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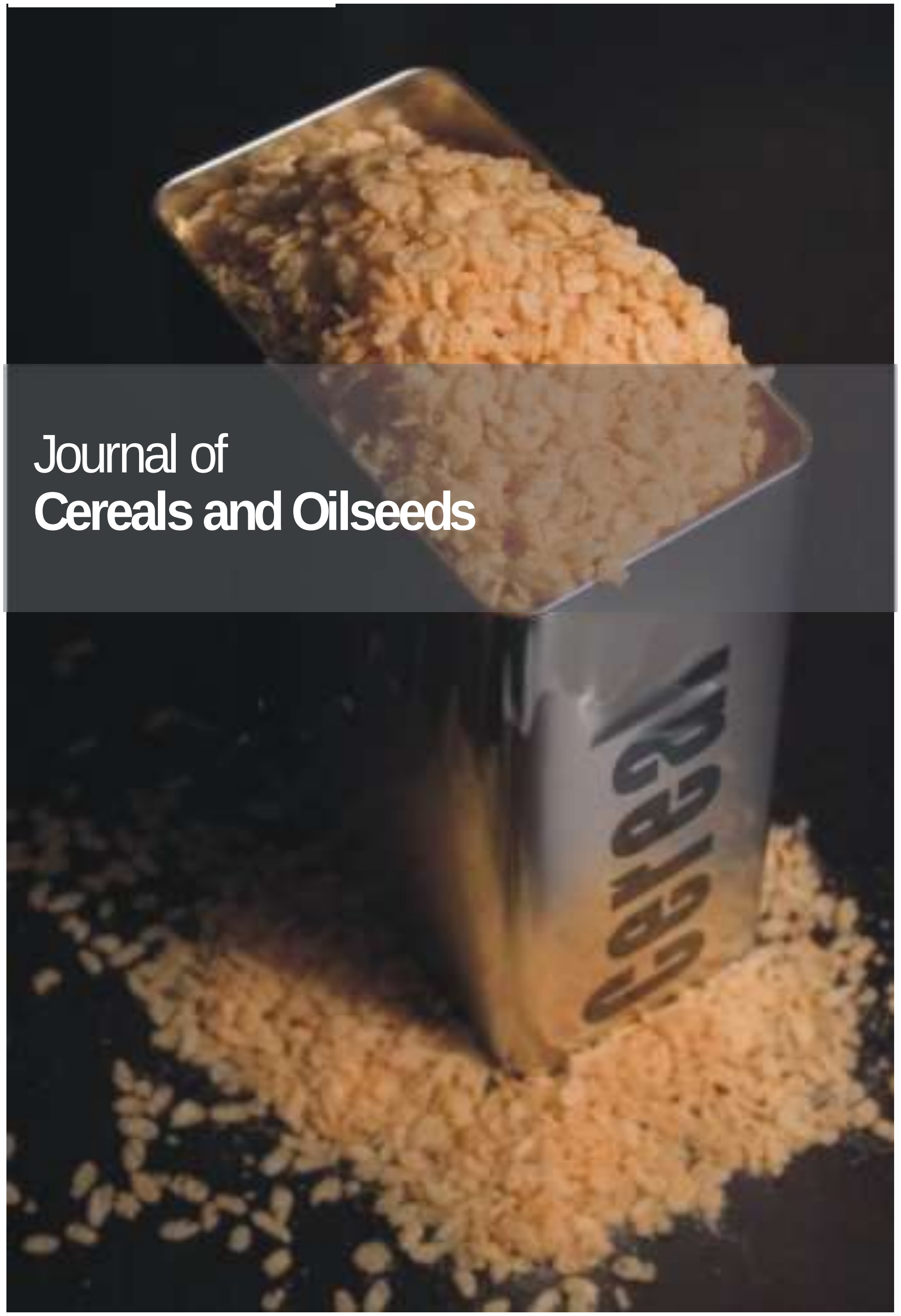

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Journal of Cereals and Oilseeds

Full Length Research Paper

Genotype × environment interaction and stability of oil content of sesame (*Sesamum indicum* L.) genotypes in Northern Ethiopia

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The experiment, for oil content analysis, was conducted for two growing seasons under rain fed condition (2012-2013) in Humera and Dansha, and in a single year (2013 cropping season) in Sheraro (a total of five environments). The experiment, comprised of 13 sesame genotypes, laid out in randomized complete block design of three replications with the objective of determining the magnitude of Genotype × Environment Interaction (GEI) and oil content. There was highly significant ($p<0.01$) oil content variation based on genotypes, environments and GEI resulting 26, 42.7 and 30.9% of the total sum of squares for the oil content variation, respectively. The grand mean of the oil content was 53.9%, yielding genotypes G4 and G11 with the highest oil content (55.1%) each and G8 with the lowest oil content (51.4%). G4 was the exceptional genotype with highest oil content (55.1%) and oil yield (512.9 kg/ha). Environments, E4 and E5 were the favorable environments and E1, E2 and E3 were unfavorable environments for sesame oil production. According to the additive main effects and multiplicative interaction (AMMI1) bi-plot, genotypes G4, G13 and G10 were stable genotypes and genotypes G2, G8, G9, G3 and G1 were unstable genotypes in most of the environments. The AMMI 2 bi-plot showed that, genotypes G2, G3 and G9 were specifically adaptable genotypes and genotypes G10, G12, G4 and G7 were widely adaptable in most of the environments for their oil content. Oil content of sesame varies highly both across years and locations.

Key words: Adaptable, additive main effects and multiplicative interaction (AMMI), bi-plot, environment, stability.

INTRODUCTION

Sesame (*Sesamum indicum* L.) is an ancient oil seed crop which has been grown for over 7,500 years in Asia and Africa even in very poor growing conditions (Langham et al., 2010). Sesame is currently widely grown for its flavorsome, edible seed and high quality oil. The sesame seed which contains about 50-60% oil content (Caliskan et al., 2004) is an excellent source of quality oil which is straw-like in color and odorless that is close in

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Table 1. Agro-climatic and soil characteristics of the experimental sites.

Location	Latitude (°N)	Longitude (°E)	Altitude (m)	Annual RF (mm)	Min - Max Temp (°C)	Soil texture		
	-	-	-	-	Clay (%)	Silt (%)	Sand (%)	
Humera	14°15'	36°37'	609	576.4	18.8-37.6	35.6	25.6	38.6
Sheraro	14°24'	37°45'	1028	676.7	18.8-34.9	21	27.3	51.7
Dansha	13°36'	36°41'	696	888.4	28.7 (mean)	-	-	-

quality to olive oil (Tunde-Akintunde and Akintunde, 2007). Owing to the excellent quality of the edible oil it produces, sesame is often called queen of the oil seed crops (Tunde-Akintunde et al., 2012).

Decorticated sesame seeds have a composition of 45-63% oil, 19-31% proteins, about 14% carbohydrates and about 3% ash (Anilakumar et al., 2010). In addition the seeds contains about 83-90% unsaturated fatty acids, and various minor nutrients such as vitamins and minerals, large amount of characteristic lignans (methylenedioxyphenyl compounds) such as sesamin, sesamol, sesamolin and tocopherols. Because of the presence of these antioxidants, sesame oil is highly stable and rarely turns rancid in hot climates (Fukuda et al., 1985). The sesame oil is rich in unsaturated fatty acids where the fatty acids composition is 14% saturated, 39% mono-unsaturated, and 46% poly-unsaturated fatty acids (Toma and Tabekhia, 1979). The functional components together impart resistance against oxidative deterioration and provide nutraceutical value to the crop. For that reason, sesame seeds with high amounts of nutritional components are consumed as a traditional health food for its specific antihypertensive effect, anticarcinogenic, anti-inflammatory and antioxidative activity (Yokota et al., 2007).

Sesame is grown mainly for its attractive domestic and international price in Ethiopia. In Ethiopia there are three sesame types commonly used for commercial production and these are the Humera type, Gondar type and Wollega types. The Humera type is appreciated worldwide for its aroma and sweet taste, and is the first sesame standard in the international market. The Humera type sesame code is not ascribed to any specific variety but to different varieties grown in the Western and North western Tigray of Northern Ethiopia. It is said to be good uniform white seeds, which are quite larger. This makes it very suitable for bakery products. The Gondar type is also suitable for the bakery market. The major competitive advantage of the Wollega type is its high oil content (Anonymous, 2012).

The Western Tigray of Northern Ethiopia is the main sesame producer with large commercial farms and many small scale farmers. Furthermore, Sesame also grows very well in the North western Tigray of Northern Ethiopia under a few commercial farming systems and by many small scale farmers as cash crop and for local oil extraction to produce '*ashera'* (the locally extracted sesame oil). In this local oil extraction the oil that the producers extracts varies from variety to variety that harvested from different places in different period of time giving an indication for the instability of sesame genotypes for their oil content. Different studies have been also undertaken to determine the magnitude of GEI and oil content stability of sesame (Zenebe and Hussien, 2009; Mohammed et al., 2015). So this study is important in identifying and supplying with high and stable oil content sesame variety/ies. Genotype x environment interaction (GEI) is both a challenge and an opportunity for plant breeders (Fiseha et al., 2015). Because it complicates cultivar recommendation due to the inconsistency of high yielding material across different environments. On the other hand, it is also an opportunities since it allows for recommendation of specifically adapted materials to given environments.

MATERIALS AND METHODS

Experimental

The experiment, for oil content analysis, was conducted for two growing seasons (2012-2013) in Humera and Dansha, and in a single year (2013 cropping season) in Sheraro (a total of five environments) under rain fed condition where: E1 and E2 are 2012 and 2013 growing seasons, respectively in Humera; E3 and E4 are 2012 and 2013 growing seasons, respectively in Dansha; and E5 is 2013 growing season in Sheraro. Edaphic and climatic description of the study areas as well as description of the genotypes is listed in Tables 1 and 2, respectively. Thirteen sesame genotypes *viz*., Acc#031 (G1), Oro 9-1 (G2), NN-0079-1(G3), Acc-034 (G4), Abi-Doctor (G5), Serkamo (G6), Acc-051-020sel-14 (G7), Tate (G8), Acc-051-02sel-13 (G9), Adi (G10), Hirhir (G11), Setit-1 (G12), and Humera-1(G13)) were sown in randomized complete block design (RCBD) with three replications and evaluated for their oil content. Each genotype was randomly assigned and sown in a plot area of 2.8 m by 5 m with 1 m between plots and 1.5 m between blocks keeping inter and intra row spacing of 40 and 10 cm, respectively.

Data collection

Each plot had a total of seven rows, of these the five experimental rows were harvested, tied in sheaves and were made to stand separately until the capsules opened. After the sheaves have dried out fully and all of the capsules opened, they were tipped out onto sturdy canvases and threshing was accomplished by knocking the sheaves. The seeds from each plot were weighed for grain yield and oil yield determination as follows:

(i) Grain yield (kg/ha): the total grain yield harvested from the net plot area was weighed using a sensitive balance.

Table 2. Description of the sesame genotypes evaluated for their oil content.

Genotype name	Code	Status	Seed color	Source
Acc#031	G1	Advanced line	White	WARC
Oro 9-1	G2	Advanced line	White	WARC
NN-0079-1	G3	Advanced line	White	WARC
Acc-034	G4	Advanced line	White	WARC
Abi-Doctor	G5	Advanced line	White	WARC
Serkamo	G6	Released	Brown	WARC
Acc-051-020sel-14	G7	Advanced line	Brown	WARC
Tate	G8	Released	Brown	WARC
Acc-051-02sel-13	G9	Advanced line	White	WARC
Adi	G10	Released	White	WARC
Hirhir	G11	Farmers seed (local check)	White	HuARC
Setit-1	G12	Released (standard check)	White	HuARC
Humera-1	G13	Released (standard check)	White	HuARC

WARC-Werer Agricultural Research Center, HuARC-Humera Agricultural Research Center

(ii) Oil contents (OC) (%): Oil content was determined by wide line nuclear magnetic resonance (NMR) spectrophotometer. Composite seeds were collected from each plot and each replication bulked separately and oven dried at 130°C for 2 h and cooled for 1 h. From each plot a sample of 22 g of oven dried clean seed was used for analysis of oil content by NMR (Newport analyzer) (Newport Pagnell, Bucks, UK). The NMR read oil content of the sample seed with reference to a standard of extracted sesame oil. The instrument provided three readings at interval of eight seconds and average of the three readings was recorded for each sample and used for the oil content analysis.
(iii) Oil yield (OY) (kg/ha): Oil yield was determined by multiplying the oil content (%) and the grain yield in kg/ha as the formula below.

Oil yield (OY) (kg/ha) = gGrain yield (kg/ha) kg*Oil content (%)

Statistical analysis

Statistical estimations and computations were performed using different statistical software. Homogeneity of residual variances was tested prior to a combined analysis over locations in each year as well as over locations and years using Bartlet's test (Steel and Torrie, 1998). Accordingly, the data collected were homogenous and all data showed normal distribution. Furthermore, different stability parameters were used to determine the oil content stability of the sesame genotypes. Additive main effects and multiplicative interaction (AMMI), additive stability value (ASV), sum of interaction principal component (SIPC) and yield stability index (YSI) were among the different stability measures used to determine the oil content stability of sesame genotypes: AMMI stability value (ASV) was calculated in the excel spread sheet using the formula developed by Purchase (1997):

$$ASV = \sqrt{\left[\frac{SS_{IPCA1}}{SS_{IPCA2}}(IPCA1_{score})\right]^2 + (IPCA2_{score})^2}$$

Where; SS is sum of squares; IPCA1 is interaction of principal component axis one; and IPCA2 is interaction of principal component axis two.

Sum of interaction principal component (SIPC) was also calculated in the excel spread sheet using the formula developed by Sneller et al. (1997):

$$SIPC = \sum_{n=0}^{N} \left|\lambda^{05}{}_{n}\gamma_{in}\right|$$

Where; $e^{05}{}_{n}\gamma_{in}$ is the interaction principal component (IPC) scores for the i^{th} genotype; n is number of IPC; and N is number of significant IPC retained in the model via F-test.

Similarly yield stability index (YSI) was also computed in the excel spread sheet using the formula developed by Farshadfar et al. (2011):

YSI = RASV + ROC

Where; RASV- is rank of AMMI stability value and ROC- is rank of oil content.

Over all rank (OR) is the oil content stability rank of the sesame genotypes based on the above mentioned parameters and a genotype with a smallest value of the summation of the rank of the different stability measures considered as first ranked (the most stable) and a largest value of the summation of the rank of the different stability measures considered as last ranked (the most unstable).

RESULTS AND DISCUSSION

Variance estimation for oil content of sesame genotypes

The combined ANOVA for oil content showed that there was highly significant variation ($p<0.01$) among the genotypes, environments (year, location, year × location) and Genotype × Environment Interaction, (Genotype × Year, Genotype x Location and Genotype x Year × Location) (Table 3). These significant variations of the

Table 3. Combined ANOVA for the oil content (%) of the sesame genotypes.

Source of variation	DF	SS	MS
Replication	2	0.01754	0.00877
Treatment	12	343.369	28.6141***
Location	2	309.059	154.529***
Year	1	229.951	229.951***
Treatment x Location	24	104.686	4.36193***
Treatment x Year	12	218.064	18.172***
Location x Year	1	24.96	24.96***
Treatment x Location x Year	12	86.2983	7.19153***
Residual	128	5.72246	0.04471
Total	194	1322.13	

Table 4. Combined AMMI analysis of variance for oil content (%) of Sesame genotypes.

Source of variation	df	TSS	TSS (%)	GEI explained (%)	Cumulative (%)	MS
Treatments	64	1316.4	99.6			20.57**
Genotypes	12	343.4	26.0			28.61**
Environments	4	564	42.7			140.99**
Blocks	10	0.3	0.0			0.03
Interactions	48	409	30.9			8.52**
IPCA 1	15	316		77.2	77.2	21.07**
IPCA 2	13	56.9		13.9	91.1	4.38**
IPCA 3	11	28.5		6.9	98	2.59**
IPCA 4	9	7.6		1.8	99.8	0.85**
Error	120	5.5				0.05
Total	194	1322.1				6.82

Where; df-degrees of freedom, TSS-total sum of squares, GEI- genotype by environment interaction and MS- mean square.

genotypes, environments and the Genotype x Environment Interaction, indicated that the response of the genotypes was highly variable and fluctuated in the oil content with change in environment and these occurrences clearly confirmed the presence of Genotype x Environment Interaction.

The AMMI model (additive main effects and multiplicative interaction) for oil content showed significant variation ($p<0.001$) for both the main and interaction effects confirming the occurrence of a wide range of variation among the genotypes, years (seasons), locations and their interactions (Table 4). Environments had a lion's share in oil content variation and accounted about 42.7% of the total sum of squares confirming that the greatest source of variation for oil content among the genotypes was mainly the environment on which the genotypes were grown. Similar results were reported in sesame by Zenebe and Hussien (2009). Interaction effects and genotypes had 30.9% and 26% contribution for the total sum of squares correspondingly. The AMMI model extracted four significant ($p<0.001$) IPCAs from the interaction component (Table 4). These four IPCAs accounted a total 99.8% of the interaction sum of squares. The extracted IPCAs are capable of providing an information on the interaction effect although their degree decreases from the first to the last IPCAs. However, according to Zobel et al. (1988) the first two IPCAs could best explain the interaction sum of squares. Therefore, the first two IPCA's with a total of 91.1% sum of squares were used to explain the interaction effect.

The grand mean of the oil content over the five environments was 53.9% (Table 5). Among the environments, E4 (in Dansha location in 2013 cropping season) was the environment with the highest oil content (56.8%) and E1 (in Humera location in 2012 cropping season) was the environment with the lowest oil content (51.6%). Hence, E4 was the most favorable environment for oil production of sesame and E1 was the most unfavorable environments among the growing environments for sesame oil production. This might be due to the reason that the Dansha location is better growing in environment because of it receiving better annual rainfall (Table 1) with comparatively favorable temperature for sesame production. Regarding to the

Table 5. Oil content (%) and combined oil yield (kg/ha) recorded from 13 sesame genotypes in each of five environments.

Genotype	Environments					Genotype Mean OC (%)	Genotype Mean OY (kg/ha)
	E1	E2	E3	E4	E5		
G1	54.3	54.8	55.8	54.3	55.8	55.0^{ab}	514.6^{a}
G2	48.5	49.9	50.3	59.1	51.0	51.7^{i}	340.4^{e}
G3	54.0	53.3	57.1	53.6	54.6	54.5^{d}	413.8^{bcd}
G4	53.1	55.8	53.9	57.3	55.1	55.1^{a}	512.9^{a}
G5	52.8	54.3	55.8	56.7	54.6	54.9^{bc}	397.7^{de}
G6	51.8	52.7	55.8	56.0	53.7	54.0^{f}	411.6^{bcd}
G7	50.4	51.6	51.0	57.0	53.5	52.7^{g}	370.7^{de}
G8	48.2	50.7	49.3	57.5	51.1	51.4^{j}	$348.^{8e}$
G9	46.5	52.2	51.6	57.9	51.9	52.0^{h}	358.2^{de}
G10	51.1	53.7	53.9	57.4	54.9	54.2^{e}	400.8^{cde}
G11	54.0	53.8	56.8	56.7	54.2	55.1^{a}	464.3^{ab}
G12	53.2	54.5	53.1	58.4	54.9	54.8^{c}	469.5^{ab}
G13	52.8	54.7	52.8	57.2	56.0	54.7^{c}	456.4^{abc}
Env Mean	51.6	53.2	53.6	56.8	54.0	53.9	420.0

Where; E1, E2, E3, E4 and E5 refers to Environments 1, 2, 3, 4 and 5, respectively, OC- oil content, OY- oil yield.

Table 6. Environmental Index (EI) and AMMI stability Value (ASV) of the Growing Environments.

Environment	Em (%)	EI	IPCA1	IPCA2	ASV	Rank
E1	51.6	-2.242	1.17015	0.62533	6.53	3
E2	53.2	-0.622	0.00044	0.73742	0.74	1
E3	53.6	-0.232	1.36798	-1.6034	7.76	4
E4	56.8	2.998	-2.6478	-0.5205	14.71	5
E5	53.9	0.098	0.10917	0.76114	0.97	2
Grand mean OC (%)	53.9					

Where; Em-environmental means, EI- Environmental Index and ASV- AMMI stability value.

genotypes, G4 (Acc-034) and G11 (Hirhir) were the genotypes with the highest oil content (55.1% each) and G8 (Tate) was the genotype with the lowest oil content (51.4%) (Table 5). Furthermore, G1 (Acc#031) and G4 (Acc-034) were the genotypes with the highest oil yield (514.6 and 512.9 kg/ha, respectively) confirming G4 (Acc-034) was the exceptional genotype with highest oil content and oil yield in comparison to the other genotypes. These oil content differences between the genotypes might be due to the inherent genetic potential difference of the genotypes and/or due to the environments on which the genotypes were tested.

Based on the Environmental Index (EI), E5 (2013 growing seasons in Dansha) with smallest EI value (0.098) was the most stable environment on which most of the sesame genotypes showed almost similar performance in their oil content (Table 6). In contrast to this, E4 (2012 growing seasons in Dansha) with highest EI value (2.998) was the most unstable environment on which some of the sesame genotypes showed highest performance and the others showed lowest performance for their oil content. Similarly based on the ASV, E4 (2012 growing seasons in Dansha) with the highest ASV (14.71) was the most unstable environment (Table 6). According to Farshadfar (2008) environments often classified as favorable and unfavorable ones based on the environmental index (EI), where environments with a negative index considered as unfavorable and those with positive regarded as favorable. Accordingly, E4 and E5 with positive EI were the environments favorable for sesame oil production and E1, E2 and E3 with negative EI were environments unfavorable for sesame oil production.

Oil content stability based on stability measures from AMMI model

AMMI stability value (ASV) analysis

The ASV is the distance from the coordinate point to the origin in a two-dimensional scatter gram of IPCA1 scores

Table 7. Mean oil content (OC), various stability measures from AMMI model and their ranking order.

Gen	OC (%)	Rank	IPCA1	IPCA2	ASV	Rank	YSI	Rank	SIPC	Rank	OR
G1	54.97	3	1.27471	0.48186	7.08	11	14	5	2.34908	11	7
G2	51.74	12	-1.4175	-0.572	7.87	12	24	10	1.62449	5	11
G3	54.52	7	1.58986	-0.3985	8.83	13	20	8	1.92029	8	9
G4	55.07	2	0.10292	0.68597	0.57	2	4	1	2.82099	12	3
G5	54.85	4	0.46249	-0.3072	2.57	5	9	3	1.85606	7	4
G6	54.01	9	0.53698	-0.7758	2.98	6	15	6	3.03265	13	8
G7	52.69	10	-0.5405	0.41849	3	7	17	7	1.0602	1	6
G8	51.36	13	-1.1626	0.0955	6.46	10	23	9	1.51203	4	9
G9	52.02	11	-1.1358	-0.6396	6.31	9	20	8	2.24469	10	10
G10	54.22	8	-0.148	0.00146	0.82	3	11	4	1.69582	6	5
G11	55.09	1	0.74588	-0.6494	4.14	8	9	3	2.05088	9	5
G12	54.81	5	-0.2741	0.63022	1.52	4	9	3	1.12201	2	2
G13	54.71	6	-0.0343	1.02895	0.19	1	7	2	1.48738	3	1

Where; YSI-yield stability index, SIPC-sum of interaction principal component, OR-over all rank.

against IPCA2 scores in the AMMI model (Purchase, 1997). The genotypes with larger magnitude of IPCA score are the more specifically adapted to certain environments and those with smaller IPCA scores indicate a more stable genotype across environments. In view of that, G13 with the lowest ASV (0.19) followed by G4 (0.59) were the most stable genotypes; whereas, G3 (8.83) followed by G2 (7.87) were ranked as less stable and more sensitive genotypes indicating their oil contents were highly fluctuating over the growing environments (Table 7).

Sum of interaction principal component (SIPC)

Sum of interaction principal component (SIPC) is another stability statistics from AMMI model developed by (Sneller et al., 1997). It is sums of the absolute value of IPC scores (SIPC) of the genotypes that were retained in the AMMI model via F-tests. The genotypes with smaller SIPC are considered as the most stable and widely adapted otherwise specifically adapted. With respect to SIPC, G7 (1.06) was the most stable genotype and considered as a widely adapted; and G6 (3.033) and G4 (2.82) as unstable genotypes with a highly variable performance of the oil content across environments (Table 7). Similar report has been made by Zali et al. (2012) in chick pea using SIPC.

Yield stability index (YSI) analysis

Yield stability index (YSI) Farshadfar et al. (2011) is recommended as a measure of stability, which is calculated by summing the rank of mean grain yield across environments and rank of AMMI stability value of genotypes. The genotypes with lowest value of this parameter are desirable genotypes with high mean oil content and stability. Hence, YSI identified G4 and G13 as the most stable genotypes for their oil content respectively whereas, G2 was recognized as the most unstable genotype as its oil content highly fluctuates over the growing environments (Table 7). Based on the OR (Over all rank) of the genotypes calculated from the different stability parameters G13 was the most stable genotype for its oil content followed by G12. On the other hand, G2 followed by G9 were the most unstable genotypes for their oil content.

AMMI 1 bi-plot

The graphical representation of AMMI1 bi-plot analysis reveals the main effect means on the abscissa and IPCA-1 scores of both host genotypes as well as the environments simultaneously on the ordinate. The interaction is described in terms of differential sensitivities of the genotypes to the most discriminating environmental variable that can be constructed. Displacement along the abscissa reflects differences in main effects, whereas displacement along the ordinate illustrates differences in interaction effects. Host genotypes or environments appearing almost on a perpendicular line have similar means and those falling almost on a horizontal line have similar interaction patterns. According to Yan and Tinker (2006), genotypes with IPCA-1 scores close to zero have small interactions and hence show wider adaptation to the tested environments. A large host genotypic IPCA-1 score have high interactions and reflects more specific adaptation to the environments with IPCA-1 values of the same sign (either positive or negative). Accordingly Genotypes G2, G8, G9, G3 and G1 which have relatively

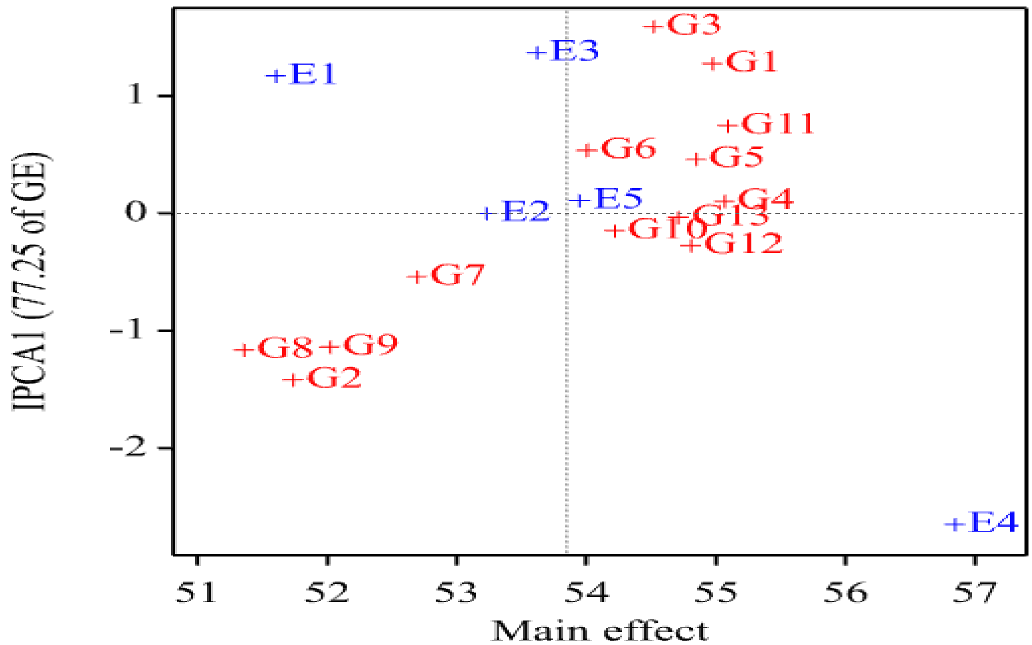

Figure 1. AMMI1 bi-plot showing Genotype and Environmental means against IPCA1. Where the environments are represented by (E) and the genotypes are represented by (G).

larger IPCA-1 scores have larger contribution for the G x E interaction and are unstable genotypes in most of the environments. Whereas, genotypes G4, G13 and G10 were genotypes with smaller IPCA-1 scores having low contribution for the G x E interaction and are stable genotypes in most of the environments (Figure 1). Regarding the environments E1, E3 and E4 were the environments with larger IPCA-1 scores indicating their favorability for some of the genotypes and unfavorable for the others. Whereas, E2 and E5 were the environments averagely favorable for most of the genotypes.

AMMI 2 bi-plot

The AMMI 2 bi-plot, containing IPCA1 in the X-axis and IPCA2 in the Y-axis, is plotted in Figure 2. The first interaction principal component (IPC1 or PC1) contained 77.25% and the second interaction principal component (IPC2 or PC2) explained about 13.92% and the two interaction principal components cumulatively explained about 91.17% of the sum of squares of the genotype by environment interaction of the genotypes (Figure 2). The closer the genotypes to the origin are the more stable and the furthest genotypes from the origin are the more the unstable ones. In addition the closer the genotypes to the given vector of any environment is the more adaptive to that specific environment and the farthest the genotypes are to the given vector of any environment the less adaptive to that specific environment (Purchase, 1997). Accordingly, genotypes G2, G3 and G9 are far apart from the bi-plot origin indicating these genotypes as the more responsive and contributed largely to the interaction component and considered as a specifically adapted genotypes for their oil content. On the other hand, G10, G12, G4 and G7 were the genotypes with least contribution to the interaction component as they are located near to the bi-plot origin indicating their wider adaptability for their oil content (Figure 2). Regarding the adaptability of the genotypes in the environments; genotype G1 was adaptive to E1; genotypes G6 and G2 were adaptive to E3 and E4 respectively; and genotypes G12 and G4 were adaptive to environments E2 and E5 respectively.

Conclusions

The significant variations of the genotypes, environments and their interaction indicated that the response of the genotypes was highly variable and fluctuated in the oil content and these occurrences clearly declared the existence of GEI. However, environments had a lion's share for oil content variation accounted about 42% of the total sum of squares. The grand mean of the oil content over the five environments was 53.9%, yielding genotypes, G4 (Acc-034) and G11 (Hirhir) with the highest oil content (55.1% each) and G8 (Tate) with the lowest oil content (51.4%). Generally most of the genotypes were significantly different among each other for their oil content yield. These all oil content differences between the genotypes might be due to the inherent

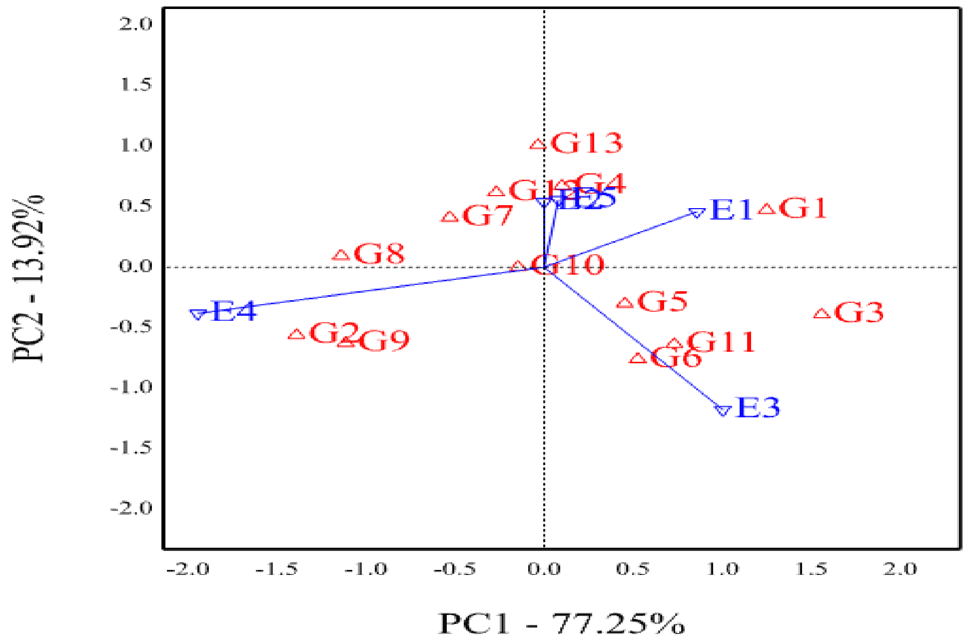

Figure 2. AMMI2 bi-plot showing PC1 versus PC2 indicating the stability of the Genotypes Where the environments are represented by (E) and the genotypes are represented by (G).

genetic potential difference of the genotypes and/or due to the environments on which the genotypes tested and/or due to the interaction. Regarding to the environments, E4 and E5 were the environments favorable for sesame oil production and E1, E2 and E3 were the environments unfavorable for sesame oil production.

According to the AMMI 1 bi-plot Genotypes G2, G8, G9, G3 and G1 have larger contribution for the Genotype x Environment Interaction and are unstable genotypes in most of the environments. Whereas, genotypes G4, G13 and G10 having low contribution for the G x E interaction and are stable genotypes in most of the environments. Generally, based on the investigations of this study oil content of sesame varies highly beyond expectation both across years and locations which needs due attention and further investigation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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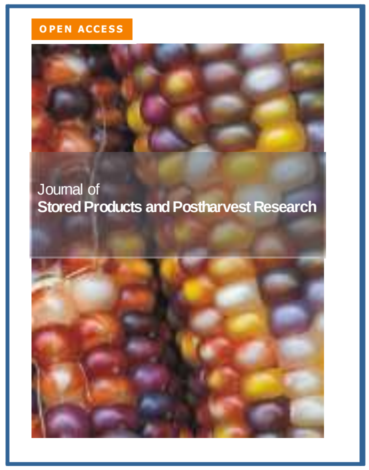

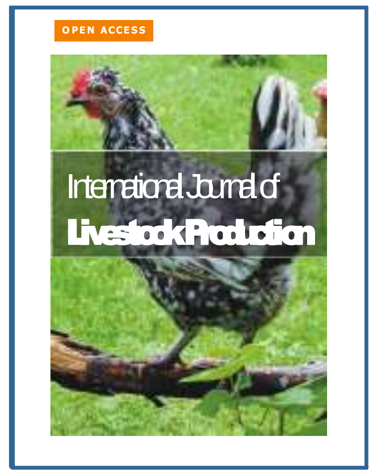

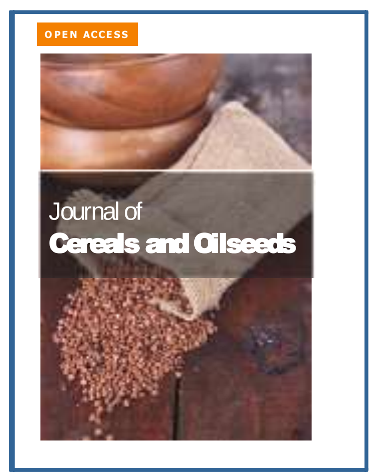

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