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Research Article

Stability for grain yield and its contributing traits in sesame (*Sesamum indicum* L.)

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Abstract
In this study, a set of seventeen genotypes of sesame (*Sesamum indicum* L.) were evaluated over three years from 2012-13 to 2014-15 to assess the stability of these genotypes for yield and its contributing traits over years and environments. Analysis of variance for stability with respect to 8 traits revealed highly significant variation due to environment for all traits which indicated differential effect of different seasons. The variance for genotypic effect was highly significant for all the traits observed, indicating thereby differential response of all the genotypes. Genotype × environment (linear) interaction was significant for seven traits namely; days to 50% flowering, plant height (cm), days to maturity, branches/plant, capsule /plant, capsule length (cm) and seed yield (g) indicating substantial amount of predictable G×E interaction. Environmental indices indicated that performance of genotypes over three environments varied apparently and environment E1 showed highest favourable impact on grain yield. The varieties TKG-478, TKG-501, TKG-503, TKG-506, TKG-306 and TKG-512 with superior mean performance, regression coefficient near to one and non-significant S2di values showed average stability for grain yield. Based on stability parameters these varieties can be considered as stable performers and may be utilized for hybridization programmes to improve sesame yields. This indicates that these genotypes performed better across environments. The stability of different yield contributing traits varied in compensating manner in different genotypes imparted grain yield stability.

Key words: Sesame, ***Sesamum indicum* L.** G×E interaction, Regression coefficient, Stability analysis, yield

Introduction

Sesame belonging to Pedaliaceae family is one of the most important and ancient oilseed crop, better known as “Queen of oil seed crops” by virtue of its edible quality oil, believed to be a native to Africa. It was cultivated and domesticated in the Indian subcontinent during Harappa and Anatolian eras (Bedigian and Harian, 1986 and Bedigian. 2003) but now it is grown in tropical and subtropical areas in many part of the world. Sesame seed is a rich source of oil (50%), protein (25%), and minerals, contains about 47% oleic acid and 39% linolenic acid (Brar and Ahuja, 1979). Although sesame is widely used for its distinctive quality and due to the presence of natural antioxidants such as sesamin and sesamol, sesame growing area is shrinking due to several reasons. Ironically, the demand for sesame seed is increasing year after year. Globally it is cultivated in an area about of 6.65 million ha with the production of 4.10 ton.In India, it occupies an area of 1.67 million ha with production of 0.68 million ton. The productivity of sesame is very low (405 kg/ha) in India compared to world average (617 kg/ha) (FAOSTAT. 2014). Sesame is a short day plant and sensitive to photoperiod, temperature and moisture stress. The yield is not stable and varies widely (Vela and Shunmugavalli. 2005), which is influenced by many morphological and physiological characters. Allard and Bradshaw (Allard and Bradshaw.1964) defined stability as adaptation of varieties to unpredictable and transient environmental conditions. This technique has been used to select stable genotypes unaffected by environmental changes. Since, productivity is the function of genotypic adaptation and stability is the measure of genotype × environment interaction, an understanding of environmental and genotypic causes leading to these interactions are highly important at all the stages of plant breeding including plant architecture, parental selection, selection based on traits and selection based on yield (Jackson *et al* 1996 and Van and Hunt .1998). The stability of a genotype over diverse environments is usually tested by the degree of its interaction with different environments under which it is grown (Asif *et al*. 2003). Therefore, an attempt was made to study the stability parameters of yield and its contributing traits of different bread sesame genotypes evaluated over three seasons.

Materials and methods

The experimental material comprised of seventeen released/advanced genotypes of *Sesame indicum* L. *viz* TKG-466, TKG-471, TKG-477, TKG-478, TKG-501, TKG-503, TKG-506, TKG-509, TKG-511, TKG-512, TKG-516, TKG-518, TKG-520, TKG-22, TKG-308, TKG-306 and JTS-8 were grown in randomized block design with three replication over three environments (E1, E2 and E3) during rainy season (kharif) 2012-13, 2013-14 and 2014-15 at AICRP sesame centre, Tikamgarh. Each plot consisted of 6 rows each 5 m long with a row to row spacing of 30 cm. The data was recorded for 8 characters, *viz* days to 50% flowering, plant height (cm), days to maturity, branches/ plant, capsules/plant, capsule length (cm), 1000 seed weight (cm) and Seed yield (g). Except days to 50% flowering and days to maturity, where data was recorded on plot basis, the data for rest of the morphological traits were recorded on randomly selected ten competitive plants in the middle 3 rows of each plot in all three replications. Seed yield was recorded on plot basis and converted to kg/ha. The recommended package of practices was followed to raise a good crop. The mean values of 10 samples, except for characters recorded on whole plot basis, were used for detailed statistical analysis. The data were subjected to analysis of variance as per the procedure suggested by Sukhatme and Amble (Sukhatme and Amble.1989). Genotype-environment interactions were found to be significant in respect of all the characters studied; and hence the data were subjected to stability analysis to assess the stability of different genotypes (Eberhart and Russell.1966). A genotype with regression coefficient of unity (bi =1) and the deviation not significantly different from zero ($\check{S}^2$di = 0) was taken to be a stable genotype with unity response. The data obtained were analyzed for stability parameters as per method proposed by Eberhart and Russell (1966).

Results and Discussion

Each environment analysis of variance on 8 characters was carried out separately as well as pooled over the years. Analysis of variance revealed significant differences amongst genotypes in each of the three environments as the estimates for variance due to genotype were highly significant for all the traits, indicating the presence of considerable amount of genetic variability in the genotypes. The analysis of variance of stability (Table 1) revealed that the variance due to environment was significant for all the traits which indicate the distinct and differential effect of different environments over three seasons. Similarly, the variance for genotypic effect was also highly significant for all the traits indicating thereby differential response of all the genotypes. The variance due to genotype × environment (G×E) have shown highly significant interaction for days to 50% flowering, plant height (cm),days to maturity, branches/plant, capsule /plant and seed yield (g) indicating differential response of the varieties to different environments. The significant G×E interaction has been reported for various traits by Laurentin *et al. (*2007) and Kumar *et al.* (2008) which confirm the findings of present investigation. Mean squares due to environment + (genotype × environment) interactions were highly significant for days to 50% flowering, plant height (cm), days to maturity, branches/plant, capsule /plant, capsule length (cm) and seed yield (g) which showed that genotypes interacted considerably with environmental conditions over different seasons. However, this interaction was non-significant for the 1000 seed weight (g) indicating thereby that this character is stable over environments and seasons.

Genotype × environment (linear) interaction was significant for all the observed traits except 1000 seed weight indicating substantial amount of predictable G×E interaction.. The higher magnitude of linear components for seed yield as compared to non-linear was also reported by Raghuwanshi *et al*.(2003), Anuradha and Reddy. (2005) and Kumaresan and Nadarajan. (2005) but the Suvarna *et al.* (2011) observed that the magnitude of the pooled deviations was more than the G × E (linear) variance for seed yield. All the observed characters expressed non-significant pooled deviation which indicated all the portion of G×E interaction was predictable.

Eberhart and Russell.(1966) emphasized the need of considering both linear regression coefficient (bi) and nonlinear, i.e. deviation from regression (S2di) components of G×E interactions in measuring the stability of genotypes. In the present investigation three measures, *viz.* higher mean performance, regression coefficient (bi = 1) and deviation from regression (S2di = 0) were used to identify superior and stable genotypes.

The estimates of stability parameters for the eight characters (Table 2) revealed that the varieties TKG-478, TKG-501, TKG-503, TKG-506, TKG-306, and TKG-512 possessed minimum deviation from regression (S2di) indicating their high predictability in terms of grain yield. This indicates that these genotypes performed better across environments. Genotype TKG-478 was found to be stable which possessed regression coefficient (bi) value very close to unity with non-significant S2di values, however, the mean yield of these varieties was comparatively high. . The varieties TKG-478, TKG-501, TKG-503, TKG-506, TKG-306 and TKG-512 with superior mean performance, regression coefficient near to one and non-significant S2di values showed average stability for grain yield. Based on mean performance, one variety TKG-308 having higher mean yield with regression coefficient (bi) less than one and non-significant mean square deviation (S2di) signifies their stability for unfavorable conditions and showing above average stability.

Two genotypes TKG-516 and TKG-518 had regression coefficient greater than unity and non-significant deviation from regression mean thereby, these were suitable to favorable conditions, indicating average stability. Similarly the stable genotypes were also identified in sesame for seed yield by Manivannan and Ganesan. (2001), Iwo *et al*. (2002), Chaudhari *et al*. (2005), Kumar *et at.*(2006), Kumar *et al.*(2008) and Kumaresan and Nadarajan (2010).

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Hence, it has been observed (Table 2) that the varieties TKG-478 and TKG-501 showed stable performance for all the eight characters with non-significant regression coefficient and S2di values although, its average grain yield (712.800 kg & 668.700 kg per ha.) was slightly higher than the overall mean (610.882 g). Genotype TKG-478 was the highest yielding (712.800 kg) followed by TKG-512 (683.000 kg), TKG-501 (668.700 kg), TKG-506 (664.100 kg), TKG-503 (663.100 kg), TKG-306 (648.700 kg) and TKKG-518 (647.900kg) (Iwo *et al*.2002 and Chaudhari *et al*. 2005).

The high grain yield in TKG-478 was resulted from superior mean values of days to maturity, branches/plant, capsules/plant, capsule length (cm) and 1000 seed weight (g). Similarly, the high grain yield of genotype TKG512 was accompanied by days to maturity, branches/plant, capsules/plant and seed yield (g). Likewise, in TKG501 it was resulted from plant height (cm), branches/plant, capsule/plant, capsule length (cm), 1000seed weight (g) and seed weight (kg). TKG506, TKG503, TKG306 and TKG518 from days to 50% flowering, plant height (cm), days to maturity, branches / plant, capsule length (cm) and seed weight (g) on the basis of superior mean population of characteristics.

According to stability criteria's of genotype TKG478, TKG501, TKG506, TKG503, TKG306 and TKG518 were found to be superior in yield, which was compensated by stability of different contributing traits and revealed wider adaptability over the environments. (Kumar *et al*.2010 and Kumar 2013).

Variety TKG509, was found to be highly stable for days to 50% flowering, , while remaining 16 genotypes showed linear predictability due to non-significant deviation from regression (S2di).. For plant height (cm), genotype TKG-520 revealed average stability and all the varieties showed linear predictability with non-significant S2di values. For days to maturity TKG-478 and TKG-501 were found to be highly stable exhibited regression coefficient near to one with non-significant deviation from regression and higher mean performance. Based on these three parameters, the genotypes, TKG-466,TKG-471, TKG-477,TKG-501, TKG-503,TKG-506,TKG-511 and JTS-8were found to be suitable for favorable environment and genotypes, Genotype TKG-501 and TKG-306 were found to be highly stable for branches/plant, Genotype for capsules/plant, TKG-478 showed average stability with desirable mean, regression coefficient near to one and non-significant S2di values With respect to capsule length (cm), all the genotypes exhibited non-significant regression coefficient except TKG-466 and variety TKG-308 and TKG-306 showed high stability due to regression coefficient near to unity with non-significant S2di values.

For 1000 grain weight, varieties TKG-477 and TKG-506 having regression coefficient near to one with non-significant deviation from regression and higher mean values showed their high stability. For seed yield (g), the genotypes TKG-478, TKG-501, TKG-503, TKG-306 and TKG-512 showed average stability having unit linear regression coefficient and non-significant S2di values with higher mean performance. The genotypes TKG-471, TKG-477, TKG-516, TKG-518 and TKG-520 were found to be stable under favorable environment.

The comparison of environmental indices (Table 3) indicated that the performance of genotypes over three environments with respect to the grain yield varied apparently and indicated that environment E1 (season 2012- 13) showed highest favourable impact on seed yield (739.667g) followed by E2 (season 2013-14) with 709.333 kg. Environment E3 was found to be unfavourable in terms of grain yield, where most of the major yield contributing traits, *viz.* capsule length , plant height, days to 50% flowering ,branches/plant were in lower side as indicated by negative values of environmental indices.

On the basis of mean performance, regression coefficient and deviation from regression values, the genotypes identified with stability of performance under favourable and unfavourable environments in terms of seed yield and its component traits are given in Table 4. These stable genotypes may be used to develop a new strain with combination of stable characters and/or the varieties exhibited stable yield performance could be exploited for general cultivation. In nut shell, varietiesTKG-478,TKG-501, TKG-503,TKG-506,TKG-306 and TKG-512 have shown higher mean values, desirable regression coefficient and deviation from the regression coefficient for yield and contributing traits, and were good in yield also may be exploited for yield enhancement of sesame under varying environments.

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Table 1. Analysis of Variance for yield and its contributing traits in sesame in different environments (pooled over three consecutive)

Character / Source	Genotype	Environment	Genotype x Environment	Environment + (Genotype x Env.)	Environment (Linear)	Genotype x Environment (Linear)	Pooled deviation	Pooled error
d. f.	16	2	32	34	1	16	17	96
Days to 50% Flowering	20.07***	64.320***	3.156***	6.754***	128.640***	6.029***	0.26	0.16
Plant Height (cm)	107.29***	16.506*	10.842**	11.175**	33.011***	18.518***	2.97	20.33
Days to Maturity	6.13***	23.597***	0.694*	2.041***	47.194**	1.105**	0.26	1.01
Branches/ Plant	0.28***	0.089**	0.045**	0.047**	0.178**	0.074***	0.01	0.06
Capsules/ Plant	150.10***	121.937***	13.485**	19.865***	243.874***	23.402***	3.35	13.17
Capsule Length (cm)	0.02***	0.069**	0.014	0.017*	0.139***	0.021*	0.01	0.01
1000 Seed Weight (g)	0.03*	0.002**	0.009	0.008	0.004	0.008	0.01	0.01
Seed Yield (g)	15228.63***	362.256**	1323.107*	1266.586*	724.511**	2106.072**	508.37	677.16

*Significant at P = 0.05; **Significant at P = 0.01

Table 2. Mean performance and stability parameters of genotypes for seed yield and yield components over environments

Genotype	Days to 50% Flowering			Plant Height (cm)			Days to Maturity			Branches/ Plant		
	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di
TKG-466	42.444	-0.687*	-0.224	102.300	-0.608	-18.435	79.222	1.075	-0.590	2.678	-0.584	-0.063
TKG-471	40.444	0.261*	-0.282	99.800	5.219*	-19.616	77.667	1.575*	-1.231	2.767	1.416	-0.048
TKG-477	42.778	1.011	0.272	108.000	4.341	-5.139	76.556	1.424	-1.230	2.789	3.554	-0.068
TKG-478	41.444	0.902	0.903	102.800	1.026	3.649	79.778	0.992	1.224	2.678	1.093	0.027
TKG-501	39.778	1.009	0.412	107.000	0.926	0.688	78.778	1.052	-1.182	2.567	0.961	0.050
TKG-503	39.222	1.427*	-0.285	102.200	1.549	-17.793	79.000	1.075*	-1.231	2.411	0.782	-0.066
TKG-506	41.778	0.929	0.395	106.200	4.333	-17.423	82.222	1.143*	-1.233	2.589	1.040	-0.062
TKG-509	38.444	1.001	0.339	95.000	-0.671	-6.012	78.333	0.977	0.783	2.156	5.900	-0.024
TKG-511	38.000	1.235	-0.274	118.700	-4.638	-17.352	78.444	1.621	-0.894	3.278	-1.951	-0.060
TKG-512	35.222	0.069*	-0.248	103.600	0.960	0.568	77.000	0.000	-1.233	2.178	0.614	-0.059
TKG-516	36.667	0.207	0.056	109.200	-1.727	-18.876	78.556	0.235	-0.867	2.222	-2.317*	-0.069
TKG-518	35.667	0.207	0.056	99.100	0.991	-19.087	78.778	0.363	-0.637	2.911	-3.504	-0.042
TKG-520	36.889	0.276	0.322	94.600	1.015	-19.703	79.778	0.838	-1.072	2.500	3.138	-0.064
TKG-22	35.556	0.974	-0.283	97.500	5.860	-15.768	81.667	0.560	-1.216	2.767	0.050	-0.054
TKG-308	36.444	0.510	0.928*	101.400	-3.368	-17.614	80.000	0.174	-1.095	2.789	-1.624	-0.043
TKG-306	36.556	2.332*	-0.255	96.900	2.376	-18.029	78.778	0.886	-1.116	2.556	1.019	-0.068
JTS-8	36.000	1.975*	-0.257	100.200	-1.642	-16.787	79.333	1.010	-1.153	2.189	1.614	-0.069
Pop. Mean	**38.431**			**102.609**			**79.052**			**2.566**		
SE (mean)	**0.365**			**1.200**			**0.366**			**0.085**		
SE (bi)	**0.188**			**1.200**			**0.310**			**1.169**		

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Table 2. ***Contd.***

Genotype	Capsules/ Plant			Capsule Length (cm)			1000 Seed Weight (g)			Seed Yield (g)		
	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di	X	bi	S^2di
TKG-466	41.78	1.90	-5.15	2.22	5.22*	-0.01	3.21	8.50	0.07**	562.30	0.51	-227.70
TKG-471	30.22	2.73	-12.83	2.43	3.12	-0.01	3.44	3.40	0.01	596.80	18.58	1032.64
TKG-477	38.67	1.55	-12.87	2.42	1.58	-0.01	3.34	-4.25	-0.01	486.80	12.47	1814.76
TKG-478	49.78	1.06	12.62	2.50	0.99	0.90	3.24	1.08	0.91	712.80	1.03	194.98
TKG-501	50.44	1.01	13.15	2.56	1.06	1.01	3.30	1.05	0.02	668.70	1.09	231.66
TKG-503	32.22	2.69	-8.33	2.62	-1.61	-0.01	3.18	-1.70	0.01	663.10	1.08	310.87
TKG-506	37.67	1.54	-11.19	2.52	0.40	0.01**	3.34	0.98*	0.01	664.10	1.09	403.00
TKG-509	32.89	-0.03	-0.75	2.52	0.02	-0.01	3.33	1.09	0.89	439.90	0.23	520.20
TKG-511	52.56	-0.99	-12.79	2.58	-0.46	0.05	3.16	1.70**	-0.01	569.20	-4.69	-312.76
TKG-512	37.56	-0.30	-12.26	2.47	1.04	0.01	3.34	13.60**	-0.01	683.00	0.92	619.45
TKG-516	32.56	0.26	-11.49	2.56	1.02	-0.01	3.27	0.00**	-0.01	641.10	2.91	-626.50
TKG-518	37.56	0.34	-6.79	2.43	0.29	-0.01	3.19	-8.50**	-0.01	647.90	2.05	-641.14
TKG-520	42.56	-0.74	-12.84	2.46	0.54	-0.01	3.32	-8.50**	-0.01	605.30	5.12	-629.43
TKG-22	36.33	-0.02	-10.59	2.40	1.06	-0.01	3.35	-3.40**	-0.01	604.80	-8.83	1303.93
TKG-308	46.89	0.70	-10.45	2.43	1.04	-0.01	3.46	1.70**	-0.01	637.30	-9.59	-269.61
TKG-306	49.44	0.73	-11.12	2.42	0.84	-0.01	3.21	3.40**	-0.01	648.70	1.44	481.21
JTS-8	39.00	3.46	-2.97	2.45	2.47	0.01	3.40	0.00**	-0.01	553.200	1.57	-545.29
Pop. Mean	**40.48**			**2.46**			**3.29**			**610.88**		
SE (mean)	**1.29**			**0.06**			**0.07**			**15.90**		
SE (bi)	**0.48**			**0.90**			**5.95**			**3.50**		

Table 3. Effect of environment in the expression of grain yield and yield-contributing traits

Character	Environmental Indices		
	E1	**E2**	**E3**
Days to 50% Flowering	2.176	-0.608	-1.569
Plant Height (cm)	1.046	-0.135	-0.911
Days to Maturity	1.261	-0.190	-1.072
Branches/ Plant	0.065	0.012	-0.078
Capsules/ Plant	2.621	0.111	-2.732
Capsule Length (cm)	0.067	-0.006	-0.061
1000 Seed Weight (g)	-0.013	0.007	0.007
Seed Yield (g)	3.627	1.569	-5.196

Table 4: List of genotypes along with stability performance over different environments for grain yield and yield-contributing traits

Character	Days to 50% Flowering	Plant Height (cm)	Days to Maturity	Branches/ Plant	Capsules/ Plant	Capsule Length (cm)	1000 Seed Weight (g)	Seed Yield (g)
Genotypes suitable for all environments	TKG-509, TKG-22,	TKG-520	TKG-478 TKG-509	TKG-501 TKG-506	TKG-478	TKG-308 TKG-306	TKG-477 TKG-506	TKG-478 TKG-501 TKG-503 TKG-506 TKG-306 TKG-512
Genotypes suitable for favorable environment	TKG-477 TKG-478 TKG-501 TKG-506 TKG-511 JTS-8	TKG-471 TKG-477 TKG-478 TKG-501 TKG-503 TKG-506 TKG-512 TKG-520 TKG-22 TKG-306	TKG-466 TKG-471 TKG-477 TKG-501 TKG-503 TKG-506 TKG-511 JTS-8	TKG-471 TKG-477 TKG-478 TKG-509 TKG-520 TKG-306	TKG-466 TKG-471 TKG-477 TKG-478 TKG-501 TKG-503 TKG-506	TKG-466 TKG-471 TKG-477 TKG-501 TKG-512 TKG-22 TKG-308 JTS-8	TKG-471 TKG-501 TKG-506 TKG-509 TKG-511 TKG-512 TKG-308 TKG-306	TKG-471 TKG-477 TKG-506 TKG-516 TKG-518 TKG-520
Genotypes suitable for unfavorable environment	TKG-466 TKG-471 TKG-512 TKG-516 TKG-518 TKG-520	TKG-466 TKG-509	TKG-512 TKG-516 TKG-518 TKG-520 TKG-22 TKG-308 TKG-306	TKG-466 TKG-503 TKG-511 TKG-512 TKG-516 TKG-518 TKG-22 TKG-308	TKG-509 TKG-511 TKG-512 TKG-516 TKG-518 TKG-520 TKG-22 TKG-308 TKG-306	TKG-478 TKG-503 TKG-509 TKG-511 TKG-516 TKG-518 TKG-520	TKG-477 TKG-478 TKG-503 TKG-516 TKG-518 TKG-520 TKG-22 JTS-8	TKG-466 TKG-509 TKG-511 JTS-8