ISSN 2349-0837

Phenotypic Stability Analysis of Oil Yield in Sesame (Sesamum indicum L.) Verities across the Awash Valleys in Ethiopia

Mohammed Abate[1*], Firew Mekbib[2]

[1]Afar Pastoral and Agro-pastoral Research Institute, PO. Box: 016, Samara, Afar, Ethiopia.

E-mail: muhabate@gmail.com

[2]Haramaya University, College of Agriculture and Environmental Science, School of Plant Science,
Department of Plant Breeding and Genetics, Dire Dawa, Ethiopia.

E-mail: firew.mekbib@gmail.com

Abstract

A study was conducted to estimate the nature and magnitude of G x E Interaction (GEI) for oil yield in sesame varieties and to identify stable and promising varieties for general and specific adaptations. The experiment was carried out at three locations across the areas of the Awash Valley in Ethiopia; namely Assaita, Melkassa and Werer over two seasons during the 2011 cropping and 2012 off seasons. Ten improved sesame varieties were planted in a randomized complete block design (RCBD) replicated trice in each location and year. Analysis of variance using AMMI model revealed significant differences ($P<0.01$) for genotype, environment, GEI and interaction principal component (IPCA1), suggesting differential response of varieties across testing environments and the need for stability analysis. Stability analysis using Biplot graph and AMMI stability value were done to further shed light on the GEI of oil yield. The study revealed that the environment Wr1 (Werer season-I) had relatively little interaction effects with above average mean oil yield per environment. Hence, it can be recommended as ideal environment for growing the present set of sesame genotypes for breeding programme. Ranking of genotypes based on the different stability indices identified the varieties Adi and Serkamo to be the most stable genotypes across all environments. Therefore, these varieties can be recommended as promising cultivars for oil yield of sesame across diverse agro-ecologies of the Awash Valley to exploit their yield potential. On the other hand, the two high yielding varieties Abasena and Tate were found to be highly interactive and they are recommended for cultivation under favorable environmental conditions for oil yield. Moreover, the study indicated that high performance of genotypes for oil yield recorded in season two (2012). Hence, the off season generally is suggested as the best environment for oil yield of sesame across the areas of the Awash Valley. In this study, AMMI analysis with two IPCA was the best predictive model to reveal the maximum GEI for oil yield in sesame.

Keywords:

ASV; Awash Valley; Biplot; GEI; oil yield, sesame.

Abbreviations:

ASV = AMMI Stability Value, GEI = Genotype by Environment Interaction, IPCA = Interaction Principal Component.

Council for Innovative Research

Peer Review Research Publishing System

Journal: JOURNAL OF ADVANCES IN AGRICULTURE

Vol. 5, No. 2

www.cirjaa.com, jaaeditor@gmail.com

editor@cirjaa.com

1.0 Introduction

Among oil crops, sesame is one of the highest in oil content. Generally, the oil content in sesame ranges from 34 to 63% [1, 2, 3, 4, 5]. Genetic and environmental factors influence the oil content and fatty acid compositions in sesame [6]. Late maturing cultivars are reported to have higher oil content than early cultivars [1] and the indeterminate cultivars accumulated more oil than determinate ones [4]. Sesame contains high levels of antioxidants such as sesamol, sesamin, and sesamolin. Because of this, sesame oil is called the queen of the vegetable oils [7].

Among the important oil crops grown in Ethiopia, sesame seed commands a unique position chiefly on account of the fact that it is highly adapted to arid and semi-arid low land environments as well as being a major cash crop for smallholder farmers and valuable foreign exchange revenue for the economy of the country. Despite the fact sesame has superior economic potential in local consumptions and export demand, the average productivity is low as compared to other oilseeds, due to mainly the lack of improved varieties for use by the farmers, erratic rainfall distribution, incidence of diseases and pests and the indeterminate growth habit [8]. The indeterminate growth habit is the main contributor for G x E interaction in sesame genotypes which may lead to differential performance under different environmental conditions. Failure of genotypes to respond consistently to variable environmental conditions is attributed to Genotype x Environment Interaction (GEI).

Seed oil content can vary considerably between cultivars and seasons. Weiss [9] stated that cultivars grown at numerous sites in the USA showed a significant sesame cultivar by location interaction of oil content. A study on oil yield of sunflower for stability and adaptability at eight locations in Pakistan indicated that the GEI contributed about 85.45% of total variation, which is an indication that a stability analysis of genotypes with respect to oil yield based on location index is important [10].

Several methods have been proposed to analyse GEI or phenotypic stability. This method can be divided into two major groups, univariate and multivariate stability statistics. Joint regression is the most popular among univariate methods because of its simplicity of application [11], whereas Additive Main Effect and Multiplicative Interaction (AMMI) is gaining popularity and is currently the main alternative approach to the joint regression analysis [12]. AMMI model appeared to be able to extract a large part of the GEI and is efficient in analyzing interaction patterns [13]. Gauch [14] reported that multivariate models captured a large portion of the GEI sum of squares clearly separating main and interaction effects, and the model often provided an agronomically meaningful interpretation of the data. 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 [15].

Several studies were carried out on GEI throughout the world by different researchers on various oil crops like linseed [16], 2002), Ethiopian mustard [17], Sunflower [10, 18] and Sesame [19, 20, 21]. They reported that mean squares for genotypes, environments and GEI were highly significant; indicating the existence of a wide range of variation between the genotypes and between the seasons and that the performance of genotypes differed over seasons.

Variety development and agronomic research in Ethiopia has resulted in the development of high yielding varieties out of introduced, locally collected and segregating populations using multi-location testing and verification. A considerable variation in oil yield is observed on released varieties and elite genotypes under trial across locations. However, studies on the effects of G x E interaction in sesame oil yield are quite few [22]. Assessing any genotype performance without including its interaction with the environment is incomplete and limits the accuracy of measured parameter estimates. Therefore, this paper is designed to study the magnitude and nature of GEI on oil yield of sesame varieties grown across different environments of the Awash Valley and to identify stable genotypes that can give high seed and oil yield under a wide range of growing conditions.

2.0 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, Werer and Melkassa (Fig. 1, Table 2) in two different seasons during the 2011 cropping and 2012 off seasons. The experiment at each location was layedout in a randomized complete block design with three replications. Each entry was planted in a plot having four rows of 4 m long with 40 cm x 10 cm spacing between rows and within plants, respectively. All the agronomic/cultural practices were normally and timely applied as per the recommendation.

Table 1. Description of sesame varieties used in the study

No.	Varieties	Code	Pedigree	Seed Color	Mean seed yield/plant	Mean oil yield/plant	Released year (GC)
1	Abasena	Abs	SPSBIMSEL	Grey	8.5	3.74	1993
2	ADI	Adi	X-3014	White	8.0	4.72	1993
3	Argene	Arg	T-85xCROSS	Mixed	6.0	2.73	2000
4	E	E	SPS111853	Dull white	9.0	3.96	1978

5	Kalafo-74	Klf	SPS111866	Light brown	8.25	3.63	1989
6	Mehado-80	M80	SPS111518	Grey	7.5	3.19	1989
7	S	S	SPS111872	Mixed (dark/br)	8.25	3.55	1990
8	Serkamo	Srk	BIMW205196	Mixed (white/br)	9.25	4.44	1993
9	T-85	T85	SPS111868	Dull white	7.0	3.05	1976
10	Tate	Tat	BCS-003	Light gray	8.25	3.96	2000

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

Fig. 1 Maps locating the study areas: Upper, Middle and Lower Awash valleys of Ethiopia.

Table 2. Characteristics of the study sites

Study Sites	Altitude (m.a.s.l.)	Location (lati. /longti.)	Rainfall (mm)	Temperture (^{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 data on various characters were recorded on plant basis, but only oil yield/plant was considered and presented in this paper. Oil content in percent was determined using Nuclear Magnetic Resonance Spectroscope (NMRS) as the proportion of oil in the seed to the total oven dried seed weight x 100; and the average oil yield per plant for each variety was obtained by multiplying the corresponding oil content with the seed yield per plant of individual variety [23].

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 jth 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.

2.3.2 Biplot analysis

The results of AMMI analysis were shown in common graph called biplot as described by Gauch and Zobel [24], which provides a clear insight into specific GEI combination and the general pattern of adaptation of genotypes. The AMMI biplot was done by placing the genotype and environment means on the abscissa (X- axis) and the respective PCA score, 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 [25] method. AMMI model does not make provision for a specific stability measure to be determined and such a measure is essential in this study in order to rank genotypes in terms of stability. Since the IPCA1 score contributes more to G x E sum of squares, a weighted value is needed. Hence, ASV was calculated for average oil yield 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.* [26]:

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

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

3.0 RESULTS AND DISCUSSION

3.1 AMMI Analysis

Pooled analysis of variance for oil yield in ten sesame varieties tested over six environments showed that the mean squares for genotypes, environments and GEI were highly significant (P < 0.01), indicating the existence of differential responses of varieties to different environments and suggests the need for the extension of G x E analysis. The two IPCA were also significant and the percentage of variability due to IPCA1 was 63.15% and IPCA2 was 18.78%, cumulatively contributed to 81.93% of the total GEI variation (Table 3). Hence, AMMI with only two IPCA was the best predictive model to reveal the maximum GEI for oil yield in sesame. Similar results were reported in previous studies in oil content of sesame [8, 19, 20, 21].

Table 3. Pooled AMMI analysis of variance for oil yield in sesame varieties tested at three locations over two seasons.

Sources of variation	Degree of freedom	Sum of squares	Mean squares	F-value	SS- explained	
					% total	% GEI
Treatment	59	217.55	3.687	8.50**	81.11	
Genotype	9	102.38	11.376	26.22**	47.06	
Environment	5	61.92	12.385	39.21**	28.46	

Rep within E	12	3.79	0.316	0.73	1.74	
G X E	45	53.25	1.183	2.73**	24.48	
IPCA 1	13	33.63	2.587	5.96**		63.15
IPCA 2	11	10	0.909	2.09*		18.78
Residuals	21	9.62	0.458	1.06*		18.07
Error	108	46.86	0.434	*	17.47	
Total	179	268.2	1.498	*		
Grand Mean = 3.99					**CV (%) = 16.4**	

****, *** = significant at $p < 0.01$ and $p < 0.05$ level respectively, SS = sum of squares.

The results of AMMI analysis can also be easily comprehended with the help of AMMI biplot. The mean oil yield and PCA1 scores for both the genotypes and environments used to construct the biplot are presented in Table 4. The mean oil yield for the individual environments ranged from 2.8g at As1 (Assaita season-I) to 4.6g at As2 (Assaita season-II). This difference was mainly due to their varying amounts of temperature and soil type, which differed greatly across locations and seasons. A similar result was reported by [27], they indicated that a change in season and soil type caused variation in oil yield of white mustard.

3.2 Biplot analysis

Figure 1 represents the AMMI biplot for oil yield of sesame varieties grown in six environments. In AMMI biplot presentation, when a variety or an environment has a PCA1 scores of nearly zero, it has small interaction effects and was considered as stable across environments. However, varieties with high mean performance and large PCA1 scores were considered as having specific adaptability to favorable environments.

As shown in the graph, the varieties and environments showed considerable variations in mean oil yield. However, it is clear from the graph that the points for genotypes are more scattered than the points for environments indicating that the variability due to genotypes was higher than that due to environments, which is in complete agreement of the ANOVA. In general, the highest mean oil yield per environment was recorded in As2, followed by Wr1 and Ml2 (Table 4). Hence, season-I for Werer, season-II for Assaita and Melkassa are considered to be suitable environments for high oil yield performance in the present set of genotypes.

Table 4. Means and PCA 1 scores of genotypes and environments for oil yield in AMMI analysis of ten sesame varieties

	Season-I (2011)			**Season-II (2012)**				
Genotype	As1	Ml1	Wr1	As2	Ml2	Wr2	**Mean**	**IPCA 1**
Abs	4.32	4.26	5.44	4.26	4.48	4.70	4.58	-0.55
Adi	4.02	4.40	4.95	6.71	4.97	4.63	4.95	0.13
Arg	1.83	3.68	3.35	3.40	3.52	3.78	3.26	-0.17
E	2.44	3.47	4.00	4.15	3.85	3.04	3.49	0.03
Klf	1.89	3.07	3.48	3.32	3.57	4.01	3.22	-0.21
M80	2.30	3.13	3.29	3.87	3.62	3.49	3.28	-0.21
S	2.05	3.91	3.65	3.88	4.32	3.82	3.61	-0.05
Srk	4.00	4.95	5.75	5.64	5.28	4.85	5.08	0.02
T85	3.33	3.61	3.62	3.55	3.74	3.14	3.50	-0.59
Tat	1.62	5.04	6.94	6.73	5.27	4.31	4.99	1.60
Envt Mean	2.8	4.0	4.4	4.6	4.3	3.98	**3.99**	
IPCA 1	1.35	-0.39	0.03	0.90	-0.15	-0.48		

Note: As1, Ml1 & Wr1= Assaita, Werer & Melkassa season-I; As2, Ml2 & Wr2 = Assaita, Werer & Melkassa season-II, respectively.

As indicated in the biplot graph, the environments As2, Wr1, Ml2 and Ml1 had the same main effects but highly varied in their interaction effects. Wr1 had very little interaction effects (nearly zero) with mean oil yield above the grand mean value. Hence, it is considered as stable environment for oil yield. In contrast, As2 was highly interactive having high interaction effects, while Ml2 and Ml1 were negatively interacting with most of the high yielding genotypes. The variety

Abs, Srk and Tat had relatively lower interaction effects because of the relatively smaller distance from the coordinate to the abscissa and are considered as stable genotypes across environments with high mean oil yield. Whereas, Adi was highly interacting variety and it is specifically favored in As2. On the other hand, M-80 exhibited minimum interaction effects with mean oil yield below the grand mean; hence it can be considered as stable to low-yielding environments. However, the rest of varieties since they had below average mean oil yield and high interaction effects, they are unstable to any of the environments.

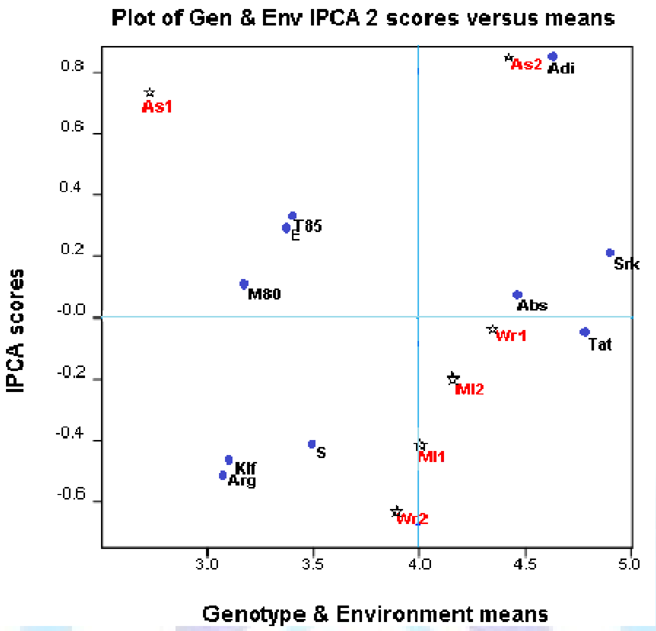

Fig. 2. AMMI Biplot for oil yield

Note: As1, Ml1 & Wr1= Assaita, Werer & Melkassa (season-I); As2, Ml2 & Wr2 = Assaita, Werer & Melkassa (season-II), respectively.

3.3 AMMI stability value (ASV) Analysis

Table 5 presents the ASV ranking with PCA1 and PCA2 scores for each sesame variety. In ASV method, a variety with high pooled mean and least ASV score is the most stable (Purchase *et al.*, 2000). Accordingly, the variety Srk showed lowest interaction with high mean oil yield, hence it is considered as the most stable across all environments. In contrast, verities Abs, Adi and Tat were found to have large ASV and high mean oil yield. These varieties are therefore suited to specific environments with high mean performance. However, the remaining varieties, whatever ASV rank they had, since they exhibited below the average performance, are not considered to any environment for oil yield. This result generally was not consistent with the AMMI biplot analysis.

Table 5. AMMI stability value (ASV) and ranking of genotypes for oil yield (g) in sesame varieties tested over six environments

No.	Genotype	IPCA1	IPCA2	ASV	R	MOY	R
1	Abs*	-0.549	0.013	3.613	9	**4.58**	4
2	Adi*	0.131	0.925	0.926	8	**4.95**	3
3	Arg	-0.165	-0.557	0.564	6	3.26	9
4	E	0.028	0.246	0.246	2	3.49	7
5	Klf	-0.212	-0.521	0.538	5	3.22	10
6	M80	-0.212	0.051	0.430	3	3.28	8
7	S	-0.048	-0.466	0.466	4	3.61	5
8	Srk**,	0.017	0.149	0.149	1	**5.08**	1
9	T85	-0.591	0.272	0.827	7	3.50	6
10	Tat*	1.600	-0.111	6.071	10	**4.99**	2
	Grand Mean					**3.99**	

****, *** = selected for wide adaptation and specific adaptation, respectively, R = rank, MOY = mean oil yield.

3.4 Ranking of varieties based on average performance of seed yield, oil content, oil yield and ASV ranks

The ranking order of the ten varieties for oil yield, based on the different stability indices is presented in Table 6. The mean oil yield (g) together with the mean oil content (%) and mean seed yield/plant (g) were used besides the ASV for screening and ranking of the varieties. Based on the ranking procedure, a variety that had high mean oil yield (greater than the grand mean) with least overall ranking (OR) was considered as the most stable variety for oil yield across all environments. Whereas, a variety having high mean oil yield with large overall ranking value was considered to have specific adaptation in favorable environments for oil yield. However, those varieties exhibiting lower mean than the grand mean oil yield with any value of OR, were not considered to any environment. Accordingly, varieties Srk and Adi exhibited highest mean oil yield with lowest overall rank, which are then most stable varieties for oil yield across environments. Whereas, varieties Abs and Tat expressed high overall rank but with above average mean oil yield, which are then suitable for specific adaptation in favorable environments. However, the rest of varieties, since they had below average mean oil yield and high overall rank, they can be regarded as poorly responsive and unstable varieties over all environments for oil yield. This result was more or less in agreement with the finding of ASV.

Table 6. Ranking order of 10 sesame varieties based on seed yield, oil content, oil yield and ASV

Variety	SY(g)	R	OC (%)	R	OY (g)	R	ASV	R	OR
Abs*	9.85	3	46.49	7	4.58	4	3.61	9	6
Adi**	7.80	5	52.66	1	4.94	3	0.93	8	2
Arg	6.87	9	49.73	4	3.26	9	0.56	6	9
E	9.39	4	46.82	6	3.49	7	0.25	2	4
Klf	9.92	2	46.88	5	3.22	10	0.54	5	5
M80	7.13	8	46.07	9	3.28	8	0.43	3	8
S	9.93	1	46.16	8	3.60	5	0.47	4	3
Srk**	7.68	6	51.17	2	5.08	1	0.15	1	1
T85	7.45	7	45.57	10	3.50	6	0.83	7	10
Tat*	6.55	10	50.05	3	4.97	2	6.07	10	7
	8.26		**48.16**		**3.99**				

** = stable & widely adapted, * selected for specific environments, ASV = AMMI stability value, OC= oil content, OY= oil yield, R= rank, OR = overall rank, SY= seed yield.

4.0 CONCLUSION

In conclusion, the present set of sesame varieties showed varied response to environmental changes. Thus, the influence of environment was highly prominent in the manifestation of oil yield along the areas of Awash Valley. Moreover, the study indicated that high performance of genotypes for oil yield recorded in season two (2012). Hence, the off season was generally identified as the best environment for oil yield of sesame across the areas of the Awash Valley. When the six environments were compared separately, Wr1 (Werer season-I) emerged as less interactive. Thus, this environment seems to be ideal for growing the present set of genotypes for breeding programme. Conversely, As1 and Wr2 were found to be the most unstable environments for oil yield in sesame. Ranking of genotypes based on mean performance and ASV scores discriminated the varieties Adi and Serkamo to be the most stable genotypes across all environments for oil yield. Therefore, these varieties can be recommended as promising cultivars for oil yield across diverse agro-ecologies of the Awash Valley to exploit their yield potential. The other high yielding varieties Abasena and Tate were highly interactive and they are recommended for cultivation under favorable environmental conditions for oil yield. In this study, AMMI analysis with two IPCA was the best predictive model to reveal the maximum GEI for oil yield in sesame.

5.0 ACKNOWLEDGEMENTS

The authors are grateful to the financial grant provided by the Rural Capacity Building Project (RCBP) of the World Bank and Afar Pastoral and Agro-pastoral Research Institute (APARI) of Ethiopia toward this research work.

6.0 REFERENCES

1. Yermanos, D.M., Saleeb, W., Hemstree.S and Huszar, C.K. 1972. Oil content and composition of seed in world collection of sesame introductions. J. Am. Oil Chem. Soc. 49(1): 20-23.
2. Ashri, A. 1998. Sesame breeding. Plant Breed. rev. 16: 179-228.

3. Baydar, H., Marquard, R. and Turgut, I. 1999. Pure line selection for improved yield, oil content and different fatty acid composition of sesame, *Sesamum indicum*. Plant Breed. 118(5): 462-464.

4. Uzun, B., Ulger, S. and Cagirgan, M.I. 2002. Comparison of determinate and indeterminate types of sesame for oil content and fatty acid composition. Turk. J. Agric. Forest. 26(5): 269-274.

5. Were, B.A., Onkware, A.O., Gudu, S., Welander, M. and Carlsson, A.S. 2006. Seed oil content and fatty acid composition in East African sesame (*Sesamum indicum* L.) accessions evaluated over 3 years. Field Crop. Res. 97(3): 254-260.

6. Carlsson, A.S., Chanana, N.P., Gudu, S., Suh, M.C. and Were, B.A. 2008. Sesame. In: Kole, C., *et al.* (Eds.) Compendium of transgenic crop plant. Transgenic oilseed crops. pp. 227-246. Texas, USA: Wiley Blackwell, 2. ISBN 978-1-405-16924-0.

7. ASGA, Sesame Markets. 2011. Available (online) from: http://www.sesamegrowers.org/usesofsesame.htm. (Accessed 27/01/2011).

8. Mekonen, M. 2012. G x E interaction of sesame (*Sesamumindicum*L.) in Eastern Amhara region, Ethiopia. MSc Thesis Submitted to College of Agriculture and Environmental Sciences, Haramaya University. pp. 33-35.

9. Weiss, E.A. 2000. Oilseed Crops. 2nd ed. Blackwell Science ltd., London. pp: 660.

10. Ghafoor, A., Arshad, I.A. and Muhammad, F. 2005. Stability and adaptability analysis in sunflower from eight locations in Pakistan. J. Applied Sci. 5(1): 118-121.

11. Becker, H.B. and Leon, J. 1988. Stability analysis in plant breeding. Plant Breed. 101: 1-23.

12. Akcura, M., Kaya, Y. and Taner, S. 2005. Genotype-Environment Interaction and Phenotypic Stability Analysis for Grain Yield of Durum Wheat in the Central Anatolian Region. Turk J Agric. Fors. 29: 369-375.

13. Zobel, R.W., Wright, M.J. and Gauch, H.G., 1988. Statistical analysis of a yield trial. Agron. J. 80:388-393.

14. Gauch, H.G. 1992. Statistical analysis of regional yield trials. AMMI analysis of factorial designs. Elsevier Science, New York.

15. Vita, PDe., Mastrangeloa, A.M., Matteua, L., Mazzucotellib, E., Virzi, N., Palumboc, M., Stortod, ML., Rizzab, F. and Cattivelli, L. 2010. Genetic improvement effects on yield stability in durum wheat genotypes grown in Italy. Field Crop Res. 119: 68-77.

16. Adugna, W. and Labuschagne, M.T. 2002. Genotype-environment interactions and phenotypic stability analysis of linseed in Ethiopia. Plant Breed. 121: 66-71.

17. Kassa, T.G. 2002. Genetic Diversity Analysis and Genotype x Environment Interaction in Ethiopian mustard (*Brassica carinata A. Braun*). Ph.D Thesis. Alemaya University, Alemaya, Ethiopia. pp: 168.

18. Dijanovic, D., Kraljevic, B.M., Stankovic, V. and Mihajlovic, I. 2004. Stability Parameters of Oil and Protein Content in Protein Sunflower Lines. In; Proceedings of the 16th International oil seed crops.

19. Jebbaraj, S., John, A. and Subbaraman, N. 2001. Genotype by environment interaction in sesame. In: Fernandez JM. (ed.). Sesame and Safflower Newsletter. Institute of Sustainable Agriculture (ISA), Spain. 16: 13-15.

20. Boshim, K., Churl, W.K., Dong, H.K. and Jang, W.P. 2003. Interpretation of genotype x environment interaction effects on yield in sesame. In; Martinez, F.J. (ed.), Sesame and Safflower Newsletter. No. 18.Institute of Sustainable Agriculture (ISA), Spain. pp: 20-24.

21. Zenebe M. and Hussien M. 2009. Study on genotype x environment interaction of oil content in sesame (*Sesamumindicum*L.). Middle E. J. Sci. Res. 4(2): 100-104.

22. Yebio, W., Fanous, M., Coulman, B. and Omran, A. 1993. Genotype x environment study on sesame in Ethiopia. In: Oil Crops Newsletter: The IDRC Oilcrops Network Project and the Institute of Agricultural Research. In (Omran A. (ed.). No. 8, A.A., Ethiopia. pp: 23-27.

23. Heuer, B., Ravina, I. and Davido, S. 2005. Seed yield, oil content and fatty acid composition of stock (*Matthiola incana*) under saline irrigation. Aust. J. Agric. Res. 56: 45-47.

24. Gauch, H.G. and Zobel, R.W. 1997. Identifying mega environments and targeting genotypes. Crop Sci. 37: 311-326.

25. Lin, C.S. and Binns, MR. 1988. A superiority measure of cultivar performance for cultivar x location data. Canadian J. Pl. Sci. 68: 93-198.

26. Purchase, J.L., Hatting, H. and Vandenventer, Cs. 2000. G x E interaction of wheat: stability analysis of yield performance. South Africa J. Pl. Sci. 17: 101-107.

27. El-Nasr, T.H.S., Abou., Ibrahim, M.M. and Aboud, K.A. 2002. Stability Parameters in Yield of White Mustard (*Brassica Alba* L.) in Different Environments. World J. Agric. Sci. 2(1): 47-55.