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GENOTYPE X ENVIRONMENT ANALYSIS FOR SEED YIELD AND ITS COMPONENTS IN SESAME (*SESAMUM INDICUM* L.) EVALUATED ACROSS DIVERSE AGRO-ECOLOGIES OF THE AWASH VALLEYS IN ETHIOPIA

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ABSTRACT

A study was conducted to determine the genotype by environment interaction (GEI) effects on yield and its components in sesame grown at three different locations across the Awash valleys in Ethiopia using AMMI and Joint Regression models. Ten released sesame varieties were evaluated in a randomized complete block design with 3 replications for two different seasons (2010/11 & 2011/12). Both models revealed that the mean squares for genotypes, environments and GEI were significant for the characters viz., seed yield, harvest index and number of capsules, indicating the presence of sufficient genetic variation among varieties and possible selection of stable entries. However, the variances due to GEI (linear) for number of capsules was not significant with rather high environmental variances, showing that the variability due to environments was higher than that due to genotypes for this particular trait. Moreover, the squared deviation from regression (S^2di) was not significant for all characters indicating that the nonlinear sensitivity in the expressions of these traits was not important. Ranking of genotypes based on the different stability indices discriminated genotypes (Adi and Srk) for seed yield and number of capsules; (M-80, Srk and Tat) for harvest index showed high mean yield and low interaction effect which can be considered as stable varieties across environments. Whereas, genotypes (Abs and Tat) for both seed yield and number of capsules; (Adi, Arg and Klf) for harvest index, exhibited high interaction effect and are suitable for specific environments. Overall ranking revealed that genotype Srk is identified as the best variety across all environments and traits; hence it is recommended for diverse environmental conditions of the Awash valleys to exploit its yield potential. Assaita season-II and Werer season-I were the best environments where the highest mean of all traits recorded. Therefore, these environments can be ideal for increased sesame production along the Afar Rift valley of Ethiopia.

Key words: AMMI, ASV, Biplot, Eberhart and Russel's, Sesame, Yield related traits.

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) known as *selit*, is a most important and ancient oilseed crop. It is rich in oil (53.53%) and protein (26.25%). Sesame oil is noted for its stability and quality. As sesame is a short day plant and sensitive to light, heat and moisture stresses, the yield is not stable and varies widely. The variability in environments such as, location effect, seasonal fluctuations and their interactions highly influences the

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performance of genotypes in relation to yield potential. When genotypes respond differently to a change in the environment, the phenomenon of genotypes by environment interaction is said to occur. Because of the genotype by environment interaction, the selection of stable genotypes that interact less with the varying environments in which they are to be grown is required (Kumaresan and Nadarajan, 2010).

The statistical analyses used to yield data are multivariate analysis using AMMI model for analysis of variance based on linear model with additive main effects and interactions, and a joint regression analysis using a model proposed by Eberhart and Russell (1966). AMMI model has been recommended for a statistical analysis of yield trials, and it was preferred over any other statistical analyses (Gauch and Zobel, 1988). Although AMMI is very essential to identify the contribution of the different sources of variation in relation to GxE interaction, it provides no insight into the particular patterns of genotypes or environments that give rise to GEI. Generally in yield data all three sources of variance namely genotype main effect, the environment main effect and GxE interaction are statistically significant and important (Kempton, 1984). In sesame (Hagos and Fetien, 2011; Zenebe and Hussein, 2009), in linseed (Adane, 2008), in common bean (Ferreira *et al*. 2006; Carbonel *et al*., 2004; Zobel *et al*., 1988) also conducted AMMI analysis and predicted the stability on the basis of mean performance and magnitude of IPCA scores. Eberhart and Russell (1966) stressed that the most important stability parameters appeared to be the deviation from linear regression mean square because all types of gene action were involved in this parameter. They use the regression coefficients (b_i), deviation from regression (S^2d_i), and the genotype mean yields as the relevant estimated parameters of genotype adaptation, since the genotype merit on a given location depends on its mean yield and the expected GEI effect (which varies according to b_i). This model has been used widely in stability analysis for different crops in Ethiopia by Firew (2003) in common beans, Adugna (2007) in sorghum, Adane (2008) in linseed and Mekonen (2012) in sesame.

Gauch and Zobel (1998) compared the performance of AMMI analysis with ordinary ANOVA and regression and found that ANOVA fails to detect a significant interaction component and regression approach accounts only small portion of the interaction sum of square only when the pattern fits a specific regression model. Thus, the joint application of both models (AMMI and Ebrahart and Russel) provides a clear insight to find out suitable genotypes having high stability over wide range of environments.

Differences in genotype stability and adaptability to environment can be qualitatively assessed using the biplot graphical representation that scatters the genotypes according to their principal component values (Vita *et al*., 2010). In AMMI, the additive portion is separated from interaction by analysis of variance. Then the principal components analysis (PCA) provides a multiplicative model, which is applied to inspect the interaction effect from ANOVA model.

The objective of this study was to evaluate the adaptation and stability of some advanced and promising sesame genotypes across the Upper, Middle and Lower Awash Valleys in Ethiopia.

2. MATERIALS AND METHODS

2.1 Varieties and Test sites Used

Ten improved sesame varieties (Table 1) were evaluated at three locations along the Awash Valleys, namely Assaita, Melkassa and Werer (Table 2) in two different seasons during the 2010/11 cropping and 2011/12 off seasons. The *varieties* were sown in a randomized complete block design replicated trice in a plot consisting of four rows of 4 m long with a spacing of 40 x 10 cm between rows and between plants, respectively. 160 plants were maintained for each *variety* in a replication. All the necessary cultural practices were normally and timely applied.

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Table 1. Description of sesame varieties used in the study

No.	Varieties	Codes	Pedigree	Seed Color	Mean yield/ha	Released year (GC)
1	Abasena	Abs	SPSBIMSEL	Grey	16-18 Qt.	1993
2	S	S	SPS111872	Mixed (dark/br)	12-16 Qt.	1990
3	Kalafo-74	Klf	SPS111866	Light brown	12 Qt.	1989
4	ADI	Adi	X-3014	White	16-20 Qt.	1993
5	Serkamo	Srk	BIMW205196	Mixed (white/br)	15-18 Qt.	1993
6	Mehado-80	M80	SPS111518	Grey	15-22 Qt.	1989
7	Tate	Tat	BCS-003	Light gray	15-18 Qt.	2000
8	T-85	T85	SPS111868	Dull white	14-16 Qt.	1976
9	E	E	SPS111853	Dull white	12-16 Qt.	1978
10	Argene	Arg	T-85xCROSS	Mixed	15-18 Qt.	2000

Source = Werer Agricultural Research Centre (WARC), 2010. Qt. = quintal.

Table 2. Characteristics of the study sites

Study Sites	Altitude (m.a.s.l.)	Location (lati. /longti.)	Rainfall (mm)	Tempert (^{0}C)	Soil type	pH
Melkassa	1550	8^0 33’ N 39^0 17’ E	560	15.2 - 27.5	Verti-cambisol	7.4
Werer	740	9^0 60’ N 40^0 9’ E	450	19.5 - 32.5	Fluvisol & Vertisol	8.4
Ayssaita	350	11° 33’ N 40° 41’ E	250	23.8 - 37.5	Chromic-Lithosol	6.2

2.2 Data Collection

Five competitive plants were randomly selected from the middle rows of each plot and the following morphological data were recorded on plant basis: days to 50% flowering (DF), days to 75% maturity (DM), number of primary branch/plant (PBPL), number of capsules/plant (CPPL), number of seeds/capsule (SDPC), capsule length (CL) (cm), plant height (PH) (cm), biomass/plant (BMPL), harvest index/plant (HIPL), 1000 seed weight (TSW) (g), seed yield/plant (SYPL) (g) and oil content (OC) (%).

2.3 Data Analyses

2.3.1 AMMI analysis

To evaluate the interaction effects, the data were subjected to stability analysis following the AMMI model. The AMMI model is a hybrid statistical model incorporating both ANOVA (for additive component) and PCA (for multiplicative component) for analyzing two way (genotype x environment interaction) data structures. The mathematical statement of the hybrid model is given as:

$Y_{ij}^N = \mu + g_i + e_j + \Sigma\lambda_k Y_{ik}\alpha_{jk} + \Sigma_{ij}$, Where;

Y_{ij} = yield of i^{th} genotype in the j^{th} environment, μ = grand mean

giej = genotype and environment deviations from the grand mean

λ_k = eigen value of the principal component analysis (PCA) axis k

Y_{ik} and α_{jk} = genotype and environment principal components scores for axis k

N = is the number of principal components in the AMMI model, and Σij = residual term.

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2.3.2 AMMI biplot analysis

To show a clear insight into specific GEI combination and the general pattern of adaptation, a biplot of genotypes and environments were done. The AMMI biplot is developed by placing both genotype and environment values on the abscissa (X- axis) and the respective PCA axis, Eigen vector on the Y- axis.

2.3.3 AMMI stability value (ASV)

The most stable and adapted varieties can be identified using ASV as that of Lins and Binns (1986) method. ASV was calculated for average yield and its component traits for each genotype and each environment according to the relative contribution of IPCA1 and IPCA2 to the interaction sum of squares (SS) as suggested by Purchase *et al*. (2000):

$$ASV = \sqrt{\left[\frac{\text{IPCA1 SS}}{\text{IPCA2 SS}}(\text{IPCA1 score})\right]^2 + (\text{IPCA2 score})^2}$$

Where; IPCA1 and IPCA2 = Interaction Principal Component Axis one and Axis two, respectively and SS = sum of square.

2.3.4 Joint regression analysis

The data were also subjected to regression analysis using a model proposed by Eberhart and Russell (1966). The regression of each genotype in each environment on an environmental index and a function of the squared deviations from its regression would provide estimates of stability parameters. The stable varieties are those having mean yield higher than the average yield of all the varieties under test with regression coefficient (b_i) of unity and deviation from regression (S^2d_i) close to zero. The regression coefficients of the relationship between cultivars yield at each location and the mean location yield is the measure of the linear response to environmental change. The parameter was assessed by the following model:

$\mathbf{Y_{ij} = \mu_i + b_iI_j + \delta_{ij} + \varepsilon_{ij}}$, where;

Y_{ij} = mean of the i^{th} genotype at j^{th} location, μ_i = the general mean of genotype i, b_i = regression coefficient of the i^{th} genotype on environmental index, I_j = environmental index, δ_{ij} = deviation from regression of i^{th} genotype at the j^{th} environment, ε_{ij} = Effect of mean experimental error.

The stability parameters (b_i and S^2d_i) were calculated as:

$$\mathbf{bi} = \frac{\Sigma\varphi\, Y\iota\varphi\, I\varphi}{\Sigma\iota I^2 j} \quad \text{and} \quad \mathbf{S^2d_i} = \left[\frac{\Sigma j \delta^2 ij}{n-2}\right] - \left[\frac{\delta^2\theta}{r}\right]$$

Where: n = number of location, r = no. of replication, and $\frac{\delta^2\theta}{r}$ = estimate of pooled error.

The significance of deviation of (bi) from unity was tested using t-test while the significance of (S^2d_i) from zero was tested using F-test by comparing the deviations from regression with pooled error estimate.

3. RESULTS AND DISCUSSION

3.1 AMMI Analysis

AMMI analysis of variance for ten sesame varieties tested in six environments showed that the mean squares for genotypes, environments and GEI were highly significant for the studied traits (Table 3), indicating the existence of differential responses of varieties to different environments and suggests the need for the extension of G x E analysis. This result was in agreement with previous studies of Kumaresan and Nidarajan (2010), Hagos and Fetien (2011) and Mekonen (2012).

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Table 3. Pooled AMMI analysis of variance for sesame yield and its components over three locations and two different seasons (2010/11 & 2011/12)

		Mean Squares		
Source of variation	**DF**	**SYPL**	**HIPL**	**CPPL**
Treatment	59	12.78**	1545.00**	16348.00**
Genotype	9	33.40**	2353.00**	70595.00**
Environment	5	49.53**	10821.00**	46114.00**
Rep within Env	12	1.27	171.00	1329.00
G X E	45	4.58**	353.00**	2191.00*
IPCA 1	13	9.84**	451.00**	3773.00*
IPCA 2	11	3.40*	499.00**	2109.00*
Error	108	1.94	215.00	2011.00
Gr. Mean		8.26	51.23	296.7
C.V. (%)		16.7	26.8	15.1

Note: **, * significant in 1% and in 5% probability respectively, DF = degree of freedom, SYPL = seed yield per plant, HIPL = harvest index per plant, CPPL= No of capsules per plant

3.2 Biplot analysis

The results of AMMI analysis can also be easily comprehended with the help of AMMI biplot as presented in Figure 1 to 3. The mean performance and PCA1 scores for both the varieties and environments used to construct the biplots are presented in Table 4. In the biplot graphs, the quadrants represent: (Q-I & Q-II) higher mean, (Q-III & Q-IV) lower mean, (Q-I & Q-IV) +ve IPCA1 and (Q-II & Q-III) –ve IPCA1 scores (Fig. 1).

Table 4. Combined mean and PCA1 scores of genotype and environment for sesame yield and its components tested at three locations and two seasons (2010/11 & 2011/12)

		SYPL		HIPL		CPPL	
No.	**Variety**	**Mean**	**PCA1**	**Mean**	**PCA1**	**Mean**	**PCA1**
1	Abs	9.85	-0.88	39.59	-2.98	405.4	-6.78
2	Adi	9.39	0.01	62.18	0.19	347.1	0.71
3	Arg	6.55	-0.15	51.35	2.24	250.7	6.75
4	E	7.45	0.09	41.71	-1.65	290.7	-2.74
5	Klf	6.87	-0.24	54.83	2.19	224.3	-1.69
6	M80	7.13	-0.25	54.18	0.37	211.8	4.77
7	S	7.80	0.11	35.19	-2.38	257.7	0.64
8	Srk	9.92	-0.07	71.75	2.99	300.4	0.24
9	T85	7.68	-0.83	42.71	-2.43	315.2	-0.47
10	Tat	9.93	2.21	58.85	1.45	363.5	-1.42
	Environment						
1	As.1	5.82	-1.99	19.57	-4.96	235.0	1.64
2	As.2	9.33	1.10	41.27	-1.42	357.2	-8.29
3	Ml.1	8.22	0.26	59.26	2.16	289.4	1.27
4	Ml.2	8.80	0.23	72.58	2.57	289.9	5.20
5	Wr.1	9.20	0.97	50.07	-0.76	302.9	-3.63

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6	Wr.2	8.17	-0.57	64.66	2.41	305.7	3.82
	Total	**8.26**		**51.23**		**296.70**	

Note: As.1= Assaita season-I, As.2= Assaita season-II, Ml.1= Melkassa season-I, Ml.2= Melkassa season-II, Wr.1= Werer season-I, Wr.2= Werer season-II, SYPL= seed yield/plant, HIPL= harvest index, CPPL= capsules/plant, PCA1= Principal component axis one.

Thus, when a variety and environment have the same sign on PCA1 axis, their interaction is positive and if different their interaction is negative. If a variety or an environment has a PCA1 score of nearly zero, it has small interaction effect and was considered as stable over wide environments. However, varieties with high mean performance and large PCA1scores were considered as having specific adaptability to the environments.

Fig. 1 indicated that the environments As.2, Wr.1 and Ml.2 had similar main effects but their interactions were highly varied. Wr.1 is most suitable for synthesizing hybrids in the present set of materials due to low interaction effects. Whereas, As.2 had high and positive interaction effects and is suitable for specific adaptation with high mean yield. In contrast, Ml.2 was found interacting negatively with most of the high yielding verities; hence it is unstable environment. V*arieties* Abs, Srk and Tat had higher mean yield with relatively low interaction effects and they can be regarded as stable for seed yield across environments. Whereas, variety Adi was desirable for specific adaptation; it is most favored in As.2.

Biplot for harvest index (Fig. 2) revealed that the environments As.1, As.2, Wr.1 and Wr.2 showed similar main effects but had variation in the interaction effects. The varieties S and M-80 are favorable in As.2. *Varieties* with desirable mean and low interaction effects were Arg, klf and Tat, which are having wide general adaptability with respect to this character. The *variety* Srk exhibited the highest mean with large interaction effects, which is suitable to specific environments.

Fig. 3 showed that the environments As.2, Wr.1 and Wr.2 exhibited similar main effects but differed in their interaction effects. As.2 was relatively less interactive with highest mean number of capsules. This environment is favorable for the *varieties* Srk, T-85, Tat and Adi, since positive interaction was observed between them. In contrast, Wr.1 and Wr.2 were highly interactive, negatively interacting with those high yielding varieties. Hence, these environments are not suitable to select for number of capsules in the present set of varieties. The *variety* Abs expressed the highest mean and very large interaction effects (Table 4) and hence out ploted from the graph, which is then not suitable to any environment for number of capsules. Conversely, varieties S and Klf had low interaction effects and are stable in low yielding environments.

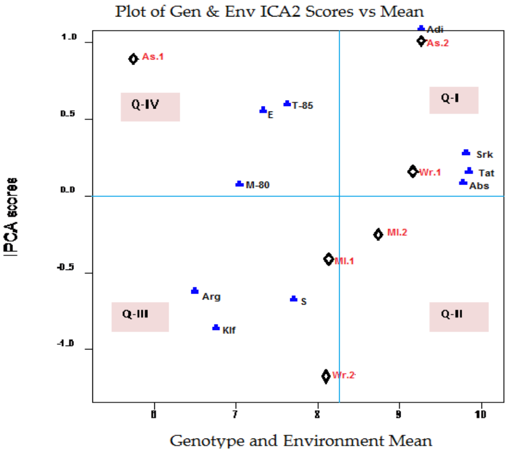

FIG. 1. AMMI BIPLOT FOR SEED YIELD PER PLANT

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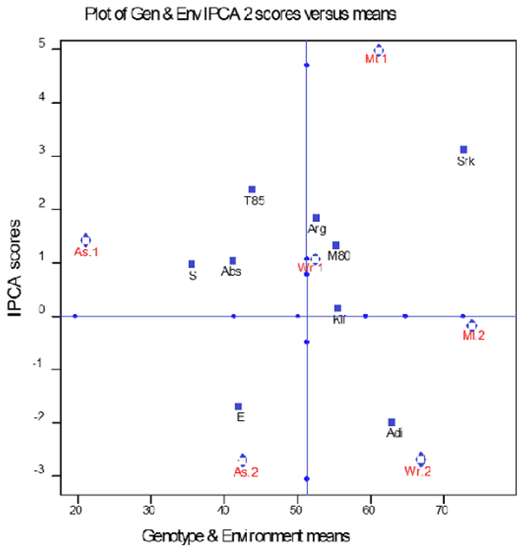
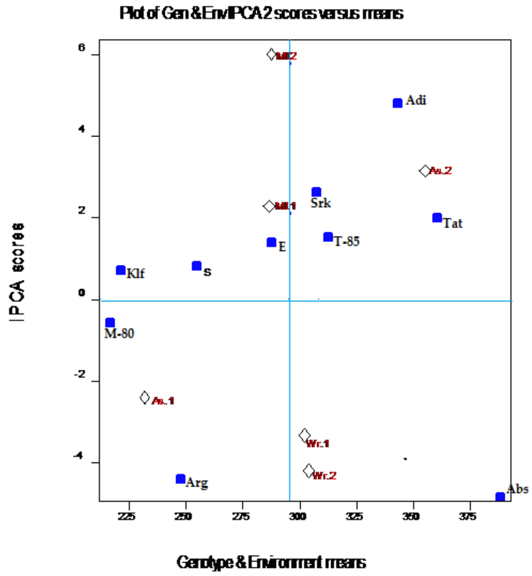
Note: As.1 =Assaita season-I, As.2 =Assaita season-II, Ml.1 =Melkassa season-I, Ml.2 =Melkassa season-II, Wr.1 = Werer season-I, Wr.2 = Werer season-II.



Biplot for Harvest Index per Plant

NOTE: SEE TABLE 4 FOR ABBREVIATIONS IN THE PLOT



GENOTYPE AND ENVIRONMENT MEAN

FIG. 3. AMMI BIPLOT FOR NUMBER OF CAPSULES PER PLANT

Note: See Table 4 for abbreviations in the plot.

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3.3 AMMI Stability Value (ASV)

The ASV analysis revealed that there were complex interactions of genotypes to the different environments for the traits considered. The AMMI model IPCA1 and IPCA2 scores and the ASV with its ranking for each *variety* are presented in Table 5. In ASV method, a *variety* characterized by mean greater than the grand mean with least ASV score is generally considered as the most stable (Purchase *et al*., 2000). Conversely, a *variety* with high mean performance and large ASV is considered as having specific adaptability to an environment. Based on this delineation, Srk was considered the most stable variety for seed yield across environments. Whereas, M-80 and Adi for harvest index; Tat, T-85 and Srk for number of capsules, respectively, showed higher mean and low ASV ranks, suggesting that these varieties can have wide adaptability across environments for the traits considered.

In contrast, Abs, Adi and Tat for seed yield; Srk and Tat for harvest index; Abs and Adi for number of capsules, respectively, exhibited higher mean with high ASV scores. These *varieties are* therefore selected for specific adaptation under favorable environments. However the rest of varieties, whatever ASV rank they had, since they had lower mean values below the grand mean, are not considered for any character to any of the environment.

The results of AMMI analysis (biplots, ASV) generally indicated that no one variety was found to be consistently stable for all traits in all environments. Similar results were reported on sesame (John *et al*., 2000; Bo Shim *et al*., 2003; Laurentin *et al*., 2007 and Mohamed *et al.,* 2008).

3.4 Eberhart and Russell's Model

The analysis of variance for the estimated stability parameters showed that the mean square for *genotypes and* environments (linear) and GEI (linear) was highly significant in the studied traits (Table 6), suggesting the existence of considerable differential performance of the *varieties* and the variation in linear response of genotypes to change in environments. On the other hand, the pooled deviation in all the traits was not significant, signifying a linear response of the traits to environments. Moreover, the squared deviation (S^2d_i) for all *varieties* in all the traits was insignificant (Table 7), indicating that the nonlinear sensitivity in the expression of these traits was not important. Similar results were reported by Mahto *et al*. (2006) in finger millet and Mekonen (2012) in sesame.

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Table 5. AMMI stability value (ASV) and ranking with PCA 1 and 2 scores for seed yield and its components in sesame varieties tested at three locations and two seasons (2010/11 & 2011/12)

	Seed yield/plant (SYPL)						Harvest index (HIPL)						Number of capsules/plant (CPPL)					
Var.	PM	R	PCA1	PCA2	ASV	R	PM	R	PCA1	PCA2	ASV	R	PM	R	PCA1	PCA2	ASV	R
Abs	9.85*	3	-0.883	0.025	5.26	9	39.59	9	-2.977	0.714	6.04	9	405.4*	1	-6.784	-5.784	9.35	9
Adi	9.39*	4	0.009	1.042	1.04	7	62.18**	2	0.193	-2.317	2.32	3	347.1*	3	0.707	4.549	4.56	7
Arg	6.55	10	-0.154	-0.707	0.71	3	51.35	6	2.239	1.509	3.12	5	250.7	8	6.749	-4.713	6.56	8
E	7.45	7	0.091	0.493	0.49	2	41.71	8	-1.647	-2.029	2.51	4	290.7	6	-2.741	1.110	4.16	6
Klf	6.87	9	-0.239	-0.919	0.93	5	54.83	4	2.190	-0.189	7.46	10	224.3	9	-1.690	0.392	3.49	5
M80	7.13	8	-0.246	-0.007	1.46	8	54.18**	5	0.373	1.003	1.03	1	211.8	10	4.767	-1.040	10.15	10
S	7.80	5	0.115	-0.736	0.73	4	35.19	10	-2.381	0.633	4.57	8	257.7	7	0.639	0.488	0.88	1
Srk	9.92**	2	-0.070	0.229	0.23	1	71.75*	1	2.996	2.786	4.17	7	300.4**	5	0.240	2.214	2.22	4
T85	7.68	6	-0.834	0.506	0.94	6	42.71	7	-2.433	2.035	1.71	2	315.2**	4	-0.469	1.182	1.14	3
Tat	9.93*	1	2.211	0.073	12.2	10	58.85*	3	1.447	-4.144	4.05	6	363.5**	2	-1.418	1.602	0.07	2
	8.26						51.23						296.7					

Note: ** = stable (widely adapted), * = specifically adapted to favorable environments. ASV = AMMI stability value, IPCA1 & 2 = interaction principal component axis 1 and axis 2, PM = Pooled mean, R= rank, Var. = variety.

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Table 6. Analysis of variance for the estimated stability parameters for average seed yield and its component by Ebrehart and Russel's model

		Mean Squares		
Source of Variation	**DF**	**SYPL**	**HIPL**	**CPPL**
Genotypes	9	11.132**	784.30**	23531.75**
Envt. + (Geno x Envt.)	50	3.025	966.57	3194.30
Environment (linear)	1	82.547**	17035.57**	74356.00**
Genotypes X Env. (linear)	9	4.461**	710.55**	2535.77**
Pooled Deviation	40	0.714	84.95	588.46
Abs	4	1.046	20.90	1908.70**
S	4	0.724	12.09	194.79
Klf	4	1.059	91.65	213.91
Adi	4	1.724**	110.22	630.49
Srk	4	0.113	120.70**	188.75
M80	4	0.273	19.27	1053.40
Tat	4	1.044	198.65**	249.94
T85	4	0.236	115.22*	286.23
E	4	0.263	79.46	380.29
Arg	4	0.654	81.31	778.02
Pooled Error	120	0.626	58.91	660.74

Note: **, * significant in 1% and in 5% probability respectively, DF = degree of freedom, SYPL = seed yield per plant, HIPL = harvest index per plant, CPPL = capsules per plant.

Stability parameters for the studied traits (Table 7) revealed that Abs and Adi (for seed yield); Adi, Srk and Tat for (harvest index); Abs, Adi, Srk and T-85 (number of capsules) showed higher mean performance with insignificant deviation of b_i and S^2d_i from unity and zero, respectively, suggesting wide adaptability of these *varieties* across environments. In contrast, Tat (for seed yield and number of capsules); Klf, M-80 and Arg (for harvest index) exhibited higher b_i differing significantly from unity, indicating better response of these varieties to favorable environments. Variety Srk (for seed yield) had lower b_i value significantly differ from unity; hence this variety can have better adaptation to unfavorable environments with high mean yield. The regression analysis generally identified the variety Adi as stable genotype for all traits across environments.

Table 7 Stability parameters for average seed yield and its components in 10 sesame varieties by Ebrehart and Russel's model

	Seed yield/plant (SYPL)			**Harvest index/plant** (HIPL)			**Capsules/plant** (CPPL)		
Variety	Poold Mean	b_i	S^2di	Poold Mean	b_i	S^2di	Poold Mean	b_i	S^2di
Abs	9.85	0.211	0.420	39.59	0.51	-38.00	405.4	1.407	1248.005
S	7.80	1.194	0.099	35.19	0.62**	-46.82	257.7	0.993**	-465.950
Klf	6.87	0.956	0.433	54.83	1.33**	32.74	224.3	1.340**	-446.836
Adi	9.39	0.952	1.098	62.18	1.10	51.31	347.1	1.089	-30.254

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Srk	9.92	0.894**	-0.513	71.75	1.50	61.80	300.4	0.904	-471.992
M80	7.13	0.835	-0.353	54.18	1.10**	-39.64	211.8	0.816	392.659
Tat	9.93	2.861**	0.418	58.85	1.26	139.75	363.5	1.360**	-410.808
T85	7.68	0.168	-0.390	42.71	0.64	56.31	315.2	0.813	-374.517
E	7.45	1.010	-0.363	41.71	0.75	20.55	290.7	1.117	-280.450
Arg	6.55	0.920	0.028	51.35	1.29**	22.40	250.7	0.162	117.273
Gr. Mean	**8.26**			**51.23**			**296.7**		

Note: **, significant in 1% probability, b_i = regression coefficient, S^2d_i = deviation from regression.

3.5 Ranking of *varieties* based on stability parameters

The ranking order of ten sesame varieties for the studied traits, based on the different stability parameters is presented in Table 8. According to ranking measures, varieties showing high mean value with low overall ranking were considered as generally adaptable to all environments for a trait considered. Whereas, those *varieties* having high mean performance with large overall ranking value were selected for specific adaptation to favorable environments. Accordingly, the *varieties* Srk and Adi for (seed yield); M-80 and Tat (harvest index); Adi, Srk and T-85 (number of capsules) scored higher mean and lowest overall rank, which are then considered as stable and widely adapted across all environments. Whereas, Abs and Tat for (seed yield & number of capsules); Klf, Adi and Srk for (harvest index) exhibited high overall ranks with desirable means; these *varieties* are therefore specifically suited to favorable environments. However, the rest *varieties,* since they had mean values below the grand mean, are not considered to any of the environments. Results of the present study generally suggested that a *variety* stable for one character was not found to be stable for the other traits. This is in accordance with earlier findings of Rathnasamy and Jegathesan (1982) and Kumaresan and Nadarajan (2010).

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Table 8. Ranking order of 10 sesame varieties for seed yield and the related traits based on the different stability parameters

	Seed yield per plant (SYPL)								**Harvest index per plant (HIPL)**								**Number of capsules (CPPL)**							
Variety	PM	R	b_i	R	S^2d_i	ASV	R	OR	PM	R	b_i	R	S^2d_i	ASV	R	OR	PM	R	b_i	R	S^2d_i	ASV	R	OR
Abs	9.85	3	0.21	8	0.42	5.26	9	7	39.59	9	0.51	9	-38.00	6.04	9	10	405	1	1.41	9	1248	9.35	9	7
S	7.80	5	1.19	7	0.10	0.73	4	5	35.19	10	0.62	2	-46.82	2.32	3	2	258	7	0.99	1	-466.0	0.88	1	1
Klf	6.87	9	0.96	2	0.43	0.93	5	4	54.83	4	1.33	10	32.74	3.12	5	9	224	9	1.34	7	-446.8	3.49	5	8
Adi	9.39*	4	0.95	3	1.10	1.04	7	3	62.18	2	1.10	8	51.31	2.51	4	8	347*	3	1.09	2	-30.25	4.56	7	2
Srk	9.92*	2	0.89	5	-0.51	0.23	1	1	71.75	1	1.50	6	61.80	7.46	10	4	300*	5	0.90	3	-472.0	2.22	4	3
M80	7.13	8	0.84	6	-0.35	1.46	8	10	54.18*	5	1.10	1	-39.64	1.03	1	1	212	10	0.82	6	392.7	10.15	10	9
Tat	9.93	1	2.86	10	0.42	12.19	10	9	58.85*	3	1.26	4	139.75	4.57	8	3	364	2	1.36	8	-410.8	0.89	2	5
T85	7.68	6	0.17	9	-0.39	0.94	6	8	42.71	7	0.64	3	56.31	4.17	7	6	315*	4	0.81	5	-374.5	1.14	3	4
E	7.45	7	1.01	1	-0.36	0.49	2	2	41.71	8	0.75	5	20.55	1.71	2	7	291	6	1.12	4	-280.5	4.16	6	6
Arg	6.55	10	0.92	4	0.03	0.71	3	6	51.35	6	1.29	7	22.40	4.05	6	5	251	8	0.16	10	117.3	6.56	8	10
Gr. M	**8.26**								**51.23**								**297.0**							

Note: * = Stabe over wide environments, ASV = AMMI stability value, b_i = regression coefficient, Gr. M = Grand mean, OR = overall rank, PM= pooled mean, R= rank, S^2d_i = deviation from regression.

CONCLUSION

The ten sesame varieties used in this study differed in response to the environments for each trait considered and the influence of environment was predominant in the manifestation of yield. The AMMI and Eberhart and Russell's analyses results allowed the identification of stable *varieties* for individual traits across environments and of *varieties* that are most responsive to favorable and/or unfavorable environments. In the present study, both models were not consistent in the identification of stable *varieties* for each trait in the test environments. A *variety* stable for one character was not found to be stable for the other character. The environments As.2 (Assaita season two) and Wr.1 (Werer season one) were found to be the best environments where the highest mean performance of the studied genotypes were being recorded. Thus, these two locations are identified as ideal environments for growing the present sets of sesame *varieties* along the Awash Valleys. Ranking of *varieties* based on the various stability indices, discriminated the *variety Srk (*Serkamo) as the most stable genotype across all environments for seed yield and the related trait. Therefore, this variety can be recommended for varied environments along the Awash Valleys to exploit its yield potential. Overall, the results suggested that the second season (off-season) was the best environment for sesame production in most heat stressed areas of the Afar Rift Valley.

5. ACKNOWLEDGEMENT

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