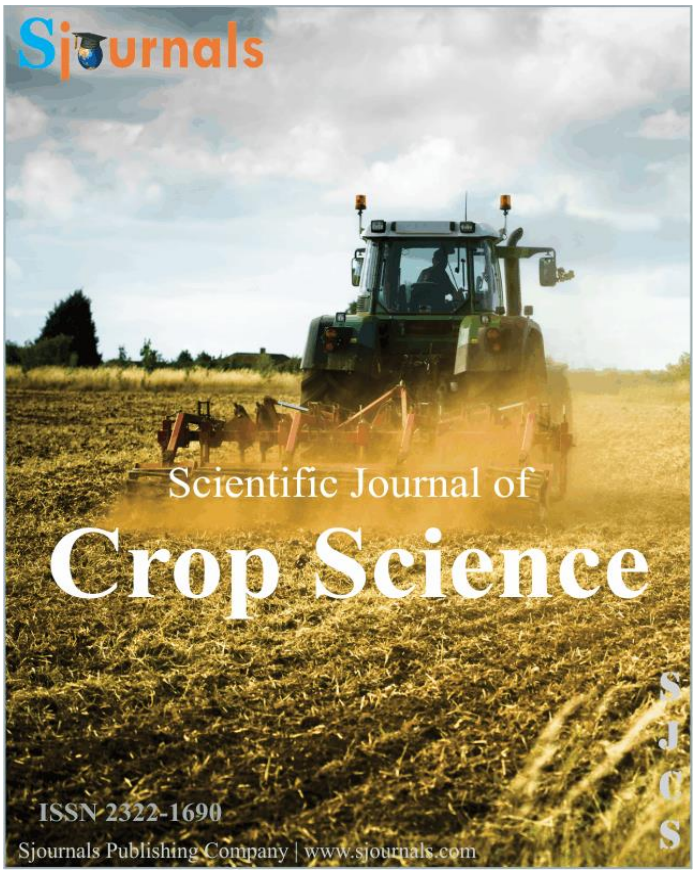

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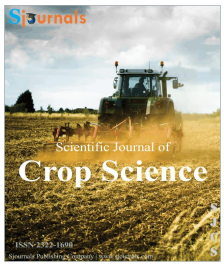

Original article

Evaluation of agronomic performance and grain yield stability of field pea genotypes in the highlands of Bale, Southeastern Ethiopia

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ABSTRACT

Multi-environment trials (MET) are commonly conducted in plant breeding programs to evaluate cultivars and hybrids. Sixteen field pea genotypes were evaluated at three locations for three years (2017 to 2019) in the highlands of Bale using randomized complete block design with four replications, The objective of this trial was to identify stable and high yielding field pea genotype with tolerant/resistant to major field pea diseases. Combined analysis of variance for grain yield revealed that genotypes, environments, and genotype by environment interaction effect were highly significant (P≤ 0.01). The environments, genotype, and GEI, were accounted for 57.5%, 6.33%, and 2.97%, of the total sum squares, respectively, indicating that field pea grain yield was significantly affected by the changes in the environment followed by genotypes and their interaction. From the combined analysis genotypes G8 (EH08003-2) gave the maximum grain yield (4.03t/ha) followed by G2 (3.59t/ha) and G10 (3.58t/ha). Based on the stability parameters like regression coefficient and deviation from regression G8, G10, G3 and G1 have a regression coefficient equal to unity and their deviation from the regression near to zero indicating these genotypes were very stable. But out of these genotypes, G8 gave grain yield higher than the checks with a yield advantage of 18% over the checks. Therefore, this genotype because of its stability, and higher grain yield over the checks, it

was identified as candidate genotype to be verified in the highlands of bale for possible release.

1. Introduction

Field pea can be grown on a wide range of soil types, from light sandy to heavy clay. It has moisture requirements similar to those of cereal grains. However, peas have lower tolerance to saline and waterlogged soil conditions than cereal grains. Peas will not survive long in waterlogged conditions. Poorly drained and saline soils should be avoided when growing field pea. Field pea commonly is grown in rotation following small grains. Field pea will fix the majority of the plants' required nitrogen if the seed is inoculated properly. Pea is highly nutritive, containing high percentage of digestible protein, carbohydrates, fats along with minerals (Ca, P and Mg) and vitamins A, B and C. High quality starch, protein, or oligoside isolates are being extracted from dry pea seeds. Because dry seeds contain little anti-nutritional factors, they are used as a protein source. Even though field pea is grown in a wide range of environments, the yield of several genotypes tested across locations and over years differed due to high GEI, which indicates that some genotypes are adapted to a broad range of environmental conditions, while others have their own specific adaptation. Thus, the performance of test entries over a series of environments when analyzed using ANOVA gives information on GEI, but does not give a measurement of the stability of individual entries (Eberhart and Russell, 1966).

The performance of any character is a combined result of the genotype (G) of the variety, the environment (E) and the interaction between genotype and environment (GE). GE interactions exist when the responses of two genotypes to different levels of environmental stress are not consistent. Better understanding of GE interactions and stability in crops was used as a decision tool, particularly at the final stage of variety introduction process, to generate essential information on pattern of adaptation in breeding lines, screen new varieties for release, and determine the recommendation domains for released varieties (Yan and Kang, 2003). GE interaction was quantified using several procedures based on evaluation of genotypes under multiple environments. These methods divided into univariate and multivariate stability statistics. The most widely used uni-variate methods are based on regressing the mean value of each genotype on the environmental index or marginal means of environments (Yates and Cochran, 1938; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). The basic cause of differences among genotypes (varieties) in relation to production stabilities is the genotype x environment (GE) interaction, so that the performance of the genotypes depends on the specific environmental conditions where they are grown (Ferreira et al., 2006). Keeping this in view, The present research study was conducted with objective to estimate the magnitude of GEI and to identify stable and high yielding field pea genotypes that can adapt under changing environments/ in diverse agro ecological regions of highlands Bale, Southeastern Oromia.

2. Materials and methods

A total of sixteen field pea genotypes along with two standard checks, and local cultivar (Table 1) were evaluated using a randomized block design with four replications for three consecutive years (2017 to 2019) at three locations, Sinana, Goba and Agarfa, in the highlands of Bale, Southeastern Ethiopia. Analysis of variance for each environment was done for grain yield and other traits, using the CropStat, ver. 7.2 computer programs A combined analysis of variance was done from the mean data from each location, to create the means data for the different statistical analysis methods.

Stability analysis. The method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi), deviation from regression (Sdi2) and coefficient of determination (Ri^2). It was calculated by regressing mean grain yield of individual genotype/environments on the environmental/genotypic index. The linear model proposed by Eberhart and Russell (1966) is: Yij = µi +bilj +S2dij

Where Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the jth environment; µi is the mean of the ith variety over all the environments; bi is the regression coefficient which measures the response of ith variety to varying environments; S2dij is the deviation from regression of ith variety in the jth environment and Ij is the environmental index of the jth environment.

The genotype with a value of the regression coefficient (Bi ~1) and smaller value deviation from regression (Sdi 2) value are thus more stable.

Table 1
Lists of genotypes and their source.

Genotype code	Genotypes	Source of genotypes	Genotype code	Genotypes	Source of genotypes
G1	EH07004-1	Brought from Holeta ARC	G10	EH08003-1	Brought from Holeta ARC
G2	EH07016	Brought from Holeta ARC	G11	EH07005-1	Brought from Holeta ARC
G3	EH07006-3	Brought from Holeta ARC	G12	EH08036-1	Brought from Holeta ARC
G4	EH08033-4	Brought from Holeta ARC	G13	EH08036-4	Brought from Holeta ARC
G5	EH08034-3	Brought from Holeta ARC	G14	Harena	Released From Sinana ARC
G6	EH08033-1	Brought from Holeta ARC	G15	T/shenen	Released From Sinana ARC
G7	EH07006-5	Brought from Holeta ARC	G16	Local check	Local cultivar
G8	EH08003-2	Brought from Holeta ARC			
G9	EH07007-3	Brought from Holeta ARC			

3. Results and discussion

The combined analysis of variance for mean grain yield of field pea genotypes revealed highly significant variation for genotypes, environment, and GEI interaction at P<0.01. The environment, genotypes and the interaction accounted for 57.5%, 6.33% and 2.97% of the total variation, respectively (Table 2). This implies that the grain yield was highly affected by the diverse nature of the environments followed by genotypes and interaction respectively. Yasin and Hussen (2013), Sowmya et al. (2018) on field pea, and Hongyu et al. (2014) on maize have reported highly significant variation for Environment, genotypes and GE interaction.

Table 2
ANOVA for combined mean grain yield of field pea genotypes over locations and years.

Source of variation	Degree freedom	Sum squares	Mean squares	% of the variation
YEAR (Y)	2	14.4316	7.2158**	1.48
Location (L)	2	561.133	280.566**	57.5
Replication	3	2.02404	0.674681	0.21
Genotype (G)	15	61.2433	4.08289**	6.28
Y X L	4	93.6363	23.4091**	9.59
G X E	30	28.0478	0.934928**	2.87
Y X L X G	90	57.6001	0.640001**	5.90
Residual	429	157.746	0.367706	16.16
Total	575	975.9		

The mean grain yield of genotypes across environments ranged from 2.77t/ha for the improved variety, Tullushenen, to 4.03t/ha for the G8(EH08003-2). From the nine environments the highest grain yield was obtained at Sinana 2018 followed by Sinana 2019, Sinana 2017, Goba 2019 and Goba 2018. Whereas the least grain yield was obtained at Agarfa 2018 (Table 3).

From this combined mean data genotypes need 62 to 67 days to flower, 135 to 140 days to reach physiological maturity whereas they have plant height ranged from 131cm to 149cm, and also gave mean number of pods/plant from 10 to 13. The thousand seed weight for the genotypes ranged from 140 to 224g. The best genotypes G8 gave the highest number of pods/plant, has seed weight better than most of the genotypes with the highest mean grain yield (Table 4).

Table 3
Mean grain yield of sixteen field pea genotypes grown at nine environments in the highlands of Bale, Southeastern Ethiopia.

		2017			2018			2019			
Entry	**T. code**	**Sinana**	**Agarfa**	**Goba**	**Sinana**	**Agarfa**	**Goba**	**Sinana**	**Agarfa**	**Goba**	**Means**
EH07004-1	G 1	4.7	3.2	3.6	4.9	1.5	3.5	4.8	1.8	3.7	3.52
EH07016	G 2	4.6	3.6	3.1	5.6	1.6	3.5	4.7	1.9	3.7	3.59
EH07006-3	G 3	4.5	3.2	3.8	4.4	1.3	3.9	4.6	1.5	4.1	3.48
EH08033-4	G 4	4.4	3	3.1	5.3	1.7	3.7	5.5	1.4	3.9	3.56
EH08034-3	G 5	4.6	2.9	3.5	4.7	1.5	3.9	4.4	2	4.1	3.51
EH08033-1	G 6	4	3.2	3.1	4	1.3	3.5	5.3	1.7	3.7	3.31
EH07006-5	G 4	4.2	2.6	2.6	5.6	1.5	3.4	5.1	2.3	3.6	3.43
EH08003-2	**G 8**	**5.2**	**4.1**	**4**	**5.4**	**2.8**	**4.2**	**4.6**	**1.7**	**4.3**	**4.0**
EH07007-3	G 9	4	2.6	3	4.8	1.3	3	4.5	2.3	3.2	3.19
EH08003-1	G 10	4.5	3.3	3.2	5.4	1.6	4	4	2	4.2	3.58
EH07005-1	G 11	4.7	2.9	3.6	4.7	1.5	2.9	5.3	1.4	3.1	3.34
EH08036-1	G 12	4.7	3.2	3.8	5	1.4	2.9	5.2	1.6	3.2	3.44
EH08036-4	G 13	4.2	3.4	2.8	4.4	1.4	3.4	4.4	1.5	3.6	3.23
Harena(st ch	G 14	4	3.2	3.5	3.9	2.2	3.1	3.8	1.7	5.1	3.39
T/shenen	G15	3.3	3	2.9	4	1.2	3.3	2.7	1.3	3.2	2.77
Local check	G16	4.7	3.1	2.3	2.6	1.3	2.7	4.6	1.3	2.6	2.8
Mean		4.39	3.16	3.24	4.67	1.57	3.43	4.59	1.71	3.71	3.39
LSD 5%		0.9	0.8	0.9	0.7	0.6	0.8	14	0.6	0.8	
CV%		14	18	19	11	21.2	16		22.3	15	

Table 4
Combined agronomic performance of for sixteen field pea genotypes over locations and years.

						Disease scor (1-9 scale)				
Entry	**DF**	**DM**	**Pl.ht (cm)**	**No. Pod/pl**	**No. Seed/p**	**PM**	**DM**	**ASB**	**1000 seed wt.**	**Seed Yield (t/ha)**
EH07004-1	67	139	136	11	4	6	4	6	176	3.52
EH07016	65	139	141	10	4	7	5	7	200	3.59
EH07006-3	63	140	146	11	4	7	4	6	224	3.48
EH08033-4	65	139	141	10	4	7	4	6	186	3.56
EH08034-3	67	140	140	11	4	7	4	6	201	3.51
EH08033-1	67	140	148	10	4	8	5	6	163	3.31
EH07006-5	66	139	132	10	4	7	5	6	217	3.43
EH08003-2	**67**	**139**	**139**	**11**	**4**	**4**	**5**	**4**	**212**	**4.03**
EH07007-3	67	139	131	10	4	7	4	7	218	3.19
EH08003-1	66	139	135	10	3	7	4	5	212	3.58
EH07005-1	65	140	142	11	4	7	4	6	203	3.34
EH08036-1	64	139	149	10	4	8	5	6	183	3.44
EH08036-4	67	140	142	10	4	8	5	6	163	3.23
Harena	63	138	140	11	4	5	4	4	184	3.39
T/shenen	62	138	134	12	4	7	4	6	157	2.77
Local check	62	138	142	13	4	7	5	7	140	2.8
Mean	65	139	140	11	4				190	3.39
LSD 5%	0.68	0.75	6.41	2.1	0.33				9.17	0.28
CV%	2.2	1.2	18.7	9.9	20.7				10.4	17.9

The significant variation of G x E interaction revealed as the tested environments were very diverse and complex and resulted in different response in grain yield among the genotypes tested. Therefore, there is a need to find genotypes that can perform more or less in similar fashion or with stable performance over the tested sites. Thus, to identify the stable genotypes over the study areas, regression model developed by Eberhart and Russel (1996) was used. It is known that the regression of genotype on the environment provides two simple measures of the phenotypic changes to environments, namely, regression coefficient and deviation from the regression slope (Pabale et al., 2010). According to this study, the mean grain yield ranged from 2.77 t/ha to 4.03t/ha. The genotype G8 gave the highest mean grain yield of 4.03t/ha and 3.64t/ha with regression coefficient of 1.01 with 0.14 value of deviation from regression followed by G10 with mean grain yield of 3.64t/ha and regression coefficient and deviation from regression 1.06 and 0.09, respectively, indicating as these two genotypes were highly stable over the tested environments. Other genotypes *viz.* G2 with a mean grain yield of 3.61t/ha, and G5 with grain yield of 3.64t/ha though they gave a mean grain yield better than the checks, they gave regression coefficient of 1.12 and deviation from regression 0.09 and 0.11 respectively. These two genotypes since they have bi>1, were responsive to favorable environments, and showed unstable performance (Table 5).

The square of the correlation coefficient (R^2), is the most powerful to measures the goodness-of-fit of the regression model to the data have been proposed. It is the proportion of the variation in one factor that is accounted by the variation in another factor. R^2 varies between zero (no linear relationship) and one (perfect linear relationship). Accordingly, in this study, genotype G4, G5, and G8 had the square of the correlation coefficient 0.98, 0.88 and 0.93 respectively, implying these three genotypes were perfectly fit to the data of stability.

Table 5
Mean grain yield, linear regression, deviation from regression and squared correlation for the sixteen field pea genotypes tested over locations and years.

Genotypes	Mean	Slope (bi)	MS-DEV (S^2di)	R^2
EH07004-1	3.48	1.04	0.03	0.66
EH07016	3.61	1.12	0.09	0.24
EH07006-3	3.5	1.07	0.1	0.08
EH08033-4	3.46	1.11	0.06	0.98
EH08034-3	3.63	1.12	0.11	0.88
EH08033-1	3.21	0.91	0.05	0.65
EH07006-5	3.44	1.11	0.32	0.38
EH08003-2	4.08	1.01	0.14	0.93
EH07007-3	3.2	0.94	0.15	0
EH08003-1	3.64	1.06	0.09	0.22
EH07005-1	3.2	1.01	0.15	0.54
EH08036-1	3.46	1.18	0.18	0.62
EH08036-4	3.31	1.08	0.11	0.12
Harena	3.45	0.77	0.36	0.5
T/shenen	2.88	0.84	0.07	0.71
Local check	2.58	0.63	0.54	0.38

Where: bi=slop, S^2di=deviation from regression, R^2=square of the correlation coefficient.

4. Conclusion

From the present study for identifying stable and high yielder genotypes, based on different stability parameters used to investigate stability, usimg Eberhart and Russel model, G8 had stable performance since it had high mean grain yield with yield advantage of 18% over the best check, Harena. It also has regression coefficient of close to unity and the deviation from regression close to zero. Likewise G2, G4, G5 and G10 has though they gave a mean grain yield better than the checks, they were unstable because they showed a regression coefficient greater than unity meaning they need more favorable environments. Therefore, based on the mean grain yield performance and its advantage over the checks, and due to its stable performance over the testing environments

this genotype, G8 (EH08003-2) has been identified as candidate genotype to be verified in the coming main cropping season for possible release in the highlands of bale, Southeastern Ethiopia and similar agro-ecologies.

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