STABILITY ANALYSIS FOR ECONOMIC TRAITS IN SESAME (*SESAMUM INDICUM* L.)

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ABSTRACT:- This study examined 10 elite genotypes of sesame across three locations for the estimation of genotypes environment(GE) interaction and to identify stable genotype(s) using stability parameters, and to determine inter-parameters correlation. Two locations (NARC and D.I. Khan) were suitable for high productivity. PR-19-9-S produced maximum (341 kgha^{-1}) at NARC and V-90005 produced 344 kgha^{-1} and PARS-I produced 304 kgha^{-1} at D.I Khan. The variance due to GE interaction was highly significant for all the traits showing heritable variation among the genotypes. The linear component of GE interaction was also significant for all traits except branches per plant. Pooled deviation was significant only for yield indicating the differential genotypic response across the locations. The significant variance due to environment (linear) indicated that the performance of genotypes was under genetic control. The b-values of V-90005, T-89 and PARS-I were larger than unit regression; hence were suitable for favourable environments for yield. Whereas, V-III and Sanghar-I were with b-values less than unity indicating their below average response. For branches per plant, Sanghar-1 and S-17 had regression coefficients less than one with negative sign making them suitable only for poor environment. Four genotypes namely, Sanghar-I, S-17, PR-19-9-S, and Rattodero-1 had greater than unity and non-significant regression coefficients with high response towards better agronomic conditions and were stable due to low deviation from regression. Correlations of mean with b-value and S^2d, for seed yield were highly significant and positive suggesting that average yield could be considered as a measure of response and stability.

Key Words: Sesamum indicum; Stability; Yield; Yield Components; Genotype -Environment Interaction; Pakistan.

INTRODUCTION

Sesame (*Sesamum indicum* L.) also known as "Til" or "Gingelly" is an oil producing crop belonging to the family Pedaliaceae. Its seed contain 50-60 % semi drying oil of premium quality. It is a high value oilseed crop grown on 5 million acres (20,000 km^2) in the world. In Pakistan, it was grown over 79,800 ha with 33,400t production and average yield of 419 kgha^{-1} during 2009-10. The country is producing only 30% of its edible oil requirement while 70% is met through import. At present, the cultivated varieties are low yielding (Mirza et al., 2012). Genotype x Environment (GE)

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interactions are often described as inconsistent differences among genotypes from one environment to the other (Yang and Baker, 1991). Due to wide spread presence of GE interactions, yield stability is one of the most important objectives in any crop (Lin et al., 1986). However, the importance of yield testing of crop genotypes over a wide range of environments has been recognized by many plant breeders and stable performance of a variety across environments is regarded desirable. Eberhart and Russell (1966) demonstrated that the evaluation could be planned to identify a stable variety, if the stability of performance is under genetic control. Information about good phenotypic stability is valuable in selecting the varieties for general cultivation in the region. A cultivar to be commercially successful must show high performance for yield and other essential agronomic traits across a range of agro-climatic conditions. However, the environmental influence on the phenotypic expression of a variety can easily be identified by growing it under different environments and locations (John et al., 2001). Ahmad et al. (1996) discussed that due to strong influence of environmental effects, consistency in yield has invariably been a problem. Many workers had described the importance of GE interaction and suggested that only mean yield is not a satisfactory measure, hence emphasis must be given on the evaluation of genotype which could perform better even besides fluctuation in the environment (Byth, 1977; Mehratra, 1980; Golmirzaie et al., 1990). Stability parameters are estimated in the presence of significant GxE interaction to determine the superior genotype. GxE interactions can be partitioned into linear and non-linear components using regression analysis of Eberhart and Russell (1966). Naazar et al. (2003) reported significant linear as well as non-linear components hence reflected the differential response of rapeseed genotypes to different environmental changes. In their study, the regression coefficient range were 0.29 and 1.35 in Syn-1 and Dp-94-8, respectively. Four genotypes shared average performance (b=1), six genotypes shared (b>1) hence with low S^2d were suitable for favourable environments. Suvarna et al. (2011) evaluated 15 sesame genotypes at six locations of the eastern dry zone of Karnataka. They reported significant differences for seed yield and identified different promising genotypes at different locations based on actual seed yield. They found three stable entries viz., Kanakapura local, ST-3 and ST-16 for seed yield. Gazal et al. (2013) evaluated 12 elite genotypes of brown sarsoon (*Brassica rapa* L.) including two checks viz., KS-101 and SBS-1 during 2011-12 across three random environments for stability performance in yield, yield contributing characters and oil content. In their findings genotypes exhibited highly significant genetic variability for all the traits viz., primary branches plant^{-1}, length of main raceme (cm), number of siliquae on main raceme, number of siliquae plant^{-1}, number of seeds siliqua^{-1}, 1000-seed weight (g), seed yield plant^{-1} (g) and oil content (%). They also reported that the mean squares due to environments were also significant for all the traits indicating different agro-climatic conditions of the selected environments. They observed GxE interactions for all the traits and found SKBR-11 variety as stable and average responsive to the environments for yield and most of the component traits.

A study of genotype x environment interaction can lead to successful evaluation of sesame varieties for stability in yield performance across locations. The information on stability and components of GxE interactions for newly developed and promising varieties of sesame is scanty in the country.The present study was carried out to identify potential and stable genotypes for yield and its component using measure of adaptability (b) and stability (S^2d) and determine the simple correlation among stability parameters.

MATERIALS AND METHOD

The experimental materials used in this study comprised 10 genotypes of sesame, namely, Rattodero-2, V-III, Sanghar-1, V-90005, S-17, PR-19-9-S, PARS-1, Rattodero-1, T-93-S and T-89 (check). These genotypes were evaluated for performance of yield and its components at 3 locations (NARC, Islamabad, Chakwal and D.I. Khan) during summer 2006. The experiment at each location was conducted in randomized complete block design with 4 replications. Each entry was planted in a plot having 4, 5m long rows. The spacing between rows and plants within row were kept 45 cm and 10 cm, respectively. All the usual agronomic/cultural practices were followed. Basal dose of fertilizer @ 35 and 23 (N: P) kg ha^{-1} was incorporated at the time of sowing. Data for plot yield (g), plant height (cm), number of branches per plant and capsules per plant were recorded at each location separately. A separate analysis of variance was undertaken for each location and a pooled analysis of variance over locations was also computed assuming genotypes as fixed variable and replications and locations effects as random (Steel et al., 1997).

The genotype x environment sum of squares were partitioned and all effects were tested against approximate error term. Results from the analysis of genotypes over environments provided evidence of genotypic, environmental and GxE effects which are prerequisite for regression and stability analysis. The estimates of regression coefficient (b) and deviation from regression (S^2d) provided additional information for selection among the genotypes tested. A genotype which has high mean performance, close to unity regression coefficient (b=1) and deviation from regression (S^2d) near to zero, is defined as a stable variety. Stability parameters were computed for all the four traits separately following Ebarhart and Russell Model (1966). Coefficient of determination (R^2) between average yield of individual genotype and average yield of all the genotypes in each location were also computed. Simple correlation coefficients were estimated between three stability parameters namely, mean, b and S^2d for plant height, branches per plant, capsules per plant and seed yield following the procedure of Gray (1982).

RESULTS AND DISCUSSION

Mean Performance

The expression of each trait was significantly different for all the genotypes in each environment (Table 1).

Table 1. Estimates of mean performance of 10 sesame genotypes under three locations in 2006

Traits	Locations	Rattodero - 2	V-III	Sanghar -I	V-90005	S-17	T-89	PR-19 -9-S	PARS-I	Rattodero -I	T-93-S	Genotype means
PHT												
	NARC	140.8	142.5	144.5	146.5	146.0	148.8	150.3	141.8	149.0	151.5	146.2 ^{a}
	Chakwal	141.0	139.8	140.8	137.5	141.8	141.8	140.3	138.0	141.0	140.5	140.3 ^{b}
	D.I.Khan	135.0	139.5	132.5	145.0	144.5	130.0	130.0	136.5	123.5	128.5	134.5 ^{c}
	Mean	138.9 ^{c}	140.5 ^{b}	139.3 ^{c}	143.0 ^{a}	144.1 ^{a}	140.2 ^{b}	140.3 ^{c}	138.8 ^{c}	137.8 ^{c}	140.2 ^{b}	140.3
BRP	NARC	7.3	7.8	7.3	7.0	7.0	7.5	6.8	7.8	8.0	7.0	7.3 ^{a}
	Chakwal	5.5	7.3	7.0	7.3	6.8	7.5	7.3	8.0	7.5	7.5	7.2 ^{a}
	D.I.Khan	5.5	7.3	7.3	5.8	7.3	6.5	6.8	7.8	7.5	7.0	6.8 ^{b}
	Mean	6.1 ^{d}	7.4 ^{a}	7.2 ^{c}	6.7 ^{c}	7.0 ^{b}	7.2 ^{b}	6.9 ^{b}	7.8 ^{a}	7.7 ^{a}	7.2 ^{b}	7.1
CAP	NARC	75.5	86.3	62.5	78.0	90.8	94.5	86.0	84.0	84.3	84.0	82.6 ^{b}
	Chakwal	72.0	72.8	101.3	85.0	134.8	88.5	87.0	79.8	86.0	83.5	89.1 ^{a}
	D.I. Khan	67.5	66.0	66.3	92.8	85.0	87.3	64.8	89.8	69.3	58.8	74.7 ^{c}
	Mean	71.7 ^{e}	75.0 ^{d}	76.7 ^{d}	85.3 ^{b}	103.5 ^{a}	90.1 ^{b}	79.3 ^{c}	84.5 ^{b}	79.8 ^{c}	75.4 ^{d}	82.1
SYH	NARC	287.0	230.8	300.3	330.8	295.0	205.8	341.0	281.3	286.8	239.8	279.8 ^{a}
	Chakwal	162.5	302.5	269.5	283.8	237.5	297.5	190.0	245.0	237.5	145.8	237.2 ^{b}
	D.I.Khan	218.8	318.8	267.5	343.8	218.8	242.0	337.5	304.0	202.3	327.0	278.0 ^{a}
	Mean	222.8 ^{d}	284.0 ^{b}	279.1 ^{b}	319.4 ^{a}	250.4 ^{c}	248.4 ^{c}	289.5 ^{b}	275.8 ^{b}	242.2 ^{c}	237.5 ^{c}	265.0

PHT = Plant height (cm): BRP= Branches per plant; CAP = Capsules per plant; SYH = Seed yield per ha (kg)
Means followed by same letter do not differ significantly at $P < 0.05$.

Mean differences between genotypes and locations were also significant ($P<0.05$) indicating substantial variation among these genotypes. Highest seed yield (280 and 278 $kgha^{-1}$) was obtained at NARC and D.I.Khan, respectively while the lowest yield (237 $kgha^{-1}$) was recorded at Chakwal. Seed yield ranking of different genotypes varied in different environments. PR-19-9-S was at the top in yield (341$kgha^{-1}$) at NARC, whereas V-90005 (344 $kgha^{-1}$) followed by PR-19-9-S (338 $kgha^{-1}$), T-93-3 (327 $kgha^{-1}$) and V-III 319 $kgha^{-1}$ were higher yielder at D.I.Khan. Overall, mean performance of V-90005 across three locations was (319 $kgha^{-1}$) followed by PR-19-9-S, V-III, Sanghar-1 and PARS-1 respectively. For number of capsules per plant, two locations viz., NARC and Chakwal were found suitable for capsule development with 83 and 89 capsules per plant. Maximum number of capsules per plant was recorded in S-17 (135) at Chakwal followed by Sanghar-1, T-89 (check) and V-90005 were found with maximum number of capsules (101, 95 and 93) at Chakwal, NARC and D.I. Khan, respectively. S-17, V-90005, T-89 and PARS-1 produced capsules per plant greater than the experimental mean of 82 capsules per plant. For the development of plant canopy especially number of branches per plant, NARC and Chakwal were found similar and suitable locations with mean value of 7.3 branches per plant. Rattodero-1 bear maximum branches (8.0) per plant followed by PARS-1 and V-III with 7.8 branches at NARC. At the remaining two locations (Chakwal and D.I.Khan), PARS-1 was at the top having 8.0 and 7.8 branches per plant, respectively. Across locations, PARS-1 (7.8) Rattodero-1 (7.7) and V-III (7.4) were having heavy branchy architecture. For less plant height, agro-climate of D.I.Khan was found suitable. Mean plant height was recorded in Rattodero-1 (138 cm), Rattodero-2 and PARS-I (139 cm) followed by Sanghar-1 (139 cm). Both S-17 and V-90005 were at par in plant height over the locations.

Genotype x Environment Interactions

Pooled analysis of variance (Table 2) revealed highly significant ($P<0.001$) difference among the genotypes for all the characters studied except plant height, indicating the presence of sufficient genetic variation among the genotypes. The variance due to GxE interaction was highly significant for all the traits under study showing the presence of heritable variation among the genotypes to interact considerably with the environments. GxE interactions are considered of notable importance in the development and evaluation of stable plant varieties. Many researchers like Jain and Pandya (1988), Naazar et al. (2001) and Ahmad et al. (1996) have also reported the same results in different crops. The variance due to GxE interaction was further partitioned into, linear [GxE (L)] and non linear (pooled deviation) components (Table 2). The linear component, when tested against pooled error, was found significant for all the traits except number of branches per plant, indicating the predictable response of the genotypes to the environment, as they did not differ in their deviation from linearity. Liu et al. (1992) and Khan et al. (1988) also reported similar results. Whereas, the non-linear component

Table 2. Pooled analysis of variance for four different characters in sesame

Source of Variation	DF	Mean squares			
		Plant height (cm)	Branches per plant	Capsules per plant	Seed yield (kg ha^{-1})
Genotypes (G)	9	10.980	0.745 **	261.54 **	2603.04 **
Environment (E)	2	339.330**	0.577	516.33 **	5825.25 **
GxE	18	26.930**	0.827 **	599.66 **	10503.83 **
Environment+GxE	20	58.170**	0.244	186.57 **	2945.88 **
Environment (linear)	1	678.650**	1.150 **	1032.65 **	11650.54 **
GxE (linear)	9	44.280**	0.210	174.27 **	3248.02 **
Pooled deviation	10	8.280	0.182	113.00	1803.51 **
Rattodero-2	1	6.665	0.796 *	20.38	2067.96 *
V-III	1	0.081	6.498 **	182.22 **	3762.25 **
Sanghar-I	1	3.611	4.072 **	348.46 **	515.47
V-90005	1	45.266**	0.328	75.35	116.96
S-17	1	8.121	7.626 **	306.26 **	2839.77 **
T-89	1	4.152	8.845 **	28.65	546.30
PR-19-9-S	1	0.171	0.163	54.78	4.29
PARS-I	1	0.989	4.072 **	5.19	307.14
Rattodero-I	1	16.098	6.498 **	22.64	3539.75 **
T-93-S	1	0.280	0.163	91.16	4335.21 **
Pooled error	81	12.970	0.337	75.70	855.83

** = $P < 0.05$ and ** = $P < 0.01$*

(pooled deviation) was highly significant only for seed yield indicating that the genotypes differed considerably with respect to their stability for this character across the environments. However, these genotypes did not differ for plant height, branches per plant and capsules per plant for their stability and the major components of the differences, were accounted by linear regression (bi) and not due to deviation from regression (S^2d). Further, variance due to environment (linear) was found highly significant for all the traits under study and indicated that the performance of these genotypes is genetically controlled and can be predicted, and the differences between environments and their considerable influence on these characters is also obvious. Naazar et al. (2001) in groundnut and Dhillon et al. (1999) in mustard also reported similar results.

Stability Parameters

As discussed by Eberhart and Russell (1966) and Paroda and Hayes (1971) all the three parameters of stability including mean, regression coefficient (bi) and deviation from regression (S^2d) were estimated for each character showing significant GxE interaction (Table 3). In this study, b-values of plant height ranged from 0.13 to 2.19; 0.09 to 3.28 for branches per plant; 0.13 to 3.37 for capsules per plant and from 0.23 to

Table 3. Comparison of stability parameters for four characters in 10 genotypes of sesame across locations

Genotype	Plant height (cm)				Branches per plant				Capsules $plant^{-1}$				Seed yield ($kgha^{-1}$)			
	$\overline{x}$	b	S^2d	R^2	$\overline{x}$	b	S^2d	R^2	$\overline{x}$	b	S^2d	R^2	$\overline{x}$	b	S^2d	R^2
Rattodero-2	138.9	0.49	-0.06	0.71	6.1	3.28	-0.01	0.61	71.7	0.34	-0.55	0.37	222.7	2.21	12.12	0.73
V-III	140.5	0.28	-0.12	0.87	7.4	0.94	-0.02	0.61	75.0	0.54	1.06	0.14	284.0	0.73	29.06	0.14
Sanghar-I	139.0	1.00	-0.09	0.95	7.2	-0.09	-0.03	0.62	76.7	2.34	-0.00	0.62	279.1	0.37	-3.40	0.24
V-90005	143.0	0.14	-0.32	0.63	6.7	2.88	-0.01	0.75	85.3	-0.57	2.30	0.31	319.4	1.27	-7.38	0.94
S-17	144.0	0.13	-0.05	0.13	7.0	-0.64	-0.062	0.39	103.5	3.37	-0.47	0.79	250.4	0.52	19.38	0.10
T-89 (C)	140.2	1.60	-0.08	0.98	6.7	2.23	-0.002	0.87	90.1	0.12	-0.21	0.65	248.4	1.78	-3.09	0.87
PR -19-9-S	140.3	1.73	-0.13	0.99	6.9	0.18	-0.001	0.62	79.3	1.59	-0.75	0.82	289.5	3.57	-8.51	0.60
PARS-I	138.8	0.43	-0.12	0.93	7.8	0.09	-0.003	0.62	84.5	-0.69	-0.53	0.99	276.8	1.12	-5.48	0.82
Rattodero-1	137.8	2.19	-0.03	0.95	7.7	0.94	-0.003	0.61	79.8	1.19	0.15	0.87	242.2	0.23	26.56	0.62
T-93-S	140.0	1.97	-0.13	0.99	7.2	0.18	-0.002	0.82	75.4	1.78	1.12	0.78	237.5	3.22	34.79	0.74
Mean	143.3	-	-	-	7.1	-	-	-	82.1	-	-	-	265.0	-	-	-

$\overline{x}$=Mean value; b = Regression coefficient; S^2d = Deviation from regression; R^2 = Coefficient of determination

3.57 for yield. Various breeders suggested that a variety may be stable over different locations (environments) if it shows unit regression coefficient (b=1) with low deviation from regression (S^2d=0). With these conditions high mean performance of a variety over environments is also a positive criterion to rate the variety as stable. However, b- value is considered as measure of sensitivity of the genotype to changes in the environment, whereas, deviation from regression is the measure of stability across the environment (Naazar et al., 2001; 2003; Gray, 1982; John et al., 2001; Suvarna et al., 2011 and Gazal et al., 2013).

Above average yield performance was noted in five varieties including V-90005 followed by PR-19-9-S, V-III, Sanghar-1 and PARS-1 (Table 3). Out of these varieties, regression coefficients of V-90005 and PARS-1 were larger than unity (b>1) indicating that these genotypes will only perform well in favourable environments and they also contributed maximum towards the GxE interaction, while in V-III and Sanghar-1, b- values were less than unity indicating their below average response and suitability for poor environments. Generally, regression coefficients of six varieties were greater than unity and ranged from 1.12 to 3.22. Maximum b-value was noted in T-93-S (b=3.22) followed by Rattodero-2 (b=2.21) with below average performance hence most sensitive towards growing conditions due to their unpredictable performance. The test of significance of bi and S^2d values of individual genotypes with respect to branches per plant showed absence of both linear and non linear components for all genotypes as it is evident from non significant linear component in pooled analysis for this trait. For branches per plant, Sanghar-1 and S-17 had regression coefficients of 0.09 and 0.64, respectively. Due to the negative sign of the coefficients, these varieties are suitable only for poor environment and are stable (Dhillon et al., 1999). Rattodero-2, V-90005 and T-89 having 3.28, 2.88 and 2.23 b-values were high in response and stable. PARS-1 followed by V-III was the genotypes with good branching but their regression coefficients were less. Whereas, Rattodero-1 and V-III showed above average branching with good response (b= 0.94) and were suitable nearly for all environments. For the character, plant height, Sanghar-1 had average response (b=1.0) and was stable (S^2d) hence suitable for all the environments. Two vareties namely, S-17 followed by V-90005 gained maximum height across the locations and proved suitable for poor management. PARS-I showed average performance with below average response to changes in locations and was stable.

For number of capsules per plant, stability parameter (b and S^2d) were non significant for all the genotypes indicating their less contribution towards GxE interaction (Paroda and Hayes, 1971). Two varieties (V-90005 and PARS-1) had regression coefficients with negative sign and below average response, hence suitable for poor agronomic conditions and were stable. Genotypes Sanghar-1, S-17, PR-19-9-S, Rattodero-1 and T-93-S had non-significant regression coefficients with values of 2.34, 3.37, 1.59, 1.19 and 1.78, respectively, indicating their high response towards better agronomic conditions and were stable due to their low S^2d (Table 3).

The genotype never makes it on its own rather its performance is always in partnership with the environment. Coefficient of determination (R^2) between average yield of each genotype and average yield of all the genotypes at each location is estimated as a measure of relative determination accuracy. R^2 were more variable and ranged from 0.13 to 0.99 in plant height, from 0.39 to 0.87 in branches per plant; from 0.14 to 0.99 for capsules per plant, and from 0.10 to 0.94 in yield. However, most of the genotypes had coefficients above 0.90.

Inter- parameter Correlation Coefficients

The correlation coefficients between three stability parameters, namely mean, b and S^2d for each four characters were estimated (Table 4) to determine whether selection for stability for more than one trait would be possible as explained by Anderson et al. (1989). There was a significant negative association (-0.60) between mean and b-value of plant height and indicated that branching habit and capacity of these genotypes to respond to environmental variations is inversely related (Jain and Pandya, 1988). For branching per plant, a negative and significant association was noted between mean and b, indicating that branching habit and capacity to respond to agronomic, conditions were inversely associated. Association between b and S^2d was positive and significant (0.73) for branches per plant. This indicated a strong association between linear and non linear components of GxE interaction for this trait. Similar

Table 4. Simple correlation coefficient among means, b and S^2d for plant height, branches/ plant, capsules/plant and seed yield of 10 genotypes based on 3 environments

Statistics-1	Statistics-2	Correlation coefficient			
		Plant height (cm)	Branches Plant^{-1}	Capsules Plant^{-1}	Seed yield (kgha^{-1})
X_1	b	- 0.60 **	- 0.58 **	0.28 NS	0.67 **
X_2	S^2d	0.42 NS	- 0.86 **	0.27 NS	0.55 **
b	S^2d	- 0.29 NS	0.73 **	0.73 **	-0.11 NS

X = mean, b = regression coefficient, S2d = deviation for regression

association (0.73) was also found between b and S^2d stability parameters for capsules per plant suggesting that high adaptability for this trait could be considered along with its predictability. The estimates of correlations of stability parameters between traits revealed that for seed yield, mean performance was significantly and positively associated with regression coefficient (b) and deviation from regression (S^2d) suggesting that average yield could be considered as a measure of response and stability despite the negative association between linear and non linear components of GxE interactions. Our results are in line with those of Yadav and Kumar (1983).

It is concluded from these results that the performance of genotypes is genetically controlled, hence can be predicted.

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