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Study on genotype x environment interaction of sesame (*Sesamum indicum L.*) oil yield

Mekonnen Misganaw*, Firew Mekbib, Adugna Wakjira

Department of Plant Sciences Haramaya University, Ethiopia

ABSTRACT

Sesame is an oilseed crop grown for its seed and oil for local and export markets and is a great source of income for farmers, traders, processers and the national economy of Ethiopia. However, its productivity and production are influenced by environmental factors. This experiment was, therefore, carried out to estimate the nature and magnitude of interaction of genotypes with the environment and to identify stable sesame genotypes in Eastern Amhara Region. Twelve sesame genotypes were studied in five locations at eight environments in 2010 and 2011 main cropping seasons. The highest oil yields were obtained from genotypes Acc.00047, NN-0143 and Borkena (339.2, 306.0 and 287.5 kg ha-1), respectively. There were highly significant difference (P<0.01) among genotypes, environments and GEI, indicating that genotypes performed differently across locations and the need for stability analysis. Proportion of variance captured by environment 49.6 %, genotypes 13.8 % and GEI 32.1 % of the total variation. IPCA1 and IPCA2 of AMMI model were significant (P<0.01) and captured the largest portion of variation (75.1%) from the total GEI indicated that the AMMI model 2 was the best for the data evaluate. Genotypes Borkena and NN-0143 were stable but genotype Acc.00047 had specific adaptability at potential environment.

Keywords: Magnitude, Potential, Specific adaptation, Stability, Wide adaptation

***Correspondence to Author:**
Mekonnen Misganaw
Department of Plant Sciences Haramaya University, Ethiopia

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INTRODUCTION

Sesame (*Sesamum indicum* L) belongs to the genus *Sesamum*, order Tubiflorae and family pedaliaceae and is a diploid species with 2n = 2x = 26 chromosomes. *Sesamum* has numerous wild relatives in Africa and small numbers in India (FAO, 2012). It is the oldest self-pollinating annual oilseed originated in Africa, Ethiopia domesticated over 5000 years ago. Although originated in Africa, it was spread early through West Asia to India, China and Japan which became secondary distribution centers and it is now cultivated in many parts of the world (Yamanura, 2008). Sesame's seed chemical compositions are: oil (45-55%), protein (18-25%), vitamins E, A and B complex, carbohydrate, ash and minerals like calcium, phosphorus, iron, copper, magnesium, zinc, and potassium (Ceccarelli, *et al*., 2009). From the composition of sesame oil, oleic and linoleic fatty acids are 85% and they make the oil to have long shelf-life because these fatty acids have high degree of resistance against oxidative rancidity and the linoleic acid is known to lower cholesterol content in human blood (Khanna, 1991). Sesame is grown in tropical to the temperate zones from about 40° N latitude to 40° S latitude, it grows best on a fairly warm growing season on well drained moderately fertile soils and needs a growing period of 70 to 150 days and requires 500-650 mm of rainfall per annum. The optimum pH for growth ranges from 5.4 to 6.7 and it is susceptible to water logging and very acidic or saline soils. The optimum temperature for growth varies with cultivar in the ranges 27 °C to 35 °C (Yamanura, 2008).

Sesame world production is estimated as 3.24 million metric tons in 2007 and increased to 3.84 million metric tons in 2010 and almost 90% of production area was in Asia and Africa. Ethiopia was the 7th major sesame producing country in the world in the year 2004 with area coverage 65,000 hectare, production about 49,000 tons and productivity about 479 kg ha^{-1} and now, Ethiopia is the 4th with area coverage 384,682.79 hectare, production about 327,740.92 tons and productivity is estimated as 852 kg ha^{-1} (CSA, 2011/12).

Next to coffee, sesame seed is the second largest export earner for Ethiopia and it is an important cash crop as it has an excellent demand in the international market and is consumed by existing domestic large and small-scale oil mills (CSA, 2011/12).

Ethiopia grows many varieties of sesame seed such as the Humera, Gondor and Welega types which are well-known in the world market by their white color, sweet taste and aroma. The Humera and Gondar sesame seeds are suitable for bakery and confectionary purposes; on the other hand, the high oil content of the Welega sesame seed gives a major advantage for edible oil production (Yamanura, 2008).

In the Amhara region, 207,103.06 hectares of land was covered by sesame in the year 2011, production is 157,751.9 tons, productivity 762 kg ha^{-1} and it accounts (53.84 %) area coverage, (48.13%) production in Ethiopia (CSA, 2011/12).

Despite the fact sesame has superior economical potential in local consumptions and export demand, the average productivity is low as compared to other oilseeds, due to the complex yield constraints; such as abiotic factors (erratic rainfall in distribution and intensity, soil property, *etc*.) and biotic factors (incidence of diseases and pests, the indeterminate growth habit of the crop *etc*.). The biotic and abiotic factors are the main contributors for GEI in crops yield uncertainty which are a typical yield constraint of North-East Ethiopia in general and Eastern Amhara Region in particular. The indeterminate growth habit of sesame genotypes may lead to differential performance under different environmental conditions which can also increase GEI.

Genotype and some factors of the environment, such as fertilizer rate, plant population, and pests, can be controlled by the researcher. But other factors of environment, such as sunshine, rainfall, and some soil properties, are generally fixed and difficult to modify for a given site and planting season. Thus a researcher with a one-time experiment at a single site can evaluate only the controllable factors but not the environmental factors that are beyond his/her control (Zobel *et al*., 1988). The term genotype means a cultivar or variety and environment is relates to the set of abiotic, biotic and management conditions in an individual trial carried out at a given location and year. Genotypes respond (adapt) differently in different number of environments and the property causing the specific adaptation is termed as

Table 1. Mean oil yield (kg ha^{-1}) of 12 sesame genotypes tested at 8 environments, 2010-11

Genotypes	Environments								Mean
	E1	E2	E3	E4	E5	E6	E7	E8	
Acc.00035	108.5^{h}	307.8^{bcd}	318.6^{ab}	254.2^{cde}	332.6^{cd}	517.6^{a}	151.9^{de}	253.4^{c}	280.6^{b}
Local variety	132.9^{de}	162.1^{g}	303.0^{abc}	132.3^{f}	230.7^{g}	139.1^{g}	135.4^{ef}	197.7^{d}	179.2^{e}
Acc. 00044	158.7^{c}	275.9^{de}	220.1^{de}	419.1^{b}	311.6^{def}	291.4^{f}	280.3^{a}	286.0^{b}	280.4^{bc}
Acc. 00046	143.7^{d}	336.4^{b}	236.3^{cde}	412.4^{b}	259.9^{fg}	360.7^{de}	229.8^{b}	305.2^{ab}	285.6^{bc}
Acc. 00047	168.4^{bc}	440.1^{a}	239.6^{cde}	516.4^{a}	379.4^{c}	413.1^{cd}	233.9^{b}	322.5^{a}	339.2^{a}
Acc. 018	130.9^{def}	211.2^{f}	303.5^{abc}	210.1^{e}	362.7^{cd}	517.8^{a}	128.5^{ef}	317.2^{ab}	272.7^{bc}
Hirhir-Kibe	137.9^{de}	239.7^{f}	364.1^{a}	224.1^{de}	274.2^{efg}	467.6^{abc}	146.1^{e}	244.6^{c}	262.3^{b}
Acc.202-344	179.5^{b}	322.3^{bc}	185.4^{e}	248.2^{cde}	488.4^{a}	522.3^{a}	186.7^{c}	288.8^{ab}	302.7^{ab}
NN-0143	196.6^{a}	292.1^{cd}	296.6^{abc}	282.0^{cd}	431.2^{b}	481.1^{ab}	175.7^{cd}	292.9^{ab}	306.0^{ab}
Acc.202339	125.1^{efg}	310.7^{bcd}	209.4^{e}	126.2^{f}	349.9^{cd}	351.7^{e}	152.9^{de}	322.7^{a}	243.6^{c}
Acc.202340	118.6^{fgh}	243.5^{ef}	250.0b^{cde}	120.7^{f}	319.8^{de}	271.4^{f}	120.3^{f}	303.7^{ab}	218.5^{c}
Borkena	113.4^{gh}	315.3^{bc}	289.4^{bcd}	303.3^{c}	345.0^{cd}	440.8^{bc}	181.0^{c}	312.0^{ab}	287.5^{b}
Env. Mean	142.9	288.1	268.0	270.8	340.5	397.9	176.9	287.2	271.5
CV (%)	5.0	7.0	14.0	13.8	8.9	8.6	7.9	6.5	16.28
LSD	12.11	34.06	63.39	63.33	51.16	58.09	23.65	31.59	42.17

Note: E1= Chefa 2010. E2= Kobo 2010, E3= Shewarobit 2010, E4= Chefa 2011. E5= Kobo 2011 and E6= Shewarobit 2011, E7= Jari 2011, E8= Sirinka 2011, CV= Coefficient of variability, Env. Mean= Environmental mean, LSD =Least significant difference; Values with the same letters in a column were not significantly different.

Table 2.Wricke's ecovalence value of oil yield for 12 sesame genotypes

Sr. no	Genotypes	Wi	R^{a}	Oil Yield	R^{y}
1	Acc. 00035	18895.5	3	280.6	7
2	Local variety	56856.8	12	179.1	12
3	Acc. 00044	46927.2	10	280.4	8
4	Acc. 00046	32835.3	8	285.5	6
5	Acc. 00047	54542.9	11	339.2	1
6	Acc. 018	29100.0	7	172.7	9
7	Hirhir-Kibe	25120.7	6	292.7	4
8	Acc.202-344	39543.3	9	302.7	3
9	NN-0143	9517.5	2	306.0	2
10	Acc.202339	22958.9	5	243.6	10
11	Acc.202340	22827.2	4	218.5	11
12	Borkena	3568.0	1	287.5	5

Note: Wi = Wricke'secovalence; R^{a} = Wricke'secovalence, R^{y} = Oil yield rank * and ** = Significant at 5 and 1% probability level, respectively.

GEI (Zobel*et al*., 1988). In case of unfavorable environment there is a need to breed for specific adaptation so, GEI determines whether the breeding strategy, is breed for wide or specific adaptation (Gauch and Zobel, 1996). GEI is a challenge for plant breeders and complicates cultivar recommendation because of the inconsistency of best-yielding material across cropping environments, however, it may also offer opportunities, it means yields can raise through growing materials specifically adapted to a given area or through using crop management practice, or preventing yield reduction in unfavorable years through the cultivation of stable-yielding material. The main features of quantitative traits are that they are highly influenced by the environment, difficult to understand the genotype-phenotype relationship as compared to qualitative traits. In crop research, the most commonly used way to evaluate the effect of the uncontrollable environmental factors on crop response is to repeat the experiment at several sites in a single year, or over several crop seasons in a single site, or both (Gauch and Zobel, 1996). GEI is a major problem in the study of quantitative traits (*e.g*. yield) because it complicates the interpretation of plant breeding experiments and makes predictions difficult. GEI occurs at both (micro like annual rainfall, disease situation, *etc.* and macro like topography, climate, day length, *etc*.) levels and due to the confounding of its effects with those of the genetic sources, it is usually cumbersome to analyze (Gomez and Gomez, 1984).The assessment of the potential for GEI from multi-location trials is important in crop improvement because these effects can be exploited for raising yields in a target region. Genetic improvement for low-input conditions requires capitalizing on GEI. Selection for tolerance to stress generally reduces mean yield in non-stress environments and selection for mean productivity generally increases mean yields in both stress and non-stress environments (FAO. 2002). In the absence of a GEI, one would simply obtain a better evaluation of the genotypes, but if GEI were present, one would obtain precious information about consistency or inconsistency of genotype performance early in the program, hence, early multi-environment testing strategy would prevent genetic erosion resulting from testing done only in one environment (Gauch and Zobel, 1996). Assessing any genotype or agronomic treatment without including its interaction with the environment is incomplete and thus limits the accuracy of yield estimates (Crossa, 1990). Several studies were carried out on GEI by different researchers on various oilseeds like sesame genotypes (Zenebe and Hussien, 2009; Hendawey and Farag, 2010), Linseed genotypes (Crossa, 1990), linseed and sesame genotypes (Hariprasanna *et al.*, 2008).

Unpredicted agro-climatic conditions can aggravate the GEI, consecutively inconsistency of crop yields, and then variety selection is difficult. In North-East Ethiopia in general and eastern Amhara Region in particular, always a problem of yield instability due to diversified environmental conditions. In this region there is no experimental studied about GEI on sesame production. Clustering of the testing environments, identifying the degree of GEI and recommending stable genotype(s) across the environments or specific genotype(s) for each environment can reduce the undesirable effect of GEI and increase the productivity. Hence, it is important to study the extent of the influence of the environment on the expression of a trait of interest, like oil yield using appropriate materials. Therefore, this experiment was conducted to develop relatively high yielder genotype (s) and to determine the magnitude of genotype and environmental interactions for oil yield and to assess the stability of sesame genotypes.

MATERIALS AND METHODS

Twelve sesame genotypes namely Acc. 00035, Local variety, Acc. 00044, Acc. 00046, Acc. 00047, Acc. 018, Hirhir-Kibe, Acc.202-344, NN-0143, Acc.202339, Acc.202340 and Borkena were brought from Institute of Biodiversity Conservation (IBC), Sirinka Agricultural Research Center (SARC) and Werer Agricultural Research Center (WARC) for this study. The genotypes were grown at five locations viz., (i) Chefa, (ii), Jari, (iii), Kobo, (iv), Shewarobit and (v) Sirinkain in 2010 and 2011 main cropping seasons (July to December). In each location all the genotypes were evaluated in a randomized complete block design with three replications in five rows of 5 meter length. The row - to - row and plant-to-plant distances was 40 and 10 cm, respectively. Recommended package of practices were followed to raise a good crop. Oil yield per plot was

Table 3. Eberhart and Russell's analysis of variance for oil yield of 12 sesame genotypes

Source	Df	MS
Total	287	
Genotypes	11	14228.0**
Env.+in Gen. x Env.	84	11011.2
Env.in linear	1	
Gen. x Env. (linear)	11	8040.0*
Pooled deviation	72	3823.0
Residual	192	260.9

Note: Grand mean = 544.252, R-squared = 0.7037, CV = 9.94%, MS= Mean of squares and df= Degree of freedom

Table 4.Oil yield, regression coefficient (b_i) and deviation from regression (S^2_{di})

Sr. no	Genotypes	b_i	S^2_{di}	Oil Yield	R
1	Acc.00035	1.45*	1484.8**	280.6	7
2	Local variety	0.18	3912.2**	179.1	12
3	Acc.00044	0.41	4876.8**	280.4	8
4	Acc.00046	0.69	4484.5**	285.5	6
5	Acc.00047	0.98	8825.5**	339.2	1
6	Acc.018	1.47*	2876.7**	172.7	9
7	Hirhir-Kibe	1.13	3796.6**	292.3	4
8	Acc.202-344	1.45*	4729.6**	302.7	3
9	NN-0143	1.21	968.3**	306.0	2
10	Acc.202339	1.01	3564.2**	243.6	10
11	Acc.202340	0.80	3239.6**	218.5	11
12	Borkena	1.21	-14.2.6ns	287.5	5

Note: **,* =Significant at 1%, 5%, respectively and R= Oil yield rank recorded from 3 central rows' seed yield multiplied by the oil content of the plot. Stability analysis was carried out using Wricke's ecovalence (Wi) (1962), Eberhart and Russell (1966) regression coefficient (bi) and deviation from regression (S^2di), Cultivar Superiority Measure (Pi) of Lin and Binns (1988), Additive Main effects and Multiplication Interaction (AMMI) and AMMI Stability Value (ASV) Purchase (1997) models. Data on various characters were recorded, but only oil yield is considered and presented in this paper.

RESULTS

Oil yield

Oil yield in (kg ha^{-1}) was the product of seed yield in (kg ha^{-1}) and oil content in (%) (Table 1).The highest oil yields were recorded for genotypes Acc.00047 (339 kg ha^{-1}), NN-0143 (306 kg ha^{-1}) and Acc.202-344 (303 kg ha^{-1}), whereas the lowest oil yields were showed by local variety (179 kg ha^{-1}), Acc.202340 (219 kg ha^{-1}) and Hirhir-Kibe (262 kg ha^{-1}). Locations Kobo and Shewarobit gave the highest oil yield, while Sirinka gave average, but Chefa and Jari gave the lowest.

Stability

Based on Wricke's (Wi **)** Ecovalence model, the relative stable genotypes were Borkena, NN-0143 and Acc.00035; whereas the unstable genotypes were Acc.00047, Local variety and Acc. 00046 (Table 2). Eberhart and Russell's Linear Regression Coefficient (bi) stability analysis of variance revealed highly significant (P<0.01) different between genotypes, GEI (linear) interaction was significant (P<0.05), but the deviation from the regression (S^2di) was not significant (Table 3). Genotypes Borkena, NN-0143, Acc.00035, Acc.018, Hirhir-Kibe and Acc.202-344 had regression coefficients greater than unity, whereas, local variety and Acc.00044 had regression coefficient significantly lower than unity. Other genotypes like Acc.00047, Acc.202339, Acc.202340 and Acc.00046 had closer to unity (Table 4). According to Cultivar Superiority Measure (Pi), model, the most stable genotypes with the lowest (Pi) was Acc. 00047, Borkena and NN-0143 but the most unstable were Local variety, Acc.202340 and Acc.202339 (Table 5). The AMMI analysis of variance of sesame oil yield in kg ha^{-1} were significantly (P<0.01) affected by environments (E), and genotype x environment interaction (GEI). From the total variation, environments accounted (46.9%), genotypes (13.8%) and GEI (32.1%) (Table 6). The magnitudes of the GEI sum of squares were 2.3 times of the genotypes sum of squares. The AMMI2 model, the Interaction Principal Component Axes (IPCA1 and IPCA2) showed highly significant (P < 0.01) and explained 46.3% and 281.8% totally accounted 75.1% of the GEI variation, using 17 and 15 degrees of freedom from the total of 77 degrees of freedom available for the interaction. According to AMMI Stability Value (ASV) model, genotypes Borkena, Local variety and Acc.202340 were stable, whereas genotypes Acc.00047, Acc.00044 and Acc.00046 were unstable (Table 7).

Comparison of Stability Parameters

Different stability parameters were used to compare the stability and ranking of sesame genotypes. Although there was change in ranking order of genotypes from one stability parameter to another, based on the information (Table 8), genotypes Borkena, NN-0143 and Acc.00035 with mean oil yield of 288, 307 and 281 kg ha^{-1}, respectively were found stable by stability parameters Wricke's ecovalence and deviation from regression, while local variety, Acc.202-344 and Acc.018 with mean oil yield of 179, 303 and 273 kg ha^{-1}, respectively were unstable. The fifth and second high yielder genotypes (Borkena, NN-0143) were stable by most of the stability measures. The highest oil yielder genotype (Acc.00047) with mean oil yield 339 of kg ha^{-1} was the most unstable except by the stability parameter cultivar superiority performance (Pi) where it appeared as 1st stable (Table 5).

Although, most of the genotypes showed inconsistency in ranking for stability measures, when compared on overall ranking, genotype Borkena ranked 1st in stability parameter W_i, $S^2_{di}$and ASV; 2nd in P_i and genotype NN-0143 was 2nd rank in stability parameter W_i, S^2_{di} ; 3rd in P_i.

Correlation of Stability Parameters, all the stability models had non-significant correlation with oil yield. On the other hand, stability parameter deviation from regression (S^2di) had highly significant positive correlation (r=0.84) with Wricke's (Wi) and significant positive correlation (r=0.60) with AMMI Stability Value (ASV) (Table 9).

Table 5. Oil yield and their Cultivar superiority value (Pi)

Sr. no	Genotypes	P_i	R^a	Oil Yield	R^y
1	Acc.00035	8854.3*	6	280.6	7
2	Local variety	30156.6**	12	179.1	12
3	Acc.00044	9031.3**	7	280.4	8
4	Acc.00046	7619.8	4	285.5	6
5	Acc.00047	2642.6	1	339.2	1
6	Acc.018	12070.4**	8	272.7	9
7	Hirhir-Kibe	12628.7**	9	292.3	4
8	Acc.202-344	8000.3	5	302.7	3
9	NN-0143	6138.4	2	306.0	2
10	Acc.202339	16407.6**	10	243.6	10
11	Acc.202340	20732.5**	11	218.5	11
12	Borkena	6918.5	3	287.5	5

Note: R^a = Cultivar superiority value rank, R^y = Oil Yield rank, **,* =Significant at 1%, and 5%, respectively

Table 6. AMMI's ANOVA for oil yield of 12 sesame genotypes

Source of variation	df	SS	MS	Sum of Squares Explained (%)		
				Total V.E.	GEI E.	GEIcu.
Total	287	3394649	11828**			
Environments	7	1683745	240535**	49.6		
Reps within Env.	16	20743	1296*			
Genotypes	11	469523	42684**	13.8		
Interaction	77	1091080	14170**	32.1		
IPCA1	17	504613	29683**		46.3	46.3
IPCA2	15	314225	20948**		28.8	75.1
IPCA3	13	169462	13036**		15.5	90.6
IPCA4	11	56001	5091**		5.1	95.7
IPCA5	9	27542	13060**		2.5	98.2
IPCA6	7	14050	2007**		1.3	99.5
IPCA7	5	5188	1038		0.5	100
Residual	176	129557	736			

Note: ** = significant at 1%, df= Degree of freedom, GEI E. = Genotype x Environment Interaction explained, GEI cum. = Genotype x Environment Interaction explained cumulative, MS=Means of squares, SS= Sums of squares and Total V.E. =Total variation explained.

Table 7. Oil yield AMMI Stability Value (ASV), Ranks, IPCA1 and IPCA2 scores

Sr. no	Genotypes	IPCA1	IPCA2	ASV	R^a	Oil Yield	R^y
1	Acc.00035	4.22	3.79	5.35	7	280.6	7
2	Local variety	-1.75	-12.81	2.21	3	179.1	12
3	Acc.00044	-1.03	-1.08	1.30	2	280.4	8
4	Acc.00046	-8.35	1.57	10.58	11	285.5	6
5	Acc.00047	-9.77	6.11	12.38	12	339.2	1
6	Acc.018	7.28	2.00	9.22	10	272.7	9
7	Hirhir-Kibe	4.37	-1.02	5.54	8	292.3	4
8	Acc.202-344	4.72	6.56	5.98	9	302.7	3
9	NN-0143	3.43	1.89	4.35	6	306.6	2
10	Acc.202339	3.38	-2.45	4.28	5	243.6	10
11	Acc.202340	2.44	-6.53	3.10	4	218.5	11
12	Borkena	0.06	1.96	0.07	1	287.5	5

R^a = Rank by ASV, R^y = Rank by Oil Yield

Table 8. Ranks of oil yield based on various stability parameters

Genotypes	OY	R	W_i	R	b_i	R	S^2_{di}	R	P_i	R	ASV	R	O.R.
Acc.00035	280.6	7	18895.5	3	1.45	10	1485	3	8854.3	6	5.35	7	3
Local variety	179.1	12	56856.8	12	0.18	1	3912	8	30156.6	12	2.21	3	9
Acc. 00044	280.4	8	46927.2	10	0.41	2	4877	11	9031.3	7	1.30	2	6
Acc. 00046	285.5	6	32835.3	8	0.69	3	4484	9	7619.8	4	10.58	11	7
Acc. 00047	339.2	1	54542.9	11	0.98	5	8825	12	2642.6	1	12.38	12	12
Acc. 018	272.7	9	29100.0	7	1.47	12	2877	4	12070.4	8	9.22	10	9
Hirhir-Kibe	292.3	4	25120.7	6	1.13	7	3797	7	12628.7	9	5.54	8	7
Acc.202-344	302.7	3	39543.3	9	1.45	10	4730	10	8000.3	5	5.98	9	11
NN-0143	306.6	2	9517.5	2	1.21	8	968	2	6138.4	2	4.35	6	2
Acc.202339	243.6	10	22958.9	5	1.01	6	3564	6	16407.6	10	4.28	5	5
Acc.202340	218.5	11	22827.2	4	0.80	4	3240	5	20732.5	11	3.10	4	4
Borkena	287.5	5	3568.0	1	1.21	8	-14	1	6918.5	3	0.07	1	1

Note: ASV=AMMI stability value, bi = Eberhart and Russell's regression coefficient, OY= Oil yield, O.R. = Overall rank, Pi = Lin and Binns cultivar performance measure, R= Ranks for all respective parameters, S^2di = Eberhart and Russell's deviation from regression, and Wi = Wricke's ecovalence

DISCUSSION

Oil yield in (kg ha^{-1}) was the product of seed yield in (kg ha^{-1}) and oil content in (%) (Table 1). Locations Kobo and Shewarobit gave the highest oil yield, while Sirinka gave average, but Chefa and Jari gave the lowest, this was because in these locations, almost all genotypes had low seed yield. Maximum oil productions were recorded from genotypes which had highest seed yields but not highest oil contents, the reason was that the oil content of the genotypes had little different at any environments, but there was much different in seed yield between genotypes. To develop varieties that have better oil yield, breeders should seek high seed yielder genotype with relative oil content and the production area should be lowland. As seen from the output, there were different results of yields in the same location of the two years (Table 1), indicating that these locations were highly variable for the specific combinations of biotic and abiotic stresses in any particular cropping season, this indicating that the breeding strategy should be develop wide adaptable genotypes. This result was in agreement with the results reported by El-Bramawy and Shaban (2007) in sesame.

Stability analysis of sesame genotypes were carried out using different stability models. According to Wricke's (Wi) Ecovalence model, genotypes Borkena, NN-0143 and Acc.00035 showed relative stable, whereas Acc.00047, Local variety and Acc. 00046 were unstable (Table 2). The best oil yielder genotype (Acc.00047) was found the most unstable this indicated that high yielders have high ecovalence and vice versa and similar results were reported by Kassa (2002) in Ethiopian mustard. The Linear Regression Coefficient (bi) stability analysis of variance (Table 3) revealed highly significant (P<0.01) different between genotypes, suggesting considerable differential performance of the genotypes. The GEI (linear) interaction was significant (P<0.05), indicating that the stability parameter (bi) estimated by linear response to change in environment was different for all genotypes or genotypes had different slopes. This confirms that GEI was in a linear function of environments indices as the mean of all the genotypes tested. The deviation from the regression (S^2di) was not significant; indicating nonlinear sensitivity in the expressions of these traits was not important, the result was in line with Adane (2008) findings in linseed genotypes. The genotypes with the Linear Regression Coefficient (bi) greater than one, i.e. below average stability, and above average mean yield, describe with highly sensitivity to environmental change, so these genotypes were best fit for specific adaptation in favorable or high yielding environments, the genotypes with the Linear Regression Coefficient (bi) less than one, have greater resistance to environmental change (above average stability), and thus increases the specificity of adaptability to low yielding environments (Table 4), as a result, genotypes: Borkena, NN-0143, Acc. 00035, Acc. 018, Hirhir-Kibe and Acc.202-344 had Linear Regression Coefficient (bi) greater than unity, indicating their responsiveness to favorable environments, whereas, Local variety and Acc. 00044 had Linear Regression Coefficient (bi) significantly lower than unity, showing their adaptation to low yielding environments. Genotypes Acc. 00047, Acc.202339, Acc.202340 and Acc. 00046 had closer to unity; therefore, these genotypes were stable. The superior genotype would be the lowest Cultivar Superiority Measure (Pi) value, which remained among the most productive in a given set of environments. According to this model, the most stable genotypes with the lowest Pi (Table 5) were Acc. 00047, Borkena and NN-0143. These stable genotypes had least contribution to the total variation due to genotype x environment interaction. The most unstable were Local variety, Acc.202340 and Acc.202339. The most productive genotypes tended to be the most stable and hence (Pi) indicates the performance of the genotypes not actually an indication of stability, this result was agreed with Lin and Binns (1988) finding. The AMMI analysis of variance of oil yield in kg ha^{-1} revealed sesame genotypes were significantly (P<0.01) affected by environments (E), and GEI. From the total variation (Table 6), environments accounted (49.6%), genotypes (13.8%) and GEI (32.1%). The large sum of squares for environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in oil yield and the environments had great influence on sesame production. The magnitudes of the GEI sum of squares were 2.3 times of the genotypes sum of squares, indicating also that the environments are very divers and genotypes have considerable responses across environments. This showed that breeding strategy should be based on the performance of the genotypes. The result was agreed with the works of (Adugna and Labuschagne, 2002; and Adane, 2008) in linseed genotypes. The AMMI2 model, the Interaction Principal Component Axes (IPCA1 and IPCA2) showed highly significant ($P < 0.01$) and explained 46.3 % and 28.8% totally accounted 75.1% of the GEI variation. Though, the higher interaction principal component axes (IPCA3 to IPCA6) of the interactions were highly significant for the model, the prediction assessment indicated that AMMI 2 with only two interaction principal component axes were the best predictive (Zobel *et al*., 1988). Further interaction principal component axes captured mostly noise and therefore, did not help to predict validate observations. Thus the interaction of the 12 sesame genotypes with eight environments was best predicted by the first two interaction principal component of genotypes and environments. The AMMI model does not provide a measure of quantitative stability, but quantitative stability measure is essential in order to quantify and rank genotypes according to their yield stability. For this reason AMMI stability value (ASV) was proposed by Purchase (1997). Genotypes with least ASV were considered the most stable, whereas those which had highest ASV were considered unstable. According to this model, genotypes Borkena, Local variety and Acc.202340 were stable, whereas genotypes Acc.00047, Acc.00044 and Acc.00046 were unstable (Table 7); similar result was reported by Adane (2008) in linseed genotypes.

Comparison of Stability Parameters

Different stability parameters were used to compare the stability and ranking of sesame genotypes. Although there was change in ranking order of genotypes from one stability parameter to another, based on the information (Table 8), genotypes Borkena, NN-0143 and Acc.00035 with mean oil yield of 288, 306 and 281 kg ha^{-1}, respectively were found stable by stability parameters Wricke's ecovalence and deviation from regression. These genotypes had high buffering capacity to environmental changes such as diseases and drought (Becker and Leon, 1988), while local variety, Acc.202-344 and Acc.018 with mean oil yield of 179, 303 and 273 kg ha^{-1}, respectively were unstable. The fifth and second high yielder genotypes (Borkena, NN-0143) were stable by most of the stability measures. The highest oil yielder genotype (Acc.00047) with mean oil yield 339 of kg ha^{-1} was the most unstable except by the stability parameter cultivar superiority performance (Pi) where it appeared as 1st stable (Table 5). This genotype had the highest value of ASV (Table 7), where the high yielder genotypes had high ASV value and were positively correlated. Yield stability is an important issue in cultivar testing and selection, but stability is meaningful for cultivar evaluation only when the genotypes are comparable in average yield. Stability alone is meaningless, that means a less stable cultivar that performs well on average is better than a cultivar that stable and performs consistently poor (Weikai, 1999), hence, Borkena and NN-0143: 5th and 2nd in their oil yield, respectively were 1st and 2nd stable genotypes and thus they could be grown in wide environments. Similar results were identified by Adugna and Labuschagne (2002) in linseed and Hariprasanna*et al*. (2008) in groundnut. Duarte and Zimerman (1995) suggested that phenotypic stability should not be restricted to one method but personalized to the stability type of interest to the individual researcher. Inconsistency in ranking using a univariate approach was previously suggested to be difficult to reconcile into a unified conclusion Lin *et al*. (1986). According to them, the basic reason for the difficulty is that a genotype's response to environments is multivariate. This problem has been overcome by using the AMMI model (Alberts, 2004).

Since it has a power of measuring the magnitude of the sums of squares of environments, GEI and genotypes, evaluate multivariate responses of the genotypes and also shows the potential and poor environments; high and low yielder as well as stable and unstable genotypes, AMMI model is the best model of the others for this study.

Correlation of Stability Parameters, all the stability models had non-significant correlation with oil yield. The non-significant correlation among yield and stability parameters indicated that, information cannot be collected from average yield alone (Duarte and Zimermann, 1995). On the other hand, stability parameter deviation from regression (S^2di) had highly significant positive correlation ($r=0.84$) with Wricke's (Wi) and significant positive correlation ($r=0.60$) with AMMI Stability Value (ASV), indicating S^2di can evaluate genotypes in some degree similarly with these two models and a possibility to use one of them (Table 7).

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Table 9. Correlations of stability measures with oil yield

	Yield	WI	b_i	S^2_{di}	P_i	ASV
Yield						
W_i	-0.4758ns					
b_i	0.4735ns	-0.5753*				
S^2_{di}	-0.4810ns	0.8346**	-0.3303ns			
P_i	-0.4727ns	0.2523ns	-0.5456*	-0.0975ns		
ASV	-0.1058ns	0.3198ns	0.2600ns	0.5996*	-0.4108ns	

Note: *, ** significant at P<0.05 and P<0.01 respectively, ns= non-significant, ASV=AMMI stability value, bi = Eberhart and Russell's regression coefficient, Pi = Lin and Binns cultivar performance measure, S^2_{di} = Eberhart and Russell's' deviation from regression and Wi = Wricke's ecovalence