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Study on Genotype X Environment Interaction of Oil Content in Sesame (*Sesamum indicum* L.)

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Abstract: Combined analysis of variance of oil content of twenty genotypes tested at six locations showed highly significant ($p \leq 0.01$) difference between the genotypes, locations and GEI, suggesting differential response of genotypes across testing locations and the need for stability analysis. Proportion of variance captured by location is 16.8 %, genotypes 30.5 % and GEI 4.6 % of the total variation. Highest oil content of 52.5, 52.4, 52.1 and 52.0% was obtained from genotypes Temax, Acc-051-02-Sel-6, Acc-051-02-Sel-10 and Acc-212-332-4, respectively. Genotypes Abasena and S gave the lowest oil content of 49.2 and 45.9% respectively. Stability analysis was used to further shed light on the GEI of oil content. Two IPCA of AMMI were significant ($P \leq 0.01$) and captured the largest portion of variation of the total GEI for oil content, which indicated that the AMMI model 2 was the best for the data set. Genotypes Mehado 80, Argane, Addi, T-85, T-6P-32-3 and Kelafo-74 shown little GEI when both IPCA1 and IPCA2 considered and therefore stable.

Key words: AMMI (Additive Main Effects and Multiplicative Interaction) · Genotypes · GEI (Genotype by Environment Interaction) · Stability

INTRODUCTION

The adaptability of a variety over diverse environments is usually tested by its degree of interaction with different growing environments. A variety or genotype is considered to be more adaptive or stable if it has a high mean yield but low degree of fluctuation in yielding ability when grown over diverse environments [1].

Failure of genotypes to respond consistently to variable environmental conditions is attributed to Genotype x Environment Interaction (GEI). Knowledge of GEI is advantageous to have a cultivar that gives consistently high yield in a broad range of environments and to increase efficiency of breeding program and selection of best genotypes.

Seed oil content can vary considerably between cultivars and seasons. [2] 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 was important [3]. Several other studies were carried out on GEI throughout the world by different researchers on various oil crops like linseed [4], Ethiopian mustard [5], Sunflower [3, 6] and Sesame [7, 8]. They reported that the 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 content is observed on released varieties and elite genotypes under trial across locations and genotypes. However, studies on the effects of GEI on sesame oil content are quite few [9]. Assessing any genotype performance without including its interaction with the environment is incomplete and limits the accuracy of measured parameter estimates. Studies of the causal factors of the G x E effect and quantifying unexplained variation are of prime importance

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3for selection and recommendation of environmentally stable varieties [10]. Therefore, this paper is designed to study the magnitude and nature of G x E interaction of oil content of sesame genotypes grown at different locations and to identify stable genotypes that can give high oil content under a wide range of growing conditions within Southern Nations and Nationalities People's Regional State (SNNPRS).

MATERIALS AND METHODS

The experiment was carried out at six environments of Southern Ethiopia during the 2007 cropping season (July to December). These locations were situated within the altitudinal ranges of 1250 to 1400 m.a.s.l; have soil characteristics of Sandy clay loam, Clay, Clay loam, Sandy clay, Silt clay and Sandy loam; are the main variety testing sites for lowland oil crops of Southern Agricultural Research Institute (SARI). Twenty sesame genotypes, ten released varieties and ten elite lines, were used in the study. The experiment was laid out in a randomized complete block design with three replications in each environment. The unit plot size in a replication measured 5 m in length and 2 m in width accommodating 5 rows of 250 plants per genotypes after thinning keeping row to distance 0.4 m and plant to plant distance 0.1 m. Normal cultural practices were followed. Data on various characters were recorded, but only oil content is considered and presented in this paper. Analysis of variance was undertaken for the combined analysis of variance across the test environments. Following testing of the significance of the GEI mean square, means over three replications for oil content of genotype i at location j $\overline{Y_{ij}}$ were subjected to AMMI stability analysis using SAS [11]. AMMI's stability value (ASV) was calculated using the following formula, as suggested by [12].

$$ASV = \sqrt{\left[\frac{IPCA1\,sum\,of\,squares\,(IPCSA1score)}{IPCA2\,sum\,of\,squares}\right]^2 + (IPCA2score)^2}$$

Where, ASV = AMMI's stability value, SS = sum of squares, IPCA1 = interaction of principal component analysis one, IPCA2 = interaction of principal component analysis two.

RESULTS AND DISCUSSIONS

Analysis of Variance and Estimation of Variance Component for Oil Content: the combined analysis of variance (ANOVA) for oil content is shown in Table 1. Genotypes, environment and Genotype x Environment interaction showed high significant difference ($P \leq 0.01$) indicating rank difference in genotypes response at different environments and the need for extension of stability analysis. This result confirms the report of [2] who found a significant GEI where a 6% variation for oil content was due to location. The partitioning of variance components indicated that environments to be 16.8% of the total variation, 23.0% due to replications within environments, 30.5% due to genotypes, 4.6% due to GEI and 25.0% due to residual (Table 1). The higher proportion of variance due to genotypes more than environment indicates that location effects on oil content is not large.

The mean oil content averaged over environments is presented in Table 2. The mean oil content at the individual environments ranged from 49.7% at Bedessa to 52.9% at Arba Minch. This difference is mainly because of their wide range of environmental conditions primarily resulting from varying amounts of temperature, soil and rainfall. A similar result was reported by [13] in which they indicated a change in season and soil type caused variation in oil content of white mustard. Arba Minch had the largest environmental index of 2.1110 and therefore the most suitable environment for realizing oil content potential of genotypes. On the other hand Bedessa recorded the least environmental index of -1.146 and hence the poorest environment. Derashie (E) had also shown suitability for all genotypes following Arba Minch (D) in mean oil content but these environments were different in interaction. Locations Goffa (A), Kucha (B) and Bedessa (C) had similar mean oil content, interaction, negative environmental index and therefore the least favourable environments for oil content (Fig. 1, Table 2). This result shows that variation in performance of genotypes from location to location.

Additive Main Effects and Multiplicative Interaction (AMMI): Results from AMMI analysis (Table 1) showed that the first principal component axis (IPCA 1) of the interaction captured 52.4% of the interaction sum squares in 23 degree of freedom. Similarly, the second principal component axis (IPCA 2) explained a further 26.8% of the GEI sum of squares. The mean squares for IPCA 1 and IPCA 2 were significant at P = 0.05 and cumulatively contributed 79.2% of the total GEI.

The partitioning of the interaction sum of squares was effective for oil content. The mean squares (MS) of the first IPCA axis for oil content was 3.4 times that of the residual MS and the second IPCA axis was MS 1.9 times

Table 1: The analysis of variance table for AMMI of oil content for 20 sesame genotypes tested over six environments

Source	Df	SS	% SS	MS	F-value	Pr> F
Total	359	2257.61				
Environments	5	497.56	22.00	99.51	3.08	0.0511
Reps within Env.	12	387.39	17.20	32.28		
Genotype	19	745.36	33.00	39.23	15.15	0.0000
Genotype x Env.	95	246.07	10.90	2.59	1.55	0.0044
IPCA 1	23	128.93	52.40	5.61	3.35	0.0000
IPCA 2	21	65.96	26.80	3.14	1.88	0.0133
IPCA 3	19	23.43	9.50	1.23	0.74	0.7779
IPCA 4	17	20.98	8.50	1.23	0.74	0.7618
IPCA 5	15	6.78	2.80	0.45	0.27	0.9973
Residual	228	381.23		1.67		

Grand mean = 50.83 R-squared = 0.83 C.V. = 2.54 %

Table 2: Environmental mean seed yield (kg/ha), IPCA scores and index of sesame genotypes tested at six locations

No	Environment	Environmental Mean	Environmental Index	IPCA 1	IPCA 2
1	Goffa	49.9_d	-0.9494***	-1.10022	-0.92155
2	Kucha	49.9_d	-0.9011***	-0.71102	-0.64734
3	Bedessa	49.7_d	-1.1460***	-0.41095	0.12998
4	Arbaminch	52.9_a	2.1110***	0.44669	1.35912
5	Derashie	51.7_b	0.9006***	-0.30639	0.91862
6	Amarokele	50.8_c	-0.0144	2.08190	-0.83885

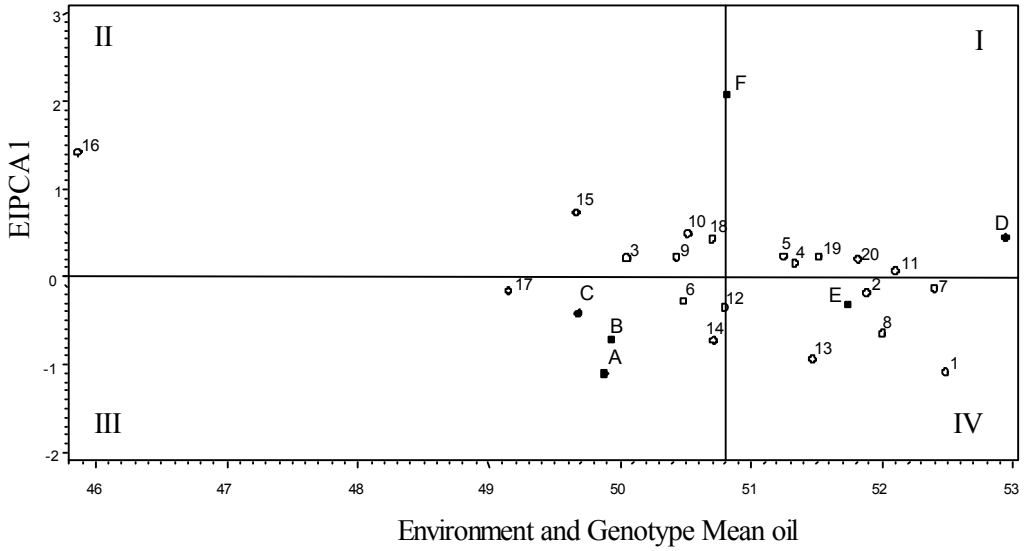

Fig. 1: Biplot of IPCA1 against both genotype and environmental mean

that of the residual MS. The combined MS for the two IPCA axis are 5.2 times that of the residual MS for oil content. Therefore, the post-predictive evaluation using an F-test at P = 0.05 suggested that two principal component axes of the interaction were significant for the model with 44 degree of freedom. The prediction assessment indicated that AMMI with only two interaction principal component axis was the best predictive model [14]. Further interaction principal component axis captured mostly noise and therefore, did not help to predict validation of observations. Thus the interaction of the 20 genotypes with six environments was best predicted by the first two interaction principal component of genotypes and environments.

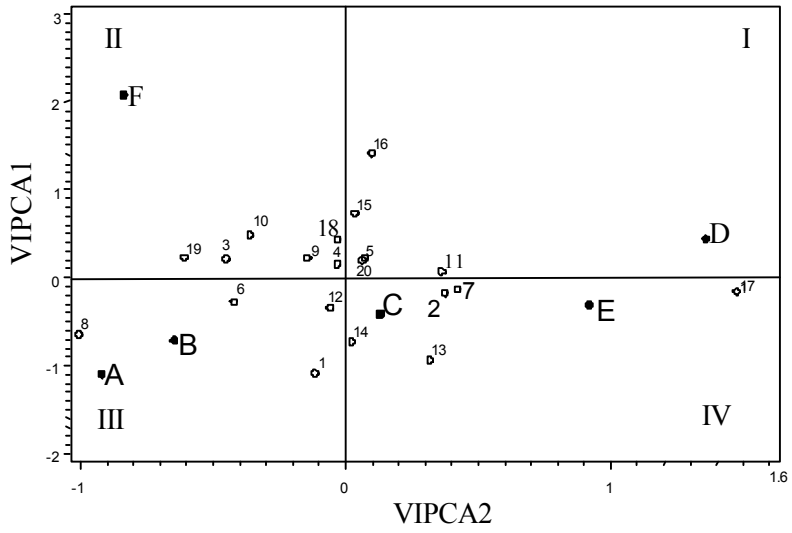

Fig. 2: Biplot of IPCA1 against IPCA2 for both genotypes and environments
Where: A = Goffa; B = Kucha; C = Bedessa; D = Arbaminch; E = Derashie; F = Amarokele; 1 = Temax; 2 = NN-0048; 3 = E; 4 = Mehado-80; 5 = Argane; 6 = NN-0136-Sel-2; 7 = Acc-051-02-Sel-6; 8 = Acc-212-332-4; 9 = Addi; 10 = Tatte; 11 = Acc-051-02-Sel-10; 12 = T-6P-32-3; 13 = Clusu-5; 14 = SPS-SIK-98; 15 = NN-0089 (3); 16 = S; 17 = Abasena; 18 = T-85; 19 = Serkamo; 20 = Kelafo-74.

Table 3: AMMI Stability value (ASV) and ranking with the IPCA 1 and 2 scores of oil content for the 20 genotypes tested at six locations

Entry	Entry Name	Mean oil	VIPC1	VIPC2	ASV	Rank
1	Temax	52.5	-1.06645	-0.11569	2.08765	19
2	NN-0048	51.9	-0.18000	0.35603	0.50053	7
3	E	50.0	0.20149	-0.45958	0.60523	8
4	Mehado-80	51.3	0.16717	-0.00082	0.32674	1
5	Argane	51.3	0.23877	0.07835	0.47322	5
6	NN-0136-se1-2	50.5	-0.28135	-0.40514	0.68305	10
7	Acc-051-02-sel-6	52.4	-0.12952	0.40760	0.47981	6
8	Acc-212-332-4	52.0	-0.67198	-1.00288	1.65253	17
9	Adi	50.4	0.22608	-0.14285	0.46440	4
10	Tatte	50.5	0.48687	-0.37921	1.02439	13
11	Acc-051-02-sel-10	52.1	0.08533	0.34213	0.38062	2
12	T-6P-32-3	50.8	-0.33218	-0.05551	0.65163	9
13	Clusu-5	51.5	-0.93237	0.34384	1.85453	18
14	SPS-SIK-98	50.7	-0.72373	0.02863	1.41486	14
15	NN-0089 (3)	49.7	0.73874	0.02778	1.44418	15
16	S	45.9	1.43560	0.08290	2.80720	20
17	Abasena	49.2	-0.13980	1.48653	1.51143	16
18	T-85	50.7	0.43653	-0.04131	0.85423	12
19	Serkamo	51.5	0.22348	-0.60808	0.74871	11
20	Kelafo-74	51.8	0.21732	0.05728	0.42861	3

As shown in Fig. 1 genotypes and environments showed considerable variation in mean oil content. NN-0048 (2), Acc-051-02-Sel-10 (11), Acc-051-02-Sel-6 (7), Kelafo-74 (20), Acc-212-332-4 (8), Temax (1), Serkamo (19), Mehado-80 (4), Argane (5) and Clusu-5 (13) were specifically adapted to high yielding environments for oil content. Among these genotypes NN-0048 (2), Acc-051-02-Sel-10 (11), Acc-051-02-Sel-6 (7), Serkamo (19), Argane(5), Mehado-80 (4) and Kelafo-74 (20) show little GxE interaction because of the relatively small distance from the coordinates to the abscissa and were stable with high oil content. Moreover, genotypes Abasena (17),

NN-0136-Sel-2 (6), SPS-SIK-98 (14) and T-6P-32-3 (12) were adapted to lower yielding environments and stable with low oil content. Genotype S (16) was unstable and not adapted to any of the environments in oil content. If however IPCA 2 is also taken into consideration (Fig. 2), genotypes Mehado 80 (4), Argane (5), Kelafo 74 (20), Addi (9), T-6P-32-3 (12) and T-85 (18) were the only genotypes shown relatively little GxE interaction in terms of both axis and therefore the most stable.

AMMI Stability Value (ASV): Table 3 indicates the AMMI model for IPCA 1 and IPCA 2 scores of oil content for each genotype and the ASV for 20 genotypes. According to the ASV ranking, the following genotypes were the most stable: Mehado-80 (4), Acc-051-02-Sel-10 (11), Kelafo-74 (20), Addi (9) and Argane (5). Four of these except Acc-051-02-Sel-10 are registered varieties. The most unstable genotypes were: S, Temax, Clusu-5 and Acc-212-332-4. In this case, three of the genotypes are elite lines while S is registered variety.

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