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Genotype x Environment Interaction and Stability Analysis for Earliness, Seed Yield and Fruit Yield in Okra Using the Additive Main Effect and Multiplicative Interaction (AMMI)

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ABSTRACT

Fifty five okra genotypes (ten lines, four testers, forty hybrids and one check) okra accessions were tested for stability in three different environments between 2014-15 using Additive main effect and multiplicative interaction (AMMI) and Genotype main effect and Genotype by Environment (GGE) models. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The mean squares due to genotypes were highly significant for all the traits when tested against pooled error and pooled deviation which indicated the presence of considerable genetic variability in the materials. Highly significant differences were also observed amongst environments for all the traits when tested against pooled error and pooled deviation which indicated the presence of considerable environmental differences for all the traits. The genotypes x environment interactions were significant for all the traits except fruit length when tested against pooled error. Both AMMI and GGE biplots identified most stable, high yielding genotypes that were overall best in performance in relation to yield and stability. Result of stability estimates of 55 genotypes revealed that none of the genotype was stable for all the traits studied. Further, IC – 045796 x GAO – 5 and VIO 47672 x GAO – 5 were the most stable hybrids in terms of fruit yield and its components. For the trait, fruit yield per plant Environment E₃ (winter season) was found to be the most unfavourable while Environment E₂ (rainy season) was the most favourable environment.

Keywords

Genotype x Environment Interaction, Stability Analysis, Additive Main Effect and Multiplicative Interaction (AMMI), *Abelmoschus esculentus* (L.) Moench

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Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] belongs to the cotton family *Malvaceae*. This warm season crop considered to have originated from India. Okra is economically and traditionally important vegetable of

tropical and sub-tropical countries of the world such as India, West Africa, South East Asia, Southern America, Brazil, Turkey and northern Australia (Rao, 1985). In India, it is grown during summer as well as in rainy season. According to the 2nd Advance Estimate of NHB Database (2017), India is

going to produce 6.1 million tons of okra from an area of 0.5 million hectare with the productivity of 12 tonnes/ha, making India the largest producer and consumer of okra in the world. India is a major okra producing country in the world comprising of 71% of total area under okra (FAOSTAT, 2014). Several high yielding hybrids have been developed by Indian Institute of Vegetable Research (ICAR-IIVR), Varanasi, India among which “Kashi Bhairav” has achieved yield up to 20-22 MT/ha (Anonymous, 2016). As mentioned earlier, an average productivity of okra in India is 12.00 tonnes/ha, a large potential yield gap exists between farmers’ yield and than that of documented by various research organizations. The major problem in okra cultivation is lack of high-yielding varieties/hybrids. The productivity of okra should be increased through hybridization and recombination followed by stability analysis (Solankey *et al.*, 2016). Several researchers have studied stability analysis in okra in details. They have also reported stable okra hybrids by using the Additive Main Effect and Multiplicative Interaction.

In multi-environment trials genotype x environment interactions is often exist (Simmonds, 1991; Kang, 1998). If there were no interaction, there is no need to conduct yield trials over different locations/environments, as trial may be conducted at only one location and providing universal results (Gauch and Zobel, 1996). Such an ideal situation does not exist in reality. Genotype x environment interaction is expected in plant breeding experiments that involve cultivars of diverse genetic background and diverse test sites (Kang *et al.*, 2006).

Genotype x environment interaction study is important to breeders to develop not only improved but also stable varieties, suitable for a particular location or multi-location. The

goal of any plant breeding programme is to develop cultivars with high yielding potential with stable performance over a wide range of environments (Olayiwola and Ariyo, 2013). Performance of various okra genotypes keeps varying 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 programmes. Thus, it is imperative to study the performance of a crop in more than one environment to identify genotypes, which give high stability for various yield related traits over a wide range of environment (Jindal *et al.*, 2008). The phenomenon of genotype – environment interaction is a common problem in plant breeding program and has long been a challenge to plant breeder. A variety developed by a plant breeder is usually grown at different locations for many years under different conditions. Assessing any genotype without including its interaction is incomplete and thus limits the accuracy of yield estimates. It is usually preferable to estimate yield stability and reliability values with reference to all GE interaction effects (Ezekiel *et al.*, 2011).

The objective of this research is evaluate the efficiency of the combined use of AMMI and GGE technique to study GEI of various traits of fifty five okra genotypes in three different seasons.

Materials and Methods

The study was conducted during September, 2013 to February, 2015 (including crossing programme during September to December, 2013). The experiment (55 genotypes including 14 parents, their 40 hybrids and one standard check) was laid out in a randomized complete block design (RBD) with three

replications over three environments (Table 1) at the Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, situated at coastal region of South Gujarat. Geographically, it is situated at 20°- 37' N latitude and 72°- 54' E longitude with an altitude of 11.98 meters above the Mean Sea Level. All recommended horticultural practices along with plant protection measures were followed uniformly and as and when required.

Parental material and recorded data

Fourteen diverse parents (Table 2) were crossed in line x tester fashion to produce forty F₁ hybrids. Selfed parental seeds, hybrid seeds and standard check were treated with Thiram 4g/kg of seeds were sown (10 plants/row) in RBD fashion at spacing of 60 x 45 cm. Randomly five plants from each plot were selected to record the observation on days to first flowering, first flowering node, plant height, number of branches, number of fruits per plant, fruit yield per plant, fruit length, fruit weight, number of seeds per pod and 100 seed weight. Plot wise means for various traits were subjected to Analysis of Variance (ANOVA) and means were separated using the Duncan Multiple range test. Further, data were analyzed statistically for stability parameters based on mean performance across the seasons as per the model suggested by Eberhart and Russell (1966) for various traits. Data was analysed using Windostat Version 8.6 (Indostat services).

Results and Discussion

Analysis of variance for phenotypic stability

Stability performance is one of the most desirable properties of a genotype for its wide

adaptation. The mean squares for phenotypic stability for different traits are presented in Table 3. The mean squares due to genotypes were highly significant for all the traits when tested against pooled error and pooled deviation which indicated the presence of considerable genetic variability in the material tested. Highly significant differences were also observed amongst environments for all the traits when tested against pooled error and pooled deviation which indicated the presence of considerable environmental differences for all the traits. The genotypes x environment interactions were significant for all the traits except fruit length when tested against pooled error. This indicated that genotype interacted significantly in different environments. The mean square due to genotype x environment interactions were also significant for days to first flowering, number of fruits per plant, plant height, fruit yield per plant and fruit weight when tested against pooled deviation. The lack of significant G x E interaction for rest of the traits under study indicated that genotypes responded consistently over the environments for these traits, hence, the results of these traits are not included in the study. The significance of G x E interactions have also been reported by Srivastava *et al.*, (2011), Ezekiel *et al.*, (2011), Alake and Ariyo (2012), Hamed and Hafiz (2012), Olayiwola and Ariyo (2013) and Javia (2014).

The mean squares due to environments (linear) were highly significant for all the traits when tested against pooled deviation except for leaves per plant. However, the same was significant for all the traits when tested against pooled error. This indicated that variation among environments was linear and it signifies unit change in environmental index for each unit change in the environmental conditions. The variance due to G x E were further partitioned in to components (i) G x E (linear) and (ii) G x E (non-linear) i.e. pooled deviation. G x E (linear) was found to be

significant for all the traits except number of branches per plant and fruit length when tested against pooled error indicating differential performance of genotypes under diverse environments but with considerably varying norms, i.e., the linear sensitivity of different genotypes is variable.

Stability estimates

Stability estimated to assess the stability over the environments is presented in Table 4. For days to first flowering, a perusal of the data revealed that non-linear component was significant for 3 genotypes, indicating larger contribution of non-linear component towards G x E interaction. Among parents, line, IC – 111493 and tester, Arka Anamika were found stable as they were flowered earlier and exhibited unit regression coefficient along with non-significant value of deviation from regression. Looking to the data of plant height, significant linear and non-linear components were reflected by 2 and 10 genotypes respectively, thereby suggesting major role of non-linear component towards G x E interaction.

Seven hybrids recorded dwarfism (lower mean values for plant height) with non-significant regression coefficient and least deviation from linear regression thus, identified as average stable for this trait. The best three among them were EC – 284327 x GJO – 3 (128.16 cm), JOL – 08 – 13 x GAO – 5 (131.47 cm), EC – 284327 x GAO – 5 (134.50 cm), JOL – 08 – 13 x Varsha Uphar (135.38 cm) and EC – 305623 x Arka Anamika (135.50 cm). Among hybrids, IC – 045796 x GAO – 5 (249.26 g) 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 first flowering and number of fruits per plant, followed by cross VIO 47672 x GAO – 5 (241.57 g), manifested average stability for

days to first flowering and fruit weight. In general, the hybrid which found stable for fruit yield also depicted stability in respect of its one or more yield component (Table 4). This indicated that the stability of various component traits might be responsible for observed stability of hybrids for fruit yield. The chance for selection of stable genotypes 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. Phenotypic stability of various component traits reflecting into fruit yield stability were also reported by various workers *viz.*, Kachhadia *et al.*, (2011), Akotkar *et al.*, (2011), Srivastava *et al.*, (2011) and Javia (2014) in okra.

Varietal improvement can encouraged by accumulation of favourable genes for yield and tolerance to various stresses (Singh, 1993). It will not be wrong to say that the accrual of all high yielding genes into one cultivar is nearly impossible task. Genotype x environment interaction plays an important role in the overall performance of a cultivar, so it becomes utmost important to identify high yielding stable varieties across multiple environments or a cultivar that have specific adaptation in specific environment/location.

Multi-location or multi-environment screening of genotypes offers opportunities for selecting genetically adapted and specifically adapted cultivars. 40 hybrids were developed by using 10 lines and 4 testers and were evaluated along with parents and one commercial check in three different environments. Obtained data was subjected to AMMI and GGE biplot analysis. GGE biplot identified cultivar. Figure 1 represents the biplot of AMMI results. The y-axis represents the IPCA 1 scores, while the x-axis represents the main effects of days to first flowering (A), first flowering node (B) and number of seeds (C), respectively.

Fig.1 Additive main effect and multiplicative interaction (AMMI) and Genotype $\times$ environment interaction (GGE) biplot analysis of (A) days to first flowering, (B) first flowering node and (C) number of seeds for 55 genotypes of okra established in 3 environments

Table.3 Analysis of variance for phenotypic stability pertaining to various traits

Source	df					
		Days to first flowering	First flowering node	Plant height (cm)	Number of branches per plant	Number of fruits per plant
Genotype (G)	54	8.723**++	0.326	225.387**++	0.088**++	7.101**++
Planting date (P)	2	549.338**++	56.936**++	198051.08**++	0.190**++	1909.41**++
G × P	108	3.769**+	0.316**	100.430**++	0.014**	2.799**++
Planting date(linear)	1	1098.676**++	113.872**++	396102.17**++	0.381**++	3818.831**++
G × E (linear)	54	5.114**++	0.288**	126.194**+	0.011	4.001**++
Pooled deviation	55	2.38*	0.34**	73.31**	1.75**	1.57**
Pooled error	324	1.652	0.0593	33.145	0.010	0.711
Source	df					
		Fruit yield per plant (g)	Fruit length (cm)	Fruit weight (g)	Number of seed per fruit	100 seed weight (g)
Genotype (G)	54	2000.29**++	0.695**++	0.6805**++	25.120**++	0.2039**++
Planting date(P)	2	465953.706**++	266.64**++	58.005**++	1704.88**++	7.940**++
G × P	108	617.68**++	0.2244	0.246**++	5.03**	0.0643**
Planting date(linear)	1	931907.41**++	533.29**++	116.01**++	3409.702**++	15.88**++
G × P (linear)	54	905.400**++	0.1746	0.327**++	4.637**	0.066*
Pooled deviation	55	323.97**	0.27	0.16	5.33**	0.06
Pooled error	324	79.735	0.190	0.167	2.923	0.045

*, ** significant at 5 and 1% level, respectively against pooled error.

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

Table.4 Stability parameters of individual genotypes for days to first flowering, plant height (cm), number of fruit per plant, fruit yield per plant (g) and fruit weight (g)

Sr. no.	Genotype	Days to first flowering			Plant height (cm)			Number of fruit per plant			Fruit yield per plant (g)			Fruit weight (g)		
		Mean	b _i	S ² d _i	Mean	b _i	S ² d _i	Mean	b _i	S ² d _i	Mean	b _i	S ² d _i	Mean	b _i	S ² d _i
Female parent (Lines)																
1.	VIO 44244	49.08	0.28	4.57	123.37	0.99	15.03	14.59	0.87	0.85	163.75	0.786*	-78.305	10.28	0.512	0.469
2.	IC – 111493	46.48	0.90	1.32	134.97	0.83	34.89	17.25	1.15	-0.69	207.31	1.103	-58.726	10.89	1.103	-0.165
3.	JOL – 08 – 13	47.72	0.98	-1.23	126.51	1.06	-21.20	15.76	0.91	0.09	179.59	0.935	141.460	10.55	1.142	-0.103
4.	EC – 284327	47.60	0.77	-0.99	124.55	0.94	-11.62	16.57	1.07	1.33	190.35	1.044	337.167*	10.62	0.864	-0.103
5.	IC – 045796	46.78	0.85	2.57	135.20	0.83	51.48	17.28	1.15	-0.69	206.12	1.130	-62.633	10.88	1.111	-0.163
6.	IC – 052273	46.48	0.65	-1.31	132.50	1.00	-30.93	15.20	0.61	0.57	175.44	0.676	212.717	10.58	0.471	-0.116
7.	JOL – 10 – 18	49.01	1.60	-1.62	131.47	0.84	101.09*	15.18	0.75	-0.26	175.55	0.745	-63.646	10.61	0.522	-0.132
8.	AOL – 09 – 17	47.89	1.19	-1.59	127.60	1.12	10.70	15.65	1.07	0.90	177.44	0.950	-45.985	10.30	0.935	0.140
9.	VIO 47672	46.74	1.02	1.64	135.47	0.84	49.53	17.26	1.15	-0.69	204.27	1.132	-60.460	10.86	1.113	-0.166
10.	EC – 305623	51.16	0.59	1.24	126.43	0.91	127.92*	14.66	0.74	1.88	161.89	0.718	-39.982	10.36	0.447*	-0.166
Male parent (Tester)																
11.	GAO – 5	46.85	1.03	2.50	134.47	0.82	63.61	17.24	1.15	-0.71	204.98	1.144	-39.399	10.85	1.102	-0.164

12.	GJO – 3	46.95	1.03	2.60	134.03	0.80	59.60	17.27	1.15	-0.69	203.54	1.132	-51.231	10.86	1.062	-0.162
13.	Arka Anamika	45.93	0.91	-0.02	120.91	1.02	43.82	14.81	0.72*	2.61	166.54	0.760	121.643	10.65	1.384	-0.144
14.	Varsha Uphar	45.61	1.13	-1.55	130.04	1.01	86.86	14.36	0.50**	13.78	164.24	0.527	2409.921**	10.69	1.050	-0.110
<i>Hybrid</i>																
15.	VIO 44244 × GAO – 5	46.70	0.61	22.15**	130.93	1.07	144.97*	14.69	0.68	4.33**	168.18	0.722	602.955**	10.78	1.229	-0.097
16.	VIO 44244 × GJO – 3	48.44	0.82	-1.53	139.29	0.96	2.88	14.60	0.79**	-0.71	173.99	0.856	-75.696	10.85	1.234	-0.129
17.	VIO 44244 × ArkaAnamika	46.30	1.24	-1.60	137.96	0.94	-1.39	14.23	0.81	-0.07	169.63	0.858	25.952	10.74	1.650	0.208
18.	VIO 44244 × Varsha Uphar	45.62	1.22	-1.31	140.33	1.05	-28.23	16.19	0.90**	-0.71	189.10	0.912	-67.719	10.75	0.971	-0.017
19.	IC – 111493 × GAO – 5	46.08	2.39	-1.57	139.20	1.28	231.09**	16.50	1.36	2.64*	204.41	1.421	1729.844**	11.03	2.036	-0.162
20.	IC – 111493 × GJO – 3	43.29	1.05	-0.90	156.92	1.11	-1.44	19.93	1.26	1.59	254.99	1.251	709.392**	11.99	0.331	0.740*
21.	IC – 111493 × ArkaAnamika	45.40	1.33	-1.60	141.27	0.916	-31.94	16.31	1.18	-0.57	195.54	1.167	37.748	11.10	1.642	0.035
22.	IC – 111493 × Varsha Uphar	48.48	1.56	12.67**	137.12	1.14	86.57	16.27	0.89	0.52	185.30	0.956	150.140	10.44	0.707	-0.166
23.	JOL – 08 – 13 × GAO – 5	46.49	1.64	-1.61	131.47	0.98	30.71	17.19	1.25	-0.67	199.95	1.196	-58.718	10.83	1.376	-0.099
24.	JOL – 08 – 13 × GJO – 3	46.15	0.46	-0.63	128.44	1.15	-21.86	16.58	1.02	-0.71	193.96	1.070	-79.727	10.69	0.811	-0.142
25.	JOL – 08 – 13 × ArkaAnamika	45.13	1.30	-1.63	142.56	1.20	51.85	18.20	1.25	-0.06	217.07	1.250	-71.632	11.00	1.015	-0.069
26.	JOL – 08 – 13 × Varsha Uphar	49.18	0.95	0.99	135.38	0.94	-1.35	17.40	1.22	-0.59	207.54	1.230	38.424	10.95	1.257	-0.161
27.	EC – 284327 × GAO – 5	47.92	1.12	-0.44	134.50	0.97	-29.32	15.77	1.04	0.00	185.02	1.021	-17.663	10.84	1.481	0.096
28.	EC – 284327 × GJO – 3	46.92	0.61	-0.25	128.16	1.08	35.01	15.31	0.66	0.79	173.14	0.732	258.483*	10.59	0.732	-0.104
29.	EC – 284327 × ArkaAnamika	48.85	1.85	-0.92	127.05	0.7*	-32.77	15.72	0.90*	2.23	174.33	0.766	847.149**	10.27	1.040	0.105
30.	EC – 284327 × Varsha Uphar	50.21	0.30	0.93	141.64	0.91	-29.49	14.33	0.88	0.66	164.75	0.938	56.166	10.40	1.349	-0.027
31.	IC – 045796 × GAO – 5	43.61	0.97	-1.64	153.38	1.05	-30.53	19.16	1.24	-0.71	249.26	1.214	-70.159	11.80	0.692*	-0.166
32.	IC – 045796 × GJO – 3	43.84	0.89	-1.62	157.56	1.14	1.01	19.93	1.30	1.70	256.16	1.349	1092.592**	11.87	0.518	1.073**
33.	IC – 045796 × ArkaAnamika	48.63	-0.03	1.38	145.40	1.10	17.27	15.57	0.78	-0.07	182.67	0.938	28.837	10.60	1.071	-0.096
34.	IC – 045796 × Varsha Uphar	46.18	0.73	10.82**	142.62	1.04	-29.51	14.37	0.60	-0.62	163.73	0.711	-52.109	10.64	0.789	-0.160
35.	IC – 052273 × GAO – 5	45.33	1.54	-1.63	144.16	1.14	-3.05	17.89	1.26	0.49	214.21	1.296	332.140*	10.96	1.078	-0.026
36.	IC – 052273 × GJO – 3	46.79	1.38	1.88	130.10	0.7*	-32.05	14.48	0.53*	3.16	165.31	0.520	709.693**	10.79	0.729	-0.147
37.	IC – 052273 × ArkaAnamika	46.32	0.53	1.66	136.61	0.97	8.94	15.46	1.12	-0.27	175.00	1.083	-48.281	10.56	1.841	-0.051
38.	IC – 052273 × Varsha Uphar	44.31	0.87	-0.70	145.46	1.13	354.2**	17.88	1.20**	4.31	219.95	1.233	1497.782**	11.27	0.756	0.373
39.	JOL – 10 – 18 × GAO – 5	48.28	-0.083	4.46	139.80	0.89	31.05	15.44	0.70	-0.47	179.61	0.675	-20.297	10.96	0.343	-0.041
40.	JOL – 10 – 18 × GJO – 3	45.18	0.67	-0.35	137.82	0.73	-8.89	16.72	0.83	0.71	201.89	0.837	229.022*	11.15	0.740	-0.039
41.	JOL – 10 – 18 × ArkaAnamika	46.63	1.84	-0.94	139.29	0.98	-7.42	15.56	0.88	0.97	179.30	0.929	-50.466	10.77	1.027	-0.162
42.	JOL – 10 – 18 × Varsha Uphar	45.08	1.03	-1.51	143.75	1.07	34.94	16.84	1.21	-0.51	192.45	1.158	-33.689	10.48	1.543	-0.012
43.	AOL – 09 – 17 × GAO – 5	46.85	1.08	0.74	141.84	1.01	-16.03	16.65	1.23	-0.53	189.89	1.163	-42.677	10.41	1.636	0.119
44.	AOL – 09 – 17 × GJO – 3	46.42	2.07	-0.75	146.30	1.24	16.65	18.00	1.36	-0.13	216.23	1.309	-57.347	11.06	1.401	-0.154
45.	AOL – 09 – 17 × ArkaAnamika	45.53	0.85	-1.23	130.19	1.08	165.72*	15.90	1.06	-0.35	182.95	1.031	10.252	10.53	1.256	-0.165
46.	AOL – 09 – 17 × Varsha Uphar	45.63	0.44	2.79	148.15	1.00	-26.34	16.81	0.81	1.93	202.42	0.804	414.997*	11.25	0.582	-0.123
47.	VIO 47672 × GAO – 5	43.49	1.09	-0.44	154.60	1.11	-16.64	18.92	1.27	-0.01	241.57	1.367	215.430	11.65	0.868	0.095
48.	VIO 47672 × GJO – 3	43.34	0.88	-1.51	160.70	1.15	2.19	20.92	1.37	1.52	278.01	1.452	611.988**	12.26	0.298	0.522*
49.	VIO 47672 × ArkaAnamika	46.20	0.38	-1.50	141.90	0.98	148.76*	16.92	0.95	-0.36	198.09	0.891	86.962	11.02	0.424	0.295
50.	VIO 47672 × Varsha Uphar	47.09	1.73	3.92	133.51	0.73	112.36*	17.53	1.16	-0.28	203.98	1.090	187.768	10.82	0.759	-0.051
51.	EC – 305623 × GAO – 5	47.63	1.38	-1.63	135.58	1.11	366.98**	15.53	1.16*	8.44	178.67	1.161	1131.122**	10.59	1.148	0.105
52.	EC – 305623 × GJO – 3	47.28	0.51	-1.34	136.93	0.98	121.91*	14.81	0.63	1.55	167.15	0.668	473.822**	10.57	0.707	-0.137
53.	EC – 305623 × ArkaAnamika	49.37	0.26	-1.57	135.50	0.98	2.16	15.29	0.75	-0.43	172.14	0.769*	-77.946	10.54	0.867	0.024
54.	EC – 305623 × Varsha Uphar	48.21	1.60	-1.47	135.30	1.12	-33.08	16.42	1.13	0.70	192.34	1.109	118.272	10.63	1.132	-0.165
55.	Check (Sonakshi)	46.29	0.81	1.52	135.86	0.83	42.17	17.30	1.15	-0.69	208.55	1.118	-62.252	10.91	1.112	-0.165
Mean		46.71	1.00	-	137.49	1.00	-	16.41	1.00	-	193.63	1.00	-	10.84	1.00	-
SEM±		1.09	0.34	-	12.7	0.1	-	6.1	0.01	-	0.10	0.33	-	0.07	1.36	-
*, ** Significant at 5 and 1% level, respectively.																

Table.1 Details of seasons during the study

	Summer, 2014, February to May
	Rainy, 2014, June to September
	Winter, 2014-2015, November 2014 to February 2015

Table.2 Parental material used for the study

Parent	Source/Origin
VIO 44244	AVRDC, Taiwan
IC – 111493	NBPGR, New Delhi, India
JOL – 08 – 13	Junagadh Agricultural University, Junagadh (Gujarat)
EC – 284327	NBPGR, New Delhi, India
IC – 045796	NBPGR, New Delhi, India
IC – 052273	Junagadh Agricultural University, Junagadh (Gujarat)
JOL – 10 – 18	Junagadh Agricultural University, Junagadh (Gujarat)
AOL – 09 – 17	Anand Agricultural University, Anand (Gujarat)
VIO 47672	AVRDC, Taiwan
EC – 305623	NBPGR, New Delhi, India
Tester	
GAO – 5	Anand Agricultural University, Anand (Gujarat)
GJO – 3	Junagadh Agricultural University, Junagadh (Gujarat)
ArkaAnamika	IIHR, Bengaluru, India
Varsha Uphar	IIHR, Bengaluru, India
Commercial check: Sonakshi (Hybrid; Nunhems Company)	

Table.5 Estimate of environmental index for various traits under different environments

Sr. No.	Trait	Environmental index		
		E ₁ (Summer-2014)	E ₂ (Rainy-2014)	E ₃ (Winter-2014-15)
1.	Days to first flowering	-1.099	-2.646	3.563
2.	Number of branches per plant	-0.062	0.007	-0.005
3.	Number of fruit per plant	0.381	5.692	-6.073
4.	Plant height (cm)	-17.737	66.877	-49.140
5.	Fruit yield per plant (g)	-93.507	90.505	3.002
6.	First flowering node	-1.173	0.528	0.645
7.	Fruit length (cm)	1.197	1.344	-2.541
8.	Fruit weight (g)	-0.120	1.081	-0.692
9.	Number of seed per fruit	1.311	4.795	-6.106
10.	100 seed weight (g)	0.078	0.335	-0.413

Genotype VIO 47672 x GJO – 3 was the overall best of them all combining relative stability and registered less number of days to first flowering, followed by genotypes VIO 47672 x GAO – 5 and IC 045796 x GJO – 3. 20 genotypes registered early flowering. The poorest genotypes due to instability and late flowering were VIO47672 x Varsha Uphar and VIO 44244 x GJO – 3 (Fig. 1A). In case of first flowering node most of the hybrids were found highly stable and adapted to high performance environments. Genotype VIO 44244 x Varsha Uphar was less than the average in terms of first flowering node. It was interesting to note that this particular genotype was highly stable in nature and was also adapted to low performance environment which was winter season in case of this study, depicting the scope of okra cultivation in off season (Fig. 1B). Lines, EC – 284327 and IC – 045796 were least stable among 55 genotypes and also registered late flowering. Figure 1C depicts the AMMI and GGe biplot analysis for number of seeds per fruit evaluated over three different environments. Most of the genotypes were found to be highly stable and adapted to high performance environment. Genotype IC – 045796 x Varsha Uphar was found to be highly stable in nature and adapted to high performance environment followed by VIO 44244 x Varsha Uphar. Genotype, JOL – 10 – 18 x Arka Anamika was found stable but recorded lowest mean for number of seeds per fruit (45.70). According to AMMI biplot analysis for number seeds per fruit, genotype, EC – 284327 recorded less number of seeds than mean and were also highly instable. The biplot revealed the genotypes that performed best in each environment and the relationship between the environments. The relationship among environments was not so close. This is explained by larger angle between these environments, whereas there was a wider variation between the rainy season and the rest. The result of AMMI revealed that IC –

045796 x GAO – 5 and VIO 47672 x GAO – 5 were the most stable genotypes because their interaction with the environment was not enough to hinder yield as indicated by their IPCA scores of zero and near.

Result of stability estimates of 55 genotypes revealed that none of the genotypes was stable for all the traits studied. Same results were reported by Patil *et al.*, (2017). Thus, any generalization regarding stability of genotypes for all the traits is too difficult since the genotype may not simultaneously exhibit uniform responsiveness and stability patterns for all these traits. The yield is polygenically controlled complex trait and is being determined by the joint action of a number of component traits. Therefore, a proper understanding of relationship between fruit yield and its component traits could be of great help in choosing the proper components that may contribute not only towards the manifestation of complex trait but also towards its stability and association with high heterosis and desirable sca effects. The identification of parents having higher mean, good gca effects and high stability across the environments is of great value to the plant breeders while formulating breeding programme. Phenotypic stability of various component traits reflecting into fruit yield stability were also reported by various workers Akotkar *et al.*, (2011), Srivastava *et al.*, (2011) and Javia (2014) in okra.

Environmental index

The estimates of environmental indices revealed that the components traits for earliness and dwarfness *viz.*, days to first flowering, plant height and first flowering node were favoured in E₁ and E₃, while the yield attributing traits like number of branches per plant, number of fruits per plant, fruit length and fruit weight were more favoured in E₂. For the trait fruit yield per

plant E₃ was found to be the most unfavourable and E₂ the most favourable. In general, the environment E₂ was found to be the most favourable for fruit yield and other related traits (Table 5).

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