Electronic Journal of Plant Breeding, 8(3): 787-791 (September 2017)
ISSN 0975-928X
DOI: 10.5958/0975-928X.2017.00124.7

Research Article

Genotype x environment interaction for fruit yield and component characters in okra [*Abelmoschus esculentus* (L.) Moench]

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(Received: 27 Jan 2017; Revised: 17 Aug 2017; Accepted: 25 Sep 2017)

Abstract
With prime objective of developing season/region specific as well as stable hybrids of okra [*Abelmoschus esculentus* (L.) Moench], the present investigation was undertaken with thirty-seven entries *viz*., eight parents, twenty eight F1's and one standard check GOH-2 over four season to obtain the information on stability parameters for fruit yield per plant and its components using stability analysis. The stability analysis exhibited significant differences among genotypes (G), environments (E) and G x E interaction for all characters except variance due to environment and G x E for ascorbic acid content indicating variable response of different genotypes for various traits under varied agro-climatic conditions. The significance of G x E (linear) and pooled deviation for fruit yield per plant and its most of the related traits suggested importance of both linear and non-linear components in building up total G x E interaction. Among the environment studied, E_2 was found to be most favourable whereas E_3 most unfavourable The parent JOL-09-8 was found to be average stable for fruit yield per plant and its attributes. Among the hybrids, eight were identified as stable over environments for fruit yield per plant and the best three among them were JOL-09-7 x JOL-09-8, JOL-09-7 x AOL-09-17 and JOL-09-7 x AOL-09-2.

Key words
Okra, stability and G x E interaction, Environments

Introduction

Vegetable crops offer higher yield, income and calories as compared to agronomical crops, hence vegetable farming has become profitable enterprise. Okra[*Abelmoschus esculentus* (L.) Moench] is grown in various regions of India and covers practically all agro-ecological zones. There are various genotypes of okra having varying yielding potential, adaptability to different climatic conditions, response to diseases, insects and pests. The performance of genotypes keeps changing in varying environmental conditions. The genotypic and environmental interactions are usually present under all conditions in pure lines, hybrids, synthetics or any other material used for breeding, which complicate the breeding work and forbid the progress of the crop improvement programme. (Eberhart and Russell, 1966). Thus, it is imperative to study the performance of a crop in more than one environment to identify genotypes, which give high productivity over a wide range of environments. Such genotypes will be very useful for utilizing their potentials for the development of high yielding and stable varieties/hybrids.

Materials and Methods

The experimental material for the study comprised of thirty seven entries including eight parents (JOL-09-7, JOL-09-8, AOL-09-17, AOL-08-5, AOL-09-13, AOL-09-2, JOL-55-3 and JOL-08-16), their 28 F_1s derived by crossing in all possible combinations excluding reciprocals and one standard check GOH-2, was laid out in a randomized block design with three replications over four seasons *viz*., summer-2011 (E_1), *kharif*-2011 (E_2), *rabi*-2011-12 (E_3) and summer-2012 (E_4) at Navsari Agricultural University, Navsari-396450 (Gujarat). Each entry was sown in a single row plot of ten plants, spaced 60 x 30 cm. All the recommended agronomic practices and plant protection measures were followed uniformly in all the four environments. Five competitive plants were randomly selected for recording the observations on different characters as mentioned in Table 1. The pooled analysis of variance over the four seasons was also done to test the interaction of genotypes and its sub-division with environments given by Comstock and Robinson (1). The statistical analysis for genotype x environment interaction and stability was carried out according to Eberhart and Russel (2) for fruit yield and its component traits in okra.

Results and Discussion

The pooled analysis of variance (Table 1) revealed highly significant mean squares for genotypes, which indicated the presence of wide genotypic variability among the genotypes involved in the study for all the characters. This provides an ample opportunity for selecting suitable genotypes with high mean for all the traits of interest. Highly significant differences were observed for environments for all the traits except for ascorbic acid content indicated the divergence among the growing environments. The highly significant effect of genotype x environment for all the characters except ascorbic acid content indicated that there is a differential response of genotypes to various environments. Therefore, the genotypes must be tested over an extensive range of

 DOI: 10.5958/0975-928X.2017.00124.7

environments for proper assessment, where these are to be ultimately grown for commercial purposes. Significant genotype x environment interaction in okra for plant growth characters and yield has been reported by Babariya *et al.* (2009), Ramya and Senthilkumar (2010), Kachhadia *et al.* (2011), Srivastava *et al.* (2011) and Alake and Ariyo (2012).

The stability analysis of variance of mean data (Table 2) revealed that the mean squares for genotypes were highly significant for all the characters indicating genetic variability among the genotypes for these characters. Similarly, the mean squares due to environments were highly significant for all the characters except for ascorbic acid content. This indicated that environments were effective in influencing the performance of the genotypes. Highly significant mean squares due to E + (G x E) were also observed for all these traits revealed that genotypes interacted significantly with the environments. While, testing the significance of mean square due to genotypes x environment interaction against pooled error, it was observed that mean square were significant for all the characters except ascorbic acid content. The mean square due to environment (linear) was significant and highly significant for all the characters when tested against pooled deviation. The co-incidence of genotype performance with environmental value was observed for plant height, internodal length, fruit length, fruit girth and fruit yield per plant as evident form significant G x E (linear) mean squares when tested against pooled deviation. The mean squares due to pooled deviation were found to be highly significant for all the traits except internodal length, fruit length, fruit girth and ascorbic acid content. On comparing relative magnitude of genotype x environment (linear) and pooled deviation from linearity (non-linear), it was found that the linear portion was considerably high for plant height, internodal length, branches per plant, no. of flowering nodes on main stem, fruit length, fruit girth, fruit weight, fruit yield per plant and ascorbic acid content, while non-linear portion was important for days to 50% flowering and fruits per plant as evidenced from larger portion of non-linear component over linear component. This indicated importance of both non-linear and linear portions in determining genotype x environment interactions for these attributes. These results are in agreement with those of Desai (1990b), Gondane and Lai (1993), Poshiya and Vashi (1997), Jindal *et al.* (2008) and Babariya *et al.* (2009).

From the estimates of environmental indices (Table-3) it was observed that the characters days to 50 per cent flowering, branches per plant, no. of flowering nodes on main stem, fruit girth and fruits per plant were favoured in E_1 and E_2, while the characters fruit length and fruit weight were more favoured in E_2. E_2 and E_4 were not found favourable for internodal length and ascorbic acid content, respectively. For the character fruit yield per plant E_3 was found to be the most unfavourable and E_2 the most favourable. In general, the environment E_2 was found to be the most favourable for fruit yield and other related traits.

According to Eberhart and Russell (1966), an ideal variety would be one that possessed high mean performance (of course greater than population mean), unit regression coefficient (bi = 1) and least deviation from regression i.e., as far as possible equal to zero ($S^2di = 0$). However, if a variety possessed negative regression coefficient then the variety should be suitable for poor / unfavourable environments. Considering these criteria, the stability of genotypes (parents and crosses) was discussed below for all the characters under study.

Stability parameters were worked out for 37 genotypes for eleven characters which revealed that none of the genotypes was stable for all the characters studied. Any generalization regarding stability of genotypes for the characters was not possible. Among 37 genotypes 1 parent and 8 crosses were found to be stable for fruit yield per plant owing to high mean, regression coefficient near unity and least deviation from regression (Table 4).

The parent JOL-09-8 was stable for fruit yield per plant as it recorded high mean, regression coefficient near unity and least deviation from regression (S^2di). Further, it was also stable for days to 50 per cent flowering, branches per plant, no. of flowering nodes on main stem and fruits per plant.Among hybrids, JOL-09-7 x JOL-09-8 (1) had high mean fruit yield per plant with regression coefficient near unity and non-significant deviation from regression. It also manifested average stability for days to 50 % flowering. plant height (cm), internodal length (cm), fruit weight (g) and fruits per plant. This hybrid followed by JOL-09-7 x AOL-09-17 (2) which had high mean fruit yield per plant with regression coefficient near unity and non-significant deviation from regression along with average stability for days to 50% flowering, plant height, internodal length, no. of flowering nodes on main stem, fruit length, fruit weight and fruits per plant. Next to it, the cross JOL-09-7 x AOL-09-2 (3) in addition to fruit yield per plant also depicted average stability fruit girth (cm), fruit weight (g) and ascorbic acid content (mg/100g). Cross AOL-09-17 x AOL-09-13 (4) in addition to fruit yield per plant also depicted average stability for days to 50% flowering, plant height, fruit girth and fruit weight. Likewise, the cross AOL-09-2 x JOL-08-16 (5) showed average stability for internodal length (cm), no. of flowering nodes on main stem and fruits per plant in addition to fruit yield per plant.The cross JOL-55-3 x JOL-08-16 (6) showed average stability for fruit length, fruit girth and fruit weight along fruit yield per plant and the cross AOL-08-5 x JOL-55-3 (7) showed average stability for plant height, branches per plant, fruit girth and fruit weight in addition to fruit yield per plant. The eighth cross JOL-09-8 x AOL-09-13 (8) showed average stability for fruit length (cm) and fruit weight (g) along with fruit yield per plant.

On the other hand four hybrids *viz*., JOL-09-7 x JOL-55-3, JOL-09-8 x JOL-55-3, JOL-09-8 x JOL-08-16 and AOL-09-17 x JOL-08-16 exhibited high fruit yield per plant but their regression coefficient significantly deviating from unity showing above average stability and found suitable for favourable environment. However they exhibited average stability for two or more component traits.

In general, the hybrids found stable for fruit yield also depicted stability in respect of its one or more yield component. This indicated that the stability of various component traits might be responsible for observed stability of hybrids for fruit yield. The chance for selection stable hybrids could be strengthened by selection in favour of stability in some yield component. Grafius (1956) also suggested that the stability of fruit yield might be due to the stability of various yield components.

The mean yield of each genotype depends on the particular set of environmental conditions. It is therefore, suggested that in order to identify stable genotype, actual testing over a wide range of environments including poor and good ones would be advantageous while making selection, attention should be paid to the phenotypic stability of characters directly related to fruit yield. Particularly fruits per plant, fruit length, fruit girth and fruit weight, so as to achieve maximum stability for the end product *i.e*., fruit yield in okra. Similar results for the above traits studied were also reported by Desai (1990b), Gondane and Lai (1993), Poshiya and Vashi (1997), Jindal *et al.* (2008), Babariya *et al.* (2009), Kachhadia *et al.* (2011), Akotkar *et al.* (2011) and Srivastava *et al.* (2011).

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DOI: 10.5958/0975-928X.2017.00124.7

Table 1. Stability analysis of variance of pooled data for different traits in okra

Characters	Sources of variation				
	Genotypes (35)	**Environments (3)**	**Replication within environments(8)**	**Geno. x Env. (105)**	**Error (280)**
Days to 50 % flowering	47.15**	647.87**	1.92	6.82**	2.75
Plant height(cm)	2440.46**	311302.10**	30.47	243.34**	82.26
Internodal length (cm)	2.53**	288.66**	0.48	0.61**	0.33
Branches per plant	0.26**	1.37**	0.01	0.09**	0.01
No. of flowering nodes on main stem	18.07**	554.17**	0.35	2.83**	0.46
Fruit length (cm)	6.01**	325.75**	0.46	0.75**	0.47
Fruit girth (cm)	1.67**	20.05**	0.05	0.14**	0.09
Fruit weight (g)	5.62**	297.00**	0.40	0.75**	0.41
Fruits per plant	24.25**	940.03**	0.10	2.78**	0.87
Fruit yield per plant (g)	6292.68**	293838.76**	209.21	477.46**	155.32
Ascorbic acid content (mg/100g)	7.07**	0.27	0.08	0.17	0.20

*, ** Significant at 5 % and 1 % level, respectively

Table 2. Stability analysis of variance of mean data for different traits in okra

Characters	Mean squares					
	Genotypes (36)	**Environments + (Genotype x Environments)**	**Environments (Linear) (1)**	**Genotype x Environments (Linear) (108)**	**Pooled deviation (74)**	**Pooled error (288)**
Days to 50 % flowering	15.29**++	8.35**	685.38**++	2.24**	2.53**	0.99
Plant height(cm)	794.33**++	2947.78**	318635.50**++	79.34**+	52.53**	26.96
Internodal length (cm)	0.84**++	2.88**	299.19**++	0.19**+	0.12	0.11
Branches per plant	0.08**++	0.04*	1.41**++	0.03**	0.03**	0.00
No. of flowering nodes on main stem	5.86**++	6.03**	569.81**++	0.92**	0.84**	0.15
Fruit length (cm)	1.96**++	3.24**	332.88**++	0.25**++	0.14	0.16
Fruit girth (cm)	0.54**++	0.23**	20.40**++	0.05*+	0.03	0.31
Fruit weight (g)	1.83**++	2.99**	305.47**++	0.24**	0.21**	0.14
Fruits per plant	7.86**++	9.58**	966.05**++	0.90**	0.89**	0.29
Fruit yield per plant (g)	2039.30**++	2868.96**	301722.60**++	154.93**+	104.28**	53.64
Ascorbic acid content (mg/100g)	2.29**++	0.05	0.27*+	0.06	0.05	0.07

*, ** Significant at 5 % and 1 % level, respectively against pooled error.
+, ++ Significant at 5 % and 1 % level, respectively against pooled deviation.

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Table 3. Estimates of environmental index for various characters under different environments.

S. No.	Characters	Environmental index			
		E_1	E_2	E_3	E_4
1	Days to 50 % flowering	-0.48	-2.86	3.18	0.16
2	Plant height (cm)	-12.95	77.00	-47.24	-16.81
3	Internodal length (cm)	-0.29	2.33	-1.50	-0.53
4	Branches per plant	0.15	0.01	-0.11	-0.06
5	No. of flowering nodes on main stem	0.91	2.32	-3.03	-0.20
6	Fruit length (cm)	-0.49	2.51	-1.48	-0.53
7	Fruit girth (cm)	0.05	0.51	-0.53	-0.03
8	Fruit weight (g)	-0.12	2.15	-1.90	-0.13
9	Fruits per plant	0.95	3.12	-3.93	-0.13
10	Fruit yield per plant (g)	5.46	63.81	-63.39	-5.87
11	Ascorbic acid content (mg/100g)	0.01	0.01	0.05	-0.07

E_1-Summer-2011, E_2-*Kharif*-2011, E_3-*RabI*-2011-12 and E_4-Summer-2012

Table 4. Stable parent and hybrids identified on the basis of high mean for fruit yield per plant and component traits

No.	Parent / Hybrids	Fruit yield per plant (g)	Average Stable for component traits
Parents			
1.	JOL-09-8	143.16	DF, BP, NFN, FP
Hybrids			
1.	JOL-09-7 x JOL-09-8	186.89	DF, PH, IL, FG, FW, FP
2.	JOL-09-7 x AOL-09-17	152.44	DF, PH, IL, NFN, FL, FW, FP
3.	JOL-09-7 x AOL-09-2	152.19	FG, FP, AAC
4.	AOL-09-17 x AOL-09-13	150.92	DF, PH, FG, FW
5.	AOL-09-2 x JOL-08-16	150.02	IL, NFN, FP
6.	JOL-55-3 x JOL-08-16	147.68	FL, FW, FG
7.	AOL-08-5 x JOL-55-3	144.24	PH, FG, BP, FW
8.	JOL-09-8 x AOL-09-13	135.40	FL, FW

DF = Days to 50 % flowering.
PH = Plant height (cm).
IL = Internodal length (cm).
BP = Branches per plant.
FL = Fruit length (cm).
NFN = No. of flowering nodes on main stem.
FG = Fruit girth (cm).
FW = Fruit weight (g).
FP = Fruits per plant.
FY = Fruit yield per plant (g).
AAC = Ascorbic acid content (mg/100g).