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Genotype X Evironment Interaction and Yield Stability for Yield and its Components in Sobean *[(Glycine Max L.)* Merrill] Across West and North West of Ethiopia

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ABSTRACT

Stability for grain yield performance and genotype by environment interaction (GEI) was studied in twelve soybean genotypes evaluated at five locations having different agro-climatic conditions in Benishangule Gumuz and Oromia Regional States of Ethiopia over two years. The combined and individual analysis of variance for locations and years was conducted. Pooled analysis of variance showed highly significant (p≤0.01) difference for genotypes, environments and genotype by environment interaction (GEI). A joint regression analysis was applied to grain yield data to estimate the stability parameters viz., regression coefficient (b), S.E (b) and deviation from regression coefficients (S2d) for each genotype. Genotype TGX-1987-9F produced the most highest yield (4982.7 kg/ha) in all environments averaged for two years, and had regression coefficient (b) close to unity (0.86) and S2d close to zero (0.7923). This indicated wider adaptation and stability of performance of TGX-1987-9F in all environments. Other high yielding genotypes TGX-1987-35F and TGX-1987-64F ranked 2nd and 3rd showing regression coefficient (b=0.78 and b=0.77 respectively) and deviation from regression (S2d=1.0767 and 1.0812 respectively) indicating specific adaptability of these genotypes to unfavorable environments. These findings suggested that both the genotypes could be used as stress tolerant genotypes under stressed environments such as drought stress.

Keywords: *Soybean, GxE Interaction, Regression, Stability Analysis, Yield*

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is the most important vegetable food sources in the world. In Ethiopia, soybean is an introduced crop and had a higher expansion of cultivated area in recent years, with crop production of 636531 quintal of harvest with average of productivity 19.98 quintal per hectare in 2013/2014cropping season [1] and [2]. Environmental factors such as abiotic (Soil, fertility, moisture, temperature, sowing time, day length) and biotic (disease and pest) are not consistent across years and locations which ultimately affect the yield stability of soybean genotypes. Grain yield is the function of genotype, environment and genotype x environment interaction [3] and [4]. Stability in yield of genotypes over a wide range of environments is of great concern to plant breeders. Genotypes x environment interaction studies thus provide a biasis for selection of genotypes that suit for general cultivation and others for the specific area and under defined environments [5]. Gangwar [8] suggested that the inconsistency for yield among genotypes from one environment to another may arise due to the expression of different sets of genes in different environments or different responses of the same set of genes to different environments. Stability in grain yield among genotypes can be described as the linear response to environmental yield and the deviation from the response [9]. An ideal genotype generally show low genotype by environment interaction (GEI) variance, above average response to environmental yield potential and lower deviations from the expected response within a target environment.

Stability for yield can be described by pooled analysis of variance using regression coefficients (b) according to method suggested by Finlay and Wilkinson [6] for common bean genotypes. They proposed that a genotype with high mean grain yield and regression coefficient (b) close to 1.0 as being average stability are desirable and considered as widely adapted or stable over all environments. Accordingly, the genotypes having b<1.0 were considered to be specifically adapted to unfavorable environments; whereas genotypes with b.1.0 were having specific adaptation to favorable or high yielding environments. Similarly, Eberhart and Russell [7] used regression coefficient as a parameter of stability and regressed the mean yield of each genotype on the mean of all genotypes for each environment (environmental index). The method suggests that a genotype is regarded stable or widely adapted over environments, if it possesses high mean yield, a unit regression coefficient (b) close to 1.0 and the lowest or close to zero S^2d. Although many new methods of stability analysis have been practiced [9], [10] and [11], yet methods stated earlier are still more commonly practiced. Stability studies (GEI) are therefore of great importance to identify superior genotypes that perform well across a wide range of environments and to detect specific adaptability of genotypes over favorable or unfavorable environments. The aim of present study was to evaluate the performance of newly developed Soybean advance genotypes and to investigate their yield stability across a range of environments over two consecutive years. The information generated by such studies will be helpful for breeders to develop soybean genotypes which could produce higher and stable yields over diversified environments.

Materials and Methods

Nine candidates TGX-1987-35F, TGX-1987-11F, TGX-1987-40F, TGX-1987-9F, TGX-1987-23F, TGX-1987-64F, TGX-1987-62F, TGX-1987-15F, and TGX-1987-36F with along with three check varieties Ethio-ugoslavia, Belessa-95 and Wogayen were evaluated at different locations of Benishangul Gumuz and Oromia Regional States having different agro-climatic conditions during 2014-2015 and 2015-2016. The trials were conducted at five sites (Assosa, Dibate, Jimma, Mankush and Pawe) in Randomized complete block design (RCBD) with four replications. Each genotype was sown with four rows 4 meters long and 30 cm apart, being plot size of 4.8m2. Four rows (3m each) were harvested and the net harvested plot was $3.6m^2$ (3m x 1.2m). Data on grain yield were recorded from each location and statistically analyzed using analysis of variance method for individual years and the means were compared using Duncan's multiple range test [12]. Pooled ANOVA for 5 common sites of two years were also conducted.

Stability analysis (GEI) for grain yield based on 5 common sites over two years was performed according to joint regression analysis method as suggested by Finlay &Wilkinson [6] and Eberhart & Russell [7]. Stability parameters calculated were regression coefficient (b) and deviation from regression coefficient (S^2d). Genotypes were considered as fixed effects and the locations were considered as random effects. Mean square deviations from linear regression response were used to compare magnitude of S.E (b) as a method in which average yield of each genotype at each location was used as an environmental index for subsequent regression analysis.

Result And Discussion

Pooled analysis of variance for 5 common sites over two years showed highly significant difference for grain yield among genotypes and environments (Table 1). All main effects viz. genotypes, environments, year x locations and genotype x year x location differed significantly ($p \leq 0.001$) for mean yield, suggesting the differential response of genotypes during each year over environments. Genotype x environment interaction (GEI) was also highly significant indicating the impact of environments in the expression of grain yield in soybean genotypes (Table 1). The results indicated that there is a significance of genotype x environment interaction (GEI) in this region as genotypes responded differently at different locations over years. Some genotypes showed wide adaptation and stability over a range of environments, while others exhibited specific adaptation to specific environments.

Table1. *Pooled analysis of variance for grain yield (kg/ha) of soybean genotypes evaluated at 5 common sites and two years in Benishangul Gumuz and Oromia Regional States.*

Source of variation	DF	Mean Square	F-Value	Probability
Genotypes	11	0.792	22.8242	0.000
Environment	4	16.086	463.3404	0.000
Year	1	1.863	53.6486	0.000
Genotyoe x environment interaction (GEI)	44	0.31	8.9374	0.000
Year x location x genotypes	44	0.262	7.5572	0.000
Year x location	4	5.822	167.7074	0.000
Year x genotype	11	0.416	11.9716	0.000
Error	360	0.035		
Total	479			
Coefficient of variation: 11.84%				

During first cropping season 2014-15, the trials were conducted at 5 different locations. The overall genotypic mean yield on environmental index ranged from 4146 kg/ha to 5027.8 kg/ha (Table 2). An advanced line TGX-1987-9F produced significantly the highest overall mean grain yield (5027.8 kg/ha) among all genotypes over all environments; whereas TGX-1987-15F produced the lowest mean yield (4146 kg/ha). Others high yielding genotype was TGX-1987-64F with mean yield of 4680.6 kg/ha. The increase in grain yield was non-significant with check varieties Ethio-ugoslavia and Belessa-95. The overall site mean yield ranged from 3695 kg/ha at Mankush to 4983 kg/ha at Pawe (Table 2). Other high yielding sites were Assosa (4812 kg/ha) and Jimma (4722 kg/ha). Line TGX-1987-9F produced the highest potential yield 5938 kg/ha at Pawe site.

In the second year (2015-2016), variation in grain yield of genotypes was more pronounced over five sites reflecting the significant role of changing climate in 2015-2016 in the yield of genotypes. In this year, the overall site mean yield ranged from 1805.08 kg/ha to 6088.08 kg/ha at Mankush and Pawe respectively (Table 3). Pawe location showed significantly higher mean yield in both the years while Mankush remained at the bottom; the possible reason could be the fertile soil and favourable temperatures at Pawe and poor soil and water scarcity at Mankush site. Other high yielding sites were Assosa and Dibate where 5871.08 kg/ha and 4628.8 kg/ha respectively yields were recorded. Overall genotypic mean grain yield during 2015-2016 ranged from 3673.6 kg/ha in TGX-1987-15F to 5206.8 kg/ha in genotype TGX-1987-35F. Genotypes TGX-1987-64F and TGX-1987-23F ranked 2nd and 3rd in yield (5173.6 kg/ha and 4999.8 kg/ha) respectively. Five genotypes produced significantly high mean grain yield than all 3 check varieties. Among local checks, Ethio-ugoslavia produced higher grain yield (4464.8 kg/ha). The highest potential yield (≥7300 kg/ha) was recorded from three advance lines TGX-1987-40F, TGX-1987-64F and TGX-1987-35F at Pawe while Ethio-ugoslavia produced high potential yield among checks (7292 kg/ha) during 2015-2016 (Table 3).

Pooled analysis of variance was conducted at 5 common sites over two years (2014-2015 to 2015-2016). The combined analysis of variance indicated that the year effects were significant for grain yield was higher in year 2014-2015 than 2015-2016. Combined results showed that TGX-1987-9F produced significantly high mean combined over grain yield (4982.7 kg/ha) than other genotypes and ranked first over all sites both years. Other high yielding genotypes were TGX-1987-64F, TGX-1987-35F and TGX-1987-40F which produced 4927.1 kg/ha, 4864.7 kg/ha and 4690.9 kg/ha respectively grain yield and ranked as second, third and fourth. Genotype TGX-1987-15F remained poor in performance (3909.8 kg/ha) in both the years. The highest site mean yield (5536.083 kg/ha) was recorded at Pawe followed by Assosa (5341.542 kg/ha) and Dibate (4538.167 kg/ha); while the lowest site mean yield (2750.125 kg/ha) was recorded from Mankush over both the years (Table 4).

Table2. *Grain yield (kg/ha) performance of soybean genotypes evaluated at 5 different locations in Benishangul Gumuz and Oromia Regional States during 2014-2015.*

Genotypes	Locations					Genotypic Mean Yield
	Pawe	Mankush	Assosa	Jimma	Dibate	
TGX-1987-35F	4210 d	3750 ab	5139 ab	4028 b	5486 a	4522.6bc
TGX-1987-11F	4792 bcd	3681 ab	5035 ab	4410 ab	4202 b	4424bcd
TGX-1987-40F	5834 ab	3820 ab	4340 ab	4583 ab	4167 b	4548.8bc
TGX-1987-9F	5938 a	4514 a	5312 a	4861 ab	4514 ab	5027.8a
TGX-1987-23F	4236 d	3472 abc	4583 ab	4479 ab	4688 ab	4291.6cd
TGX-1987-64F	5590 abc	3a264 bc	4653 ab	5278 a	4618 ab	4680.6ab
TGX-1987-62F	4521 d	3820 ab	4688 ab	5104 ab	4375 b	4501.6bc
TGX-1987-15F	4966 abcd	2500 c	4826 ab	4688 ab	3750 b	4146d
TGX-1987-36F	5069 abcd	3611 ab	5417 a	4340 ab	3750 b	4437.4bc
Ethio-ugoslavia	5035 abcd	4167 ab	5035 ab	4792 ab	4653 ab	4736.4ab
Belessa-95	4618 cd	3646 ab	4688 ab	5243 a	4792 ab	4597.4ab
Wogayen	5000 abcd	4097 ab	4028 b	4861 ab	4375 b	4472.2bc
Site mean yield	4983 a	3695 c	4812 a	4722 ab	4447 b	----

Table3. *Grain yield 9kg/ha) performance of soybean genotypes evaluated at 5 different locations in Benishangul Gumuz and Oromia Regional States during 2015-2016.*

Genotypes	Locations					Genotypic Mean Yield
	Pawe	Mankush	Assosa	Jimma	Dibate	
TGX-1987-35F	7361 b	1701 b	7326 abc	4757 b	4889 ab	5206.8 a
TGX-1987-11F	4792 d	1770 b	6909 c	3264 ef	4514 bc	4249.8d
TGX-1987-40F	7916 a	1909 b	6875 c	3472 def	3993 d	4833c
TGX-1987-9F	7015 b	2708 a	7465 ab	4236 c	3264 e	4937.6bc
TGX-1987-23F	7187 b	1458 b	7708 a	3993 cd	4653 ab	4999.8b
TGX-1987-64F	7500 ab	2431 a	7118 bc	3750 cde	5069 ab	5173.6 ab
TGX-1987-62F	5347 c	1805 b	5486cd	3160 f	4166 cd	3992.8f
TGX-1987-15F	4098 e	1423 b	5000 d	2986 f	4861 ab	3673.6g
TGX-1987-36F	4063 e	1666 b	5144 d	3750 cde	5069 ab	3938.4fg
Ethio-ugoslavia	7292 b	1492 b	3159	5173 ab	5208 a	4464.8d
Belessa-95	4722 d	1840 b	4340	5486 a	4791 ab	4235.8e
Wogayen	5764 c	1458 b	3923	4027 cd	5069 ab	4048.2f
Site mean yield	6088.08 a	1805.08 f	5871.08 b	4005 d	4628.8 c	----

Table4. *Overall grain yield (kg/ha) performance of soybean genotypes evaluated at 5 different sites in Benishangul Gumuz and Oromia Regional States during two years (2014-2015 to 2015-2016).*

Genotypes	Location					Genotypic Mean Yield
	Pawe	Mankush	Assosa	Jimma	Dibate	
TGX-1987-35F	5785.5b	2725.5b	6232.5cd	4392.5cd	5187.5a	4864.7cd
TGX-1987-11F	4792cd	2725.5b	5972f	3837d	4358ab	4336.9f
TGX-1987-40F	6875a	2864.5b	5607.5a	4027.5cd	4080bc	4690.9bc
TGX-1987-9F	6476.5a	3611a	6388.5ab	4548.5bc	3889a	4982.7a
TGX-1987-23F	5711.5b	2465bc	6145.5cd	4236cd	4670.5ab	4645.7d
TGX-1987-64F	6545a	2847.5b	5885.5ab	4514bc	4843.5ab	4927.1b
TGX-1987-62F	4934c	2812.5b	5087ef	4132cd	4270.5cd	4247.2ef
TGX-1987-15F	4532cd	1961.5c	4913f	3837d	4305.5de	3909.8g
TGX-1987-36F	4566cd	2638.5b	5280.5f	4045cd	4409.5cd	4187.9f
Ethio-ugoslavia	6163.5a	2829.5b	4097bc	4982.5ab	4930.5f	4600.6de
Belessa-95	4670cd	2743b	4514f	5364.5a	4791.5ef	4416.6de
Wogayen	5382c	2777.5b	3975.5de	4444bc	4722f	4260.2f
Site Mean Yield	5536.083 a	2750.125 e	5341.542 b	4363.375 d	4538.167 c	-------

STABILITY ANALYSIS

Stability analysis showed a wide variation among genotypes; some genotypes exhibited wide adaptation while other showed specific adaptation either to favorable or un-favorable environments. The high yielding genotype TGX-1987-9F produced the highest mean yield (4982.7 kg/ha) overall environments and years had regression coefficient (b) close to unity (0.86) and deviation from regression (S2d) close to zero (0.7923). Preferred genotypes generally show low GEI variances, high mean yield potential over environments and below deviations from the expected response within a target environment [13] and [14]. This indicated its high yielding performance based on wide adaptation and stability of performance overall environments. Genotypes TGX-1987-35F and TGX-1987-64F also produced high grain yield over range of environments showed below regression coefficient (b=0.78 and 0.77 respectively) and higher deviation from regression (S2d=1.0767 and 1.0812 respectively), indicated specific adaptability of these genotypes to unfavorable environments. It is evident that both of these genotypes could be used as stress tolerant genotypes under stressed environments such as drought, heat and salinity stress. Similarly, TGX-1987-40F and TGX-1987-23F produced high grain yield had shown below regression coefficient less than 1.0 (0.69 and 0.73 respectively) and higher S2d (1.2974 and 1.2309 respectively) are specially adapted to poor yielding or unfavorable environments. According to Finlay & Wilkinson [6] and Eberhert & Russell [7], genotypes with 'b' value less than 1.0 and higher S2d than 0.00 are said to be specially adapted to poor or unfavorable environments while genotypes having high 'b' value are specially adapted to favorable or high yielding environments. Some researchers have also opinion that the cultivar must have the genetic potential for superior performance under ideal growing conditions, and yet must also produce acceptable yields under less favorable environments [15] and [16]. Genotype TGX-1987-62F with above average regression coefficient (b=1.23) it indicated that this genotype could produce higher yield at favorable environments with fertile soil, adequate water and other inputs. The check varieties Belessa-95 and Wogayen proved to be widely adapted cultivars whereas Ethio-ugoslavia showed suitability to stress environments.

Table5. *Stability parameters of soybean genotypes evaluated at 5 locations common in two years in Benishangul Gumuz and Oromia Regional States, Ethiopia*

Genotypes	Overall grain yield (kg/ha)	Regression Coefficient (b) ± s.e (b)	Deviation from regression (S2d)
TGX-1987-35F	4927.1b	0.78 ± 0.082	1.0767
TGX-1987-11F	4336.9	0.77 ± 0.224	0.887
TGX-1987-40F	4690.9d	0.69 ± 0.141	1.2974
TGX-1987-9F	4982.7 a	0.86 ± 0.135	0.7923
TGX-1987-23F	4645.7e	0.73 ± 0.086	1.2309
TGX-1987-64F	4864.7c	0.77 ± 0.096	1.0812
TGX-1987-62F	4247.2f	1.23 ± 0.099	0.2835
TGX-1987-15F	3909.8g	0.96 ± 0.109	0.6291
TGX-1987-36F	4187.9ef	1.10 ± 0.219	0.3440
Ethio-ugoslavia	4600.6de	0.73 ± 0.316	0.8180
Belessa-95	4416.6de	0.81 ± 0.490	0.4650
Wogayen	4260.2f	1.01 0.360	0.3978

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