence of genotype by environment interaction. Therefore, G12, G8, and G6 were the three highest performing genotypes across the tested environments. The highest and the lowest thousand seed weight and seed protein content were recorded from G10 (EH 09028-3) 960.3g and 26.6% and G1 (Gora) 797.2g respectively. In terms of mean environment, the highest thousand seed weight was recorded at Assasa (1198.2g), Debark (954.9g) and Holetta (862.8g) whereas the lowest 1000 seed weight was recorded at Adet (701.7g) followed by Kulumsa (803.1g). The highest number of pods per plant was recorded from the standard check Gora, G1 (11.8) and the lowest were obtained from G5 (EH 010058-1) or G6 (9.2) but the highest and lowest number of pod per plant were found at Kofele (15.5) and Debark (5.7) respectively.**

Keywords: **Environment, Genotype, Protein content, yield component traits.**

1. INTRODUCTION

Faba bean (*Vicia faba* L.) belongs to the Fabaceae family is an important cool-season food and feed protein-rich legume. It ranks fourth in terms of total world grain legumes after pea (*Pisum sativum)*, chickpea (*Cicer arietinum*) and lentil (*Lens culinaris*) (Kumar and Baum, 2018). The crop is originated in Near Eastern and commonly known as the broad bean, horse bean and sometimes field bean (Veloso, 2016). Ethiopia is the second-largest producer in the world next to China (1.4 Mt), Ethiopia (0.8 Mt) (Puspitasari, 2017 and Yang et al., 2017). In Ethiopia, fava bean is grown in almost all regions occupying 3.45% (437,106.04 hectares) from the total area (12.61%) allotted for the pulse with 3.01% (9,217,615.35 quintals) out of the total annual pulse production in the country (CSA, 2018). It is mainly cultivated by subsistence farmers on smallholdings in highland and mid-highland altitude areas of the country with altitude ranging from 1800-3000 m.a.s.l and receiving an annual rainfall of 700–1100 mm (Tekle Edossa et al., 2016). Faba bean is indispensable in every Ethiopian life due to its utilization in the principal dish of the peoples in the country. It is also an important protein complement in cereal-based Ethiopian food, especially for people who have a low level of income and cannot afford animal protein. In terms of agricultural importance; a legume crop comes second to cereals as a source of human food and animal feed. Additionally, it also plays a great role in a sustainable farming system of the country as low input "break" crop in cereals helps to ameliorate soil fertility relative to the mono-culture of cereals (Tamene Temesgen et al., 2015). The important and diverse role played by faba bean in the farming systems and foods of poor people, makes it an ideal crop for reducing poverty and hunger, improving human well-being, nutrition and enhancing ecosystem recover. Its' importance as food crop lies primarily high in its protein content. Faba beans' grain protein is the natural supplement to cereal grain protein. It also provides fat, carbohydrate, bone-building minerals and vitamins essential for good health. Currently, the productivity of faba bean is far below the potential and is limited by several biotic and abiotic factors. Environmental factors such as soil fertility including soil moisture, planting time, temperature and day length have strong influence during various stages of plant growth (Bull et al., 1992). The environment is changing from time to time and this implies that it is necessary to evaluate crop genotypes at different locations to assess their performances.

2. MATERIALS AND METHODS

Description of Study sites: The experiment was conducted at seven different locations from June to December, 2018 in the main cropping season under rain fed condition. These locations represent the varying agro ecologies of the major central faba bean growing areas of Ethiopia.

Table 1: Description of Experimental Locations

	Geographical position		Altitude	Average	Temperature		agro-	Soil
Locations	Latitude	Longitude	m.a.s.l	Rainfall	Min.	Max.	ecology	type
Asassa	07°06′12″N	39°11′32E	2300	620	5.8	23.6	THMH	Clay
Kulumsa	08°01′00″N	39°09′32E	2200	820	10.5	22.8	TSMMH	Clay
Bekoji	07°31′22″N	39°14′46E	2780	1010	7.9	16.6	CHMH	Clay
Holetta	09°04′12″N	38°29′45E	2400	1044	6.05	22.4	TMMH	Nitosol
Kofele	07°04′27″N	38°46′45E	2660	1211	7.1	18.0	CHMH	Nitosol
Debark	130 7' N	37053'E	2900	1044	8.6	19.8	CHMH	Nitosol
Adet	110 16' N	372 29'E	2240	1119.1	11.8	25.8	THMH	Nitosol

THMH: Tepid Humid Mid-Highland; TSMMH: Tepid Sub Moist Mid-Highland; CHMH: Cool Humid Mid-Highland; TMMH: Tepid Moist Mid-Highland.

Experimental Design, Treatments and Procedures

A total of twelve faba bean genotypes that comprise ten advanced breeding lines and two recently released varieties (standard checks) were used for field experiment. The list of genotypes are G1 (Gora), G2 (EH 010002-1-1), G3 (EH 010008-5), G4 (EH 010051-1), G5 (EH 010058-1, G6 (EH 010058- 2), G7 (EH 09012-1), G8 (EH 09017-5), G9 (EH 09021-1), G10 (EH 09028-3), G11 (EH 09046-3) and G12 (Tumsa). The experiment was laid using a randomized complete block design (RCBD) with four replications. For each experimental unit, a plot size of 4m by 1.6m (6.4m2) was used with inter-row spacing of 40cm and between plant spacing of 10cm. The spacing of 0.6m and 1.5m were used between each experimental unit and replications, respectively. All the agronomic practices were applied uniformly to the experimental units according to the recommendation.

Data Collected

All yield and yield-related traits data were recorded on the two middle rows of each experimental unit (net plot size 3.2m2). The plot-based data was collected from the entire rows. For individual plant-based data were recorded from a total of five randomly taken plants from each plot and averaged for data analysis. The quality parameters Protein was

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measured in the food and nutrition laboratory of Kulumsa Agricultural Research Center. Days to Flowering: the number of days from planting to 50% plants of the plot starts to flower and recorded on the plot base for each experimental unit. Days to Maturity: The number of days starting from emergence to the date when 90% of the pods became yellow or physiological maturity. Plant height was measured the average height of five randomly taken and pre-tagged plants in each plot, measured in centimeter from the ground surface to the top of the main stem at maturity.

Grain Yield (g) was measured from the harvestable plot area (two central rows) and adjusted to 10% moisture level using the following formula; Adjusted grain yield (g/plot) = ((100-MC) x unadjusted grain yield) / (100-standard moisture (10)). The number of pods per plant (NP/PL): The average number of pods counted on the five randomly selected and tagged plants in each plot. Numbers of seeds per pod (NS/P): The average number of seeds was recorded from three pods of five pre-tagged plants in each plot. Thousand seed weight (TSW (g) was done using a random sample of 1000 seeds that were counted from the harvested plot yields immediately after grain moisture determination and was weighed in grams. The Seed protein content was determined by the micro- Kjeldahl method (AOAC, 2003) which is %N multiplied by conversion factor 6.25.

3. DATA ANALYSIS

All collected data were subjected to combined analysis of variance (ANOVA) using GenStat statistical analysis software. Bartlett's tests of homogeneity of variances were made to see the homogeneity of error variances of the individual location experiments and after proving the homogeneity of variances, the combined analyses of variance across locations were performed. The mean comparison was done using Duncan Multiple Range Test (DMRT) at the 5% probability level.

4. RESULTS AND DISCUSSION

The combined analysis of variance showed highly significance difference among genotypes, environments and genotype by environment interaction effects for all studied traits except for number of seeds per pod (Table 3). This result is in line with Abdalla *et al.*, 2015; Tekalgn Afeta, 2018; Tamene Temesgen *et al.*, (2015) and Temesgen Alene, 2015). The combined ANOVA for grain yield revealed highly significant differences among genotypes, environments at ($p<0.01$) and the interactions was significant at $p<0.05$) (Table 3). These results depicted the presence of genetic variability among genotypes and the location was diverse. Moreover, the significant G x E interaction indicated the differential response of genotypes grown across environments (Zelalem Tazu, 2011 and Iyad *et al.*, 2004). From the total variation, the highest proportion accounted for the environment (88.4%) whereas the G x E contribution is very low (2.7%). The large percentage of the total variation accounted by environment is an indication that the major factor that influence yield performance of the tested genotypes is the environment. Relatively large proportion of Genotype x Environment interaction when compared to that of genotypes main effect indicated that the variable phenotypic expression of genotype across the environments hence, it is difficult to interpret the results and identify superior genotypes across diverse environments in the presence of high significant G x E interactions. This finding is in agreement with those reported by Annathurai *et al.*, (2012) and Falconer and Mackay, 1996).

Since yield is the final result from the interaction of various plant characters and the environmental factors during the life span of the plant development, the ranking of genotypes based on grain yield can be considered as a reliable measure for genotypic performance. Thus, the mean yield of the genotypes evaluated in this experiment ranges from 2643.9 kg ha^{-1} (G7) to 3171.8 kg ha^{-1} (G12) while the mean yield of the environments ranged from 950.1 kg ha^{-1} (Adet) to 4569.1 kg ha^{-1} (Holetta) (Table 3). The relative means of genotypes across environments are adequate indicators of genotypic performance only in the absence of genotype by environment interaction. Therefore, G12, G8, and G6 were the three highest performing genotypes across the tested environments.

Table 2: Mean squares of Yield and yield component traits

Traits	Mean Square due to			
	Environment df (6)	Genotype df (11)	G X E df (66)	Pooled error df (231)
Mean seed yield ($kgha^{-1)}$)	81858910.3**	574517.1**	227393.1*	150024.6
50% Days to Flowering	1578.4**	134.4**	9.8**	2.8

Days to Mature	11556.5**	66.8**	10.3**	4.5
Plant Height (cm)	20210.8**	284.7**	34.3*	35.8
Number Pods per plant	770.5**	12.0**	6.7**	3.6
Number of Seeds per pod	2.7**	0.3**	0.1^{ns}	0.1
1000 seed weight (g)	1225150.4**	79502.9**	7019.5**	3359.9
Protein content	1909.5**	29.5**	74.3**	2.1

**,*, ns= highly significance (P≤0.01) and significant (P≤0.05) non-significant difference respectively

The overall mean comparison showed genotype G8 (EH 09017-5) was early flowering and early maturing genotype (53.1and141.8days) and at the same time G9 (EH 09021-1) was characterized as late flowering and late mature genotype across locations (Table 3). Similar results were reported by Asfaw Tilaye *et al.*, (1994) altitudinal difference has negative impact on crop phenology; the lower the temperature the longer is the period of days to flower and maturity and vice versa. However, the results for days to maturity found from this study is not similar with Iyad *et al.*, (2012) who found that non-significant differences among genotypes and environments under irrigated and rain fed conditions. The significant effect among the environment showed the importance of environments for the differential expression of the genotypes for seed weight and protein content. Similar reports were presented by Nleya *et al.*, (2000) they stated that, nutritional quality and culinary quality of food legumes are subjected to variation caused by environmental factors particularly significant G x E interaction exist for most quality traits.

The number of pods per plant is an important selection criterion for the development of high yielding genotypes and is strongly influenced by the environment in faba bean (Abdalla et al., 2015). The highest number of pods per plant was recorded from the standard check Gora, G1 (11.8) and the lowest were obtained from G5 or G6 (9.2), similarly, the highest and the lowest number of pod per plant were found from Kofele (15.5) and Debark (5.7) respectively (Table 4). The highest thousand seed weight and protein content were recorded from G10 (960.3g) and 26.6% respectively and the lowest 1000 seed weight and protein content were found from G1 Gora (797.2g) and G9 (EH 09021-1) 23.6% respectively (Table 3). In terms of mean environment the highest thousand seed weight was recorded at Assasa (1198.2g), Debark (954.9g) and Holetta (862.8g) whereas the lowest 1000 seed weight was recorded at Adet (701.7g) followed by Kulumsa (803.1g) similarly the highest protein content were obtained from Kofele (33.8%), Bekoji (31.6%) and Debark (29.9%), respectively. The lowest protein content was recorded at Assasa (19.4%), Adet (19.9%) and Holetta (20%) (Table4). This kind of variation occurred because of variation in soil type, amount of rainfall distribution or terminal moisture stress at the time of seed development.

Table 3: Mean performance for yield and yield related traits across seven environments

Genotypes	Mean YLD	MTD	PLH	PPL	SPP	TSW	FLD	Protein
G1 (S.C.)	2986	146.0^{ab}	127.5^{a}	11.8^{a}	2.6^{b}	797.2^{f}	55.5^{c}	25.3^{cd}
G2	2960	142.9^{gh}	121.1^{cd}	10.8^{b}	2.7^{b}	814.7^{ef}	53.0^{e}	26.1^{ab}
G3	3081	144.4^{def}	125.8^{ab}	10.6^{bc}	2.7^{b}	903.5^{c}	54.1^{d}	25.3^{bcd}
G4	3053	144.4^{def}	125.0^{ab}	10.9^{b}	2.9^{a}	896.2^{c}	56.0^{c}	25.8^{abc}
G5	3030	145.5^{bcd}	122.9^{bc}	9.2^{d}	2.7^{b}	941.3^{ab}	54.3^{d}	23.8^{ef}
G6	3081	142.8^{gh}	119.2^{de}	9.2^{d}	2.6^{b}	814.8^{ef}	53.4^{de}	25.2^{cd}
G7	2644	144.1^{ef}	120.7^{cd}	10.4^{bc}	2.6^{b}	840.8^{e}	56.9^{b}	25.2^{cd}
G8	3125	141.8^{h}	122.5^{bcd}	10.5^{bc}	2.6^{b}	855.6^{d}	53.1^{e}	26.5^{a}
G9	2866	147.0^{a}	122.8^{bc}	10.3^{bc}	2.6^{b}	924.7^{bc}	59.5^{a}	23.6^{f}
G10	2895	145.9^{abc}	117.0^{e}	10.4^{bc}	2.7^{b}	960.3^{a}	59.0^{a}	26.6^{a}
G11	3078	143.2^{fg}	120.2^{cde}	9.6^{cd}	2.6^{b}	901.2^{c}	54.2^{d}	24.6^{de}
G12 (S.C.)	3172	144.8^{cde}	126.7^{a}	10.7^{bc}	2.7^{b}	896.3^{c}	54.1^{d}	23.9^{ef}
Mean	2997.8	144.4	122.6	10.5	2.7	878.9	55.3	25.2
CV (%)	13.2	1.5	4.9	18.1	12.6	6.6	3	5.8

FLD = Days to flower, DTM = days to mature, PPL = pod per plant, SPP = seed per pod, PLH = plant height, CHS = chocolate- spot, TSW= thousand seed weight and S.C = standard check, YLD= yield

Table 4: Mean values of agronomic traits of faba bean genotypes of each environment

Environment	YLD	FLD	MTD	PLH	PPL	SPP	TSW	Protein
Assasa	3820	51.5	126	135.9	6.8	2.9	1198.2	19.4
Kulumsa	3245	52.6	124.7	126.1	14.1	2.8	803.1	21.6
Bekoji	3730	64.1	154.1	103.9	13.9	2.9	822.4	31.6
Kofele	3177	59	158.9	127.4	15.5	2.9	809.1	33.8
Adet	950	50.3	136.3	125	7.6	2.4	701.7	19.9
Debark	1493	60.2	148.2	88.7	5.7	2.5	954.9	29.9
Holetta	4569	49.3	162.7	151.1	9.7	2.4	862.8	20
Mean	2997.8	55.3	144.4	122.6	10.5	2.7	878.9	25.2
CV (%)	13.2	3	1.5	4.9	18.1	12.6	6.6	5.8

Conflict of Interest

There is no conflict of interest.

Summary

Combined analysis of variance indicated that the effect of environment, genotype, and genotype by environment interaction were highly significant for grain yield and yield-related components. The highest thousand seed weight and protein content were recorded from G10. This revealed the potential of the new candidate genotypes to increase faba bean production and productivity with desirable quality in Ethiopia. G8 and G12 (Tumsa) were the highest yielded genotypes therefore, these genotypes were recommended for sustainable faba bean production across the target area and the new candidate genotype serves as parent material for faba bean breeding program.

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