Original Research Article

Assessment of genotype x environment interaction and seed yield stability in sesame (*Sesamum indicum* L.) using AMMI analysis

ABSTRACT

Sesame is considered as an important oilseed crop in terms of nutritional and medicinal properties. Seed yield of any crop is highly labile to environmental factors, which may cause significant reduction in the yield performance. To get substantial stable yield production in crops like sesame, there is urgent need to identify stable genotypes that perform well under different environmental conditions. Thus, the present study has been planned with the aim to assess genotype x environment interaction (GEI) and stability analysis for seed yield per plant using additive main effect and multiplicative interaction (AMMI) model. The experiment involved evaluation of 20 sesame genotypes in randomized complete block design (RCBD) with three replications under three artificially created environments by providing different levels of fertilizers. The environment wise analysis of variance (ANOVA) revealed significant genotypic variance across all the environments. Additionally, AMMI ANOVA revealed significant environment, genotypes and GEI components. GEI component was further classified to interaction principal components (IPC), IPC1 and IPC2, which explain 66.18% and 33.82% of variance due to GEI, respectively. Further, through different stability indices (ASV and GSI) and AMMI biplots, it was revealed that genotype RT-346 and RT-351 are considered as stable genotypes and these can be further recommended to farmer under varying fertility conditions.

Keywords: AMMI, GEI, IPC, Sesame, Stability

1. INTRODUCTION

Sesame (*Sesamum indicum* L.) is an important oilseed crop renowned for its nutritional value and various medicinal applications. It is a diploid, self-pollinating species with a chromosome number 2n=26, belonging to the Pedaliaceae family. This ancient oilseed crop is cultivated across various regions worldwide, including Africa, America, and Asia. Sesame holds the distinction of being the third most vital oilseed crop, following groundnut and rapeseed-mustard. As of the year 2022, India recorded an overall sesame production of 0.26 million tonnes (mt) across a total cultivation area of 1.35 million hectares (mha), achieving a productivity of 2.39 quintals per hectare [1]. The primary sesame-growing regions in India are Uttar Pradesh, Madhya Pradesh, Rajasthan, and Gujarat, collectively contributing to 84% of the total cultivation area and production [1].

Numerous uncontrollable factors, such as variations in soil type, geographical location, fertility gradients, and seasonal fluctuations, can significantly influence the performance of a genotype, particularly in terms of its yield potential. Additionally, climatic elements like temperature, rainfall, day length, and agricultural management practices exert considerable influence on a yield of a genotype [2]. Thus, to address these uncontrollable factors, it is imperative to swiftly pinpoint genotypes that exhibit strong buffering capacity across diverse environmental conditions. Furthermore, seed yield, given its intricate nature as a quantitative trait, is highly susceptible to environmental influences, and irregular soil fertility stands out as a prominent environmental factor that exerts a substantial impact on a seed yield of any genotype.

In comparison to other oilseed crops, sesame has seen relatively fewer organized research efforts directed toward crop improvement programs. Nonetheless, diligent researchers have made noteworthy strides in enhancing the economic characteristics of sesame [3]. Sesame, a short-day plant that is sensitive to photoperiod, is predominantly grown under rainfed conditions, resulting in yield instability [4]. This instability can be attributed to factors such as geographical location, environmental factors, fertility gradients, and their complex interactions. Consequently, the identification of stable sesame varieties across diverse environments emerges as a paramount solution [5].

Several studies have been conducted to ascertain stability in sesame. For instance, Beniwal*et al.*[6] performed stability analysis on 79 sesame genotypes, pinpointing RT-54 and RT-103 as stable genotypes in terms of yield traits. Anuradha and Reddy [7] conducted stability analysis for various yield-related traits, identifying eight stable genotypes out of 71 for seed yield per plant. Suvarna *et al.*[8] studied 51 sesame genotypes in different environments of Karnataka, discerning ST-3 and ST-16 as stable for seed yield. Subsequently, Abate [9] utilized AMMI and Joint regression models to identify stable genotypes for yield and its component traits. Similarly, Chaudhari *et al.*[10] evaluated 50 hybrids and 15 parents in various locations of Gujarat, revealing three crosses that remained stable across environments. Patil *et al.*[11] identified stable genotypes for flowering and maturity traits. Raikwar[12] identified six stable genotypes for grain yield. Furthermore, Beniwal*et al.* [13] conducted stability analysis for oil content and agronomic traits, singling out genotype RT-103 as stable for most of the traits.

Nevertheless, while numerous studies have addressed stability analysis, to the best of our knowledge, very few studies have specifically examined the impact of artificially created environments through varying fertilizer dosages. Farmers in Rajasthan commonly cultivate sesame as a Kharif crop without adhering to recommended fertilizer application rates, and the fertility of Rajasthan's soil is known for its substantial variability. Consequently, the primary objective of this study is to recommend stable sesame varieties to farmers that perform consistently well under different fertilizer regimes. In light of these considerations, the present research was planned, involving evaluation of twenty sesame genotypes across three artificially created environments, to assess genotype-environment interactions and stability for seed yield per plant.

2. MATERIAL AND METHODS

2.1 Plant materials

A collection of twenty sesame genotypes was sourced from Agriculture University, Jodhpur, Rajasthan. These genotypes encompass well established varieties, mostly popular in Rajasthan (Table 1).

Table 1. Details of genotypes used in the present investigation

SN	Genotypes	Code	Releasing Institute	NBPGR Accession number	Year of release
1	RT - 46	G1	ARS, Mandor, Jodhpur, Rajasthan	IC0559407	1990
2	RT - 103	G2	ARS, Mandor, Jodhpur, Rajasthan	IC0559409	1995
3	RT - 125	G3	ARS, Mandor, Jodhpur, Rajasthan	IC0559410	1995
4	RT - 127	G4	ARS, Mandor, Jodhpur, Rajasthan	IC0559411	1999

5	RT - 346	G5	ARS, Mandor, Jodhpur, Rajasthan	IC0559412	2009
6	RT - 351	G6	ARS, Mandor, Jodhpur, Rajasthan	IC0584317	2011
7	RT - 372	G7	ARS, Mandor, Jodhpur, Rajasthan	IC0628264	2019
8	RT - 378	G8	NA	NA	NA
9	RT - 383	G9	NA	NA	NA
10	RT - 384	G10	NA	NA	NA
11	RT - 385	G11	NA	NA	NA
12	RMT - 425	G12	NA	NA	NA
13	RMT - 447	G13	NA	NA	NA
14	RMT - 450	G14	NA	NA	NA
15	RMT - 479	G15	NA	NA	NA
16	RMT - 486	G16	NA	NA	NA
17	RMT - 505	G17	NA	NA	NA
18	PRAGATI	G18	CRS, CSAUA&T, Mauranipur, Jhansi, Uttar Pradesh	NA	2003
19	TKG - 22	G19	ZARS, Tikamgarh, Madhya Pradesh	NA	1995
20	GT - 10	G20	ARS, Junagarh Agriculture University, Amreli, Gujarat	IC0527389	2002

2.2 Experimentation

In *Kharif* 2018, a study was conducted at the Research Farm of S.K.N. College of Agriculture, Jobner, involving the phenotypic assessment of 20 sesame genotypes. These genotypes were systematically evaluated using a randomized complete block design (RCBD), in which each genotype being replicated three times and grown in three artificially created environments. These environments were created by applying varying levels of fertilizers. Environment-I (E-I) received 150% of the recommended dose of fertilizer (RDF), consisting of 60 kg/ha N_2, 30 kg/ha P_2O_5 and K_2O 30 kg/ha. Environment-II (E-II) received 100% of the RDF, including 40 kg/ha N_2, 20 kg/ha P_2O_5 and 20 kg/ha K_2O. Environment-III (E-III) received 50% of the RDF, comprising 20 kg/ha N_2, 10 kg/ha P_2O_5 and 10 kg/ha K_2O. Each plot had plot size of 4.0 x 0.6 m^2 and consisted two rows of each genotype. The spacing between rows was maintained at 30 cm, while the spacing between individual plants within the rows was maintained at 10 cm by thinning.

2.3 Record of observation

In the present study, data was recorded on seed yield per plant, for which five plants were chosen at random and labeled before flowering in each plot. At physiological maturity, these plants were harvested, sun dried and subsequently threshed manually. The seeds obtained from the selected plants after threshing were weighed (in grams) using electronic weighing balance and their mean was recorded as seed yield per plant.

2.4 Data analysis

Environment wise analysis of variance (ANOVA) was carried out as per Panse and Sukhatme[14]. Further, the seed yield per plant data was subjected to stability analysis using Additive Main effect and Multiplicative Interaction (AMMI) model using Genotype x Environment Analysis with R (GEA-R)[15] software. Moreover, GEI was estimated using AMMI model and AMMI Stability Value (ASV) [16] and Genotype Selection Index (GSI) [17]. Genotype(s) having least ASV and GSI are considered as stable genotypes.

3. RESULTS AND DISCUSSION

3.1 Analysis of variance

In the current study, individual environment wise analysis of variance (ANOVA) revealed highly significant (at 1% level of significance) variance for seed yield per plant (SYPP) in all environments (Table 2), suggesting existence of great genetic variability for seed yield under different environmental conditions. The presence of substantial genetic variation is considered as initial step of any breeding programme[18,19]. Moreover, similar to present investigation, significant variability among diverse germplasm set of sesame for seed yield under different environments have also been reported [8,12].

Table 2. Environment-wise analysis of variance (ANOVA) showing mean squares for seed yield per plant

Source	DF	E-I (150% RDF)	E-II (100% RDF)	E-III (50% RDF)
Replication	2	028	101	013
Genotypes	19	437**	348**	132**
Error	38	074	041	028
CV	-	1258	1286	1470

'*', '**' significant at 5% and 1% level of significance, respectively

Table 3. AMMI analysis of variance (ANOVA) for seed yield per plant

Source	DF	SS	MSS	Percent of total variance	Cumulative percent variance
Environment	2	307	1535**	638	638
Genotype	19	10064	530**	2091	8471
Genotype x Environment interaction	38	7358	194**	1529	100
IPC1	20	4869	243**	6618	6618
IPC2	18	2489	138**	3382	100
Residuals	120	5729	048		

'*', '**' significant at 5% and 1% level of significance, respectively

Comment [NMH1]: Missing decimal place for MSS, % total variance and Cumulative % variance

3.2 Genotype x environment and stability analysis using AMMI model

The AMMI analysis is regarded as one of the most effective approaches for evaluating genotype stability and GEI [17,20]. In the current study, after individual ANOVA, genotypes were subjected to stability analysis using AMMI model. In AMMI model, pooled analysis of variance revealed highly significance of environment, genotypes and genotype by environment components (Table 3). Significance of environment indicated that artificially created environments effectively provided the varying nutrient levels to the genotypes. Significance of genotypes revealed substantial genetic diversity among genotypes for seed yield, while significant genotype x environment interaction (GEI) suggested that different genotypes exhibit varying responses when exposed to different environmental conditions. Among these components, environment contributed 63.8%, genotype contributed 20.91%, while genotype x interaction contributed 15.29% to total variance. Moreover, principal component analysis (PCA) was carried out, in which interaction principal component 1 (IPC1) explained 66.18%, while contribution of IPC2 was 33.82% to variance due to GEI, which suggested that these components significantly explain the total variance caused by GEI (Table 3). Similarly, Abate [9] and Movahedi et al.[17] reported highly significant genotype, environment and GEI component for seed yield per plant using AMMI model. Likewise, employing Eberhart and Russel model of stability for seed yield, alike results were obtained by Patil et al.[11] and Raikwar [12] under pooled ANOVA.

Table 4. Mean seed yield and principal components of different sesame genotypes and environments for seed yield per plant

Comment [NMH2]: Decimal place are also missing in this table

SN	Genotypes/Environments	IPC1	IPC2	SYPP	RYi	ASV	RASVi	GSI
1	RT – 46	-033	-047	514	12	08	11	23
2	RT – 103	058	-053	522	10	125	18	28
3	RT – 125	037	-009	407	19	073	10	29
4	RT – 127	005	059	478	14	06	6	20
5	RT – 346	006	-005	542	7	013	1	8
6	RT – 351	-009	023	527	9	029	2	11
7	RT – 372	-045	-043	604	5	098	14	19
8	RT – 378	034	-01	612	3	067	8	11
9	RT – 383	-03	03	519	11	066	7	18
10	RT – 384	-068	029	614	2	136	19	21
11	RT – 385	-055	-031	598	6	112	16	22
12	RMT – 425	1	037	482	13	199	20	33
13	RMT – 447	-048	024	627	1	097	13	14
14	RMT – 450	-059	-038	607	4	122	17	21
15	RMT – 479	043	-022	418	17	087	12	29
16	RMT – 486	-018	059	53	8	069	9	17
17	RMT – 505	015	021	417	18	036	3	21
18	PRAGATI	008	055	461	15	057	5	20
19	TKG – 22	052	-036	438	16	108	15	31
20	GT – 10	009	-043	396	20	046	4	24
21	E-I (150% RDF)	-062	-067	684	1	139	2	3
22	E-II (100% RDF)	-038	079	498	2	108	1	3
23	E-III (50% RDF)	1	-012	366	3	196	3	6

The AMMI biplot 1 between seed yield per plant and IPC1 revealed that genotypes G5 (RT - 346), G6 (RT - 351) and G16 (RMT - 486) have shown mean seed yield greater than population mean and IPC1 near to zero (Fig 1; Table 4). Likewise, AMMI biplot 2 between IPC1 and IPC2 revealed the extant of GEI exerted by individual genotypes. In the present investigation, it was found that genotypes G5 (RT - 346), G6 (RT - 351) and G17 (RMT - 505) were close to origin (Fig 2), showing least GEI (close to zero; Table 4). From these results, genotypes G5 (RT - 346) and G6 (RT - 351) were considered as stable genotypes for seed yield per plant. Moreover, these results were also confirmed through ASV and GSI values; in which, the least ASV and GSI obtained for G5 (RT - 346), 0.13 and 8, followed by for G6 (RT - 351) *i.e.*, 0.29 and 11, respectively (Table 4). Similar to present investigation, Patel et al.[21] reported these genotypes stable for various agro-morphological traits using Eberhart and Russel model. Genotypes with the highest stability might not always exhibit the best yield performance [22]. Therefore, we have considered both yield and stability indices (ASV and GSI) for the classification of stable genotypes. In addition, several genotypes were identified suitable to specific environment. For instance, under 150% RDF (E-I) fertilizer levels, genotypes G7 (RT - 372), G10 (RT - 384), G11 (RT - 385), G13 (RMT - 447) and G14 (RMT - 450) were found suitable. Genotypes G1 (RT - 46) and G9 (RT - 383) were suitable for 100% RDF (E-II), while under 50% RDF (E-III) genotypes G3 (RT - 125), G15 (RMT - 479) and G19 (TKG - 22) were found suitable. Based on the ASV and GSI values, unstable environment ranked as E-III > E-I > E-II (Table 4). Therefore, evaluation of sesame germplasm at environment II (100% RDF) would be rewarding for different breeding programmes.

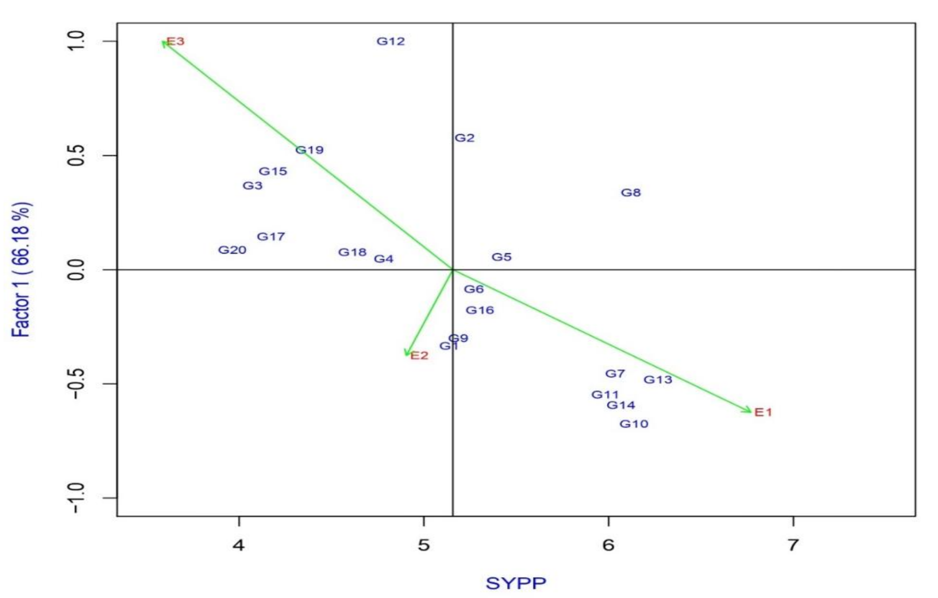

Fig 1. AMMI biplot I between IPCA1 (Factor 1) and seed yield per plant (SYPP)

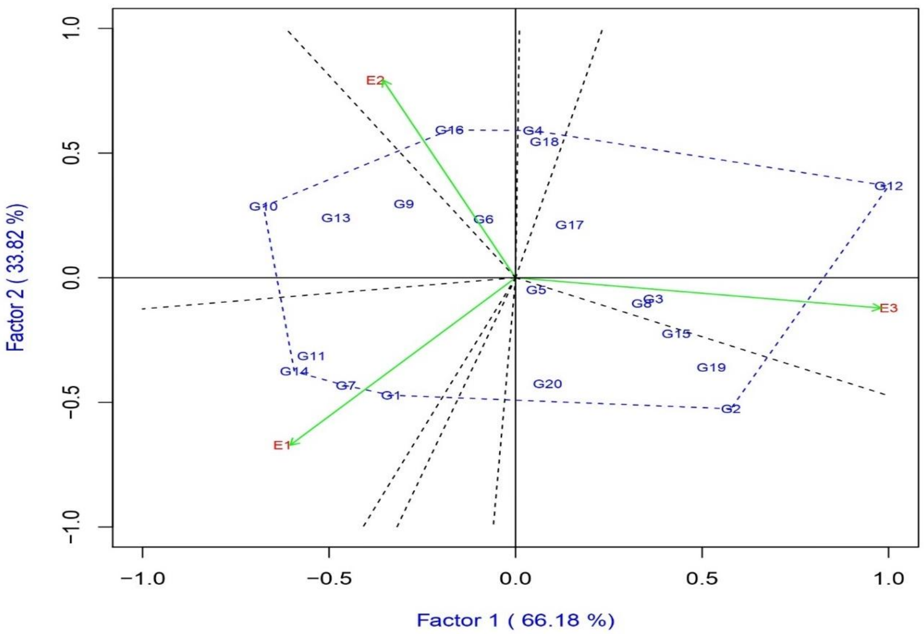

Fig 2. AMMI biplot II between IPC1 (Factor 1) and IPC2 (Factor 2) showing degree of genotype x environment interaction among genotypes for seed yield per plant

4. CONCLUSION

In the context of sesame cultivation, where environmental factors can significantly impact seed yield, this study sought to identify stable genotypes that perform consistently across diverse conditions especially under varying fertility conditions. Analysis of variance revealed significant genotypic variance across the environments and identified key components of genotype-environment interaction. Notably, two interaction principal components sufficiently explained the variance due to GEI. Moreover, using stability indices and AMMI biplots, the study identified genotype RT-346 and RT-351 as stable performers, making them valuable recommendations for farmers to obtain stable sesame production under varying fertility conditions.

REFERENCES

1.Anonymous Sesame Kharif Crop Survey *IOPEPC.* 2022;*https://iopepcorg/misc/2021_22/Final%20_Report_Sesame_2022pdf*

2. Valiki SR, Ghanbari S, Golmohammadzadeh S, Kiasari KR. Effect of different plant density on growth and yield of three cultivars of sesame (*Sesamum indicum* L.). Biol. Forum Int. J. 2015;7:1524-28.

3. Ahmed AS, Das S, Saharia DD, Sarma MK, Nath MP, Talukdar JC. Assessment of Genetic variability and Character Association for Morpho-physiological Attributes and Seed Yield in Sesame. Biol. Forum Int. J. 2022;14(2):425-30.

4. Velu G, Shunmugavalli N. Genotype x environment interaction in sesame (*Sesamum indicum* L). Sesame and Safflower Newsletter 2005;20: 1-5.

5. Verma AK, Mahto JL. Stability for yield and yield attributing characters in sesame under rainfed conditions. J. Oilseeds Res. 1994;11(2):170-3.

6. Beniwal BR, Sastry EV, Solanki ZS. Stability of hybrids and their parents in sesame. J. Oilseeds Res. 2003;20(1):61-2.

7. Anuradha T, Reddy GL. Phenotypic stability of yield and yield attributes in Sesame (*Sesamum indicum* L.). J. Oilseeds Res. 2005;22:25-8.

8. Suvarna, Manjunath MH, Nehru SD, Manjunath A. Stability analysis of sesame varieties during early kharif. Indian J. Agric. Res.. 2011;45(3):244-8.

9. Abate M. Genotype x Environment analysis for seed yield and its components in sesame (*Sesamum indicum* L.) evaluated across diverse agro-ecologies of the awash valleys in Ethiopia. J. Adv. Stud. Agric. Biol. Environ. Sci. 2015;2(4):1-4.

10. Chaudhari GB, Naik MR, Anarase SA, Ban YG. Genotype x Environment interaction for yield and yield components in sesame (*Sesamum indicum* L.). Electron. J. Plant Breed. 2015;6(1):111-7.

11. Patil VS, Wadikar PB, Chavan SK, Patil HV, Sudrik BP. Stability analysis of yield and yield components in sesame (*Sesamum indicum* L.). J. Soil. Crop. 2015;25(1):92-9.

12. Raikwar RS. Stability for grain yield and its contributing traits in sesame (*Sesamum indicum* L.). Electron. J. Plant Breed. 2016;7(4):1033-9.

13. Beniwal BR, Kumar K, Sastry EV, Solanki ZS. Phenotypic stability of hybrids and parents in sesame (*Sesamum indicum* L). Int. J. Agric. Sci. 2018;10(10):6131-4.

14. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. Statistical methods for agricultural workers.1985.

15. Pacheco A, Vargas M, Alvarado G, Rodríguez F, Crossa J, Burgueño J. GEA-R (genotype× environment analysis with R for Windows). 2015;version 4.1. hdl 11529(10203):V16.

16. Purchase JL. Parametric analysis to describe genotype x environment interaction and yield stability in winter wheat (Doctoral dissertation, University of the Free State). 1997.

17. Movahedi H, Mostafavi K, Shams M, Golparvar AR. AMMI analysis of genotype× environment interaction on grain yield of sesame (*Sesamum indicum* L.) genotypes in Iran. Biotechnol. Biotechnol. Equip. 2020;34(1):1013-8.https://doi.org/10.1080/13102818.2020.1816216

18. Ola MP, Patel MK, Kumar A, Ram M, Pant NC. Genetic variability for seed yield and its component characters in taramira (*Eruca sativa* Mill.). Pharma. Innov. J. 2023;12(3): 3102-5.

19. Patel MK, Tiwari D, Sharma V, Ola MP, Saroj R, Kumar S, Harisha R, Singh D. Deciphering the Genetic Variability for Seed Yield Components in Sesame (*Sesamum indicum* L.). Int. J. Environ. Clim. 2023a;13(10):1118-26.DOI: 10.9734/ijecc/2023/v13i102761

20. Kindeya YB, Mekbib F, Alle EA. AMMI and GGE bi-plot analysis for seed yield and oil content of sesame (*Sesamum indicum* L.) genotypes in Tigray, Northern Ethiopia. J. Agric. Crops. 2020;6(4):58-67.https://doi.org/10.32861/jac.64.58.67

21. Patel MK, Singh D, Sharma V, Tiwari D, Ola MP, Kumar S et al. Stability Analysis in Sesame (*Sesamum indicum* L.) under different Doses of Fertilizers. Biol. Forum Int. J. 2023b; 15(2):365-70.

22. Mohammadi R, Amri A. Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments. Euphytica. 2008;159:419-32.https://doi.org/10.1007/s10681-007-9600-6