



Original Contribution

ANALYSIS OF STABILITY AND ADAPTATION OF COTTON GENOTYPES USING GGE BILOT METHOD

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ABSTRACT

This research was conducted to study effects of $G \times E$ interaction on 38 selected genotypes of cotton with two commercial cultivars Golestan and Sepid (control) in a randomized complete block design with three replications at three locations in Golestan Province in 2014-15. The measured characteristics were included: plant height, sympodial length, sympodial number, boll number, boll weight, seed cotton yield and earliness. Analysis of variance showed that genotype effect is significant in 1 or 5% probability levels on measured traits except for boll number and earliness. A significant interaction effect between genotype \times locations in yield showed different variation trends in various locations. So that genotype 29 had the best performance in Hashemabad station but genotypes 24 and 18 showed their best performances in Gonbad and Anbarolum station respectively. Stability parameters were calculated and genotype No. 8 was defined according to regression slope close to 1 as the most stable genotypes among. This genotype had a smaller share in genotype and environment interaction according to Rick ecovalans and Shukla stability variance parameters and 10 and 33 were the most unstable genotypes in terms of performance. GGE biplot method showed that the first two principal components regression model explained 74% of the observed changes. GGE biplot graph plotted by software reflected the superior genotypes TJ82, ER26, DB29, DB19, DB25 and ER36 respectively. Also Hashemabad has been identified as appropriate region for ER26 genotype and TJ82 was identified as the best and most stable genotype.

Keywords: genotype and environment interaction, GGE Biplot, Cotton, Genotype, stability, adaptability.

INTRODUCTION

Cotton (*Gossypium sp. L.*) as a tropical and subtropical plant is grown worldwide. Much of the cotton crop is produced in Asia, as four Asian countries China, India, Pakistan and Uzbekistan produce about 68% of world cotton, however, USA would alone produces about 12% of the world's cotton. The role of cotton in gross domestic product (GDP) of Pakistan is 1.6% and in Syria 2.5%. The average yield in crop year 2009 to 2008 in China, India, Uzbekistan and Pakistan, are 3963, 1569, 2115 and 1959 kg per hectare, respectively (1). Cotton cultivation area in Iran is reported about 101 thousands hectares

in 2012-2013 that in comparison with the past decade, approximately 40 to 50 percent of the cultivated area has been reduced (2).

Introducing lines with high and stable yield for different regions with diverse climatic conditions is one way of increasing crop production. For selection and introduction of high yielding and stable varieties, replicated yield trials in a number of years and places are conducted. In these experiments, usually after the decomposition of variance when interaction between genotype and environment is existed, stability of genotypes in addition to performance criteria should also be considered for introducing new variety (3).

Alishah *et al.* (2) investigated 9 new varieties of cotton's agronomic characteristics in comparison with commercial varieties, Varamin, Sahel and Bakhtegan, in 9 regions

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during 2008-2009. Based on results of year \times location interaction for all quality and earliness, yield and boll weight were significantly differed at 1% probability level. Interaction of year \times genotype for fiber quality and boll weight was not significant. All cultivars had average stability to different environments, and among them cultivars SP732, SP731 and NNB had good compatibility, besides hybrid NNC as new varieties recommended for cotton areas of the country have been introduced. Damavandi *et al.* (4) investigated genotype \times environment interactions and stability of performance of 10 cotton varieties in six regions through parametric univariate method, non-parametric and AMMI model and found that 81% of changes have been occurred by two main factors I and II (IPC1,2). Based on biplot diagram of components of genotype and environment and average yield of genotypes in different environments, Chekurova, Sepid and Tabladila were the most stable cultivars, however, the cultivars 43200, Khordad and Sahel showed the highest G \times E interaction. Meanwhile, Pourdad and Jamshidy Moghadam (5) using GGE Biplot to study grain yield of 9 *brassica napus* genotypes in four regions over two years and their research led to identify 6 superior genotypes and two big environments. Also proper genotypes were determined within each environment.

Labachan (6) reported significant genotype and environment interaction for grain yield in rice and defined the stable genotypes using Eberhart and Russell method. Moreover, Li *et al.* (7) in stability analysis of important economic traits reported 7 cultivars in 12 districts in 3 years, 4 digits K326, K346, Yuniyan87 and RJ17 in terms of economic characteristics were better than the others. However, both K315 and K358 in yield and average price in areas have proper stability.

Campbell & Jones (8) evaluated genotype \times environment interactions effects on agronomic performance (lint yield, gin turnout) and fiber quality (fiber length, fiber strength, uniformity index, micronaire, fiber elongation) in a series of cotton (*Gossypium hirsutum*) performance trials in 12 location-year environments in South Carolina. Result showed genotype \times environment interactions affecting lint yield were larger in higher yielding environments, while interactions for fiber strength were greater for genotypes with lower mean fiber strength values.

Farshadfar & et al. (9) In order to determine stable bread wheat genotypes with high grain yield via a single parameter, field experiments were conducted with 14 genotypes for 3

consecutive years (2008-2011) under two different conditions (irrigated and rain fed) in a complete randomized block design with three replications in each environment. Combined analysis of variance showed highly significant differences for the GE (genotype-environment) interaction indicating the possibility of selection for stable entries. The results of AMMI (additive main effect and multiplicative interaction) analysis indicated that the first four AMMI (AMMI1-AMMI4) were highly significant ($P < 0.01$).

In present studied, a group of superior genotypes were tested at several environments (stress of saline and non-saline) in terms of quantity and quality characters.

MATERIALS AND METHODS

Thirty eight new cotton genotypes along with two commercial cultivars of Golestan and Sepid (control) were evaluated in a randomized complete block design with three replications in three regions (Hashemabad, Anbarolum and Gonbad) in Golestan province during 2014-2015. Field has been usually prepared and cotton crop technical guideline was carried out. Winter and spring cultivators to provide suitable planting was done in due time. Planting has been performed using 20 \times 80 cm pattern in second half of May in each year. To provide enough green area, thinning and weeding operations were performed during the growing season. Urea, ammonium phosphate and potassium sulphate fertilizers were applied as recommendation based on the soil sample analysis.

The measured characteristics were included: plant height, sympodial length, sympodial number, boll number, boll weight, seed cotton yield and earliness (the proportion of cotton seed of the first harvest on total performance). In order to measure the characteristics of each treatment, five random plants have been randomly selected, and all data recorded only from the selected plants. Harvesting was done after removing the half a meter from up and down of rows. For data analysis, and to evaluate the stability of genotypes and drawing graphs, SAS 9.0 and GGE biplot software were used, respectively.

RESULTS AND DISCUSSION

Analysis of variance showed that there are significant differences at 5 or 1% level among the studied genotypes in years and locations in most of traits. However, genotype \times location interaction was significant for length of sympodial and yield. It is suggested that for these traits there are various process of variation in different locations. So that, a single genotype cannot be introduced for planting in all areas, instead, it is necessary to recommend a proper genotype for each distinct region (Table 1).

Table 1. Combined analysis of variance cotton genotypes in three regions Hashemabad, Anbarolum and Gonbad (2014-15)

Source of variation	df	earliness	Cotton seed	Boll weight	Boll number	Sympodial number	Sympodial length	Plant high
Mean of square								
Year (Y)	1	101.4 ^{ns}	120228883.9 ^{**}	192.1 ^{**}	1200.8 ^{**}	399.6 ^{**}	1224.3 ^{**}	21974.3 ^{**}
Location (L)	2	147485.7 ^{**}	206486301.9 ^{**}	310.4 ^{**}	5212.6 ^{**}	2756.5 ^{**}	8560.5 ^{**}	122493.3 ^{**}
Y * L	2	25586.1 ^{**}	6643108.7 ^{**}	20.2 ^{**}	10.3 ^{ns}	562.7 ^{**}	1037.7 ^{**}	17083.4 ^{**}
Rep (Y*L)	12	33234.5	2975776.6	5.69	46.7	114.9	278.2	5220.7
Genotype	39	81432.1 ^{**}	1122640.2 ^{**}	2.09 ^{**}	15.6 [*]	26.9 ^{**}	97.7 ^{**}	1537.4 ^{**}
Y*G	39	19467.2 ^{**}	311302.3 ^{ns}	1.06 [*]	9.15 ^{ns}	11.1 ^{ns}	42.1 ^{ns}	323.4 ^{ns}
L*G	78	34752.6 ^{ns}	518293.7 ^{**}	1.73 ^{**}	12.8 ^{ns}	15.1 [*]	84.1 ^{**}	557.8 [*]
Y*L*G	78	47404.7 ^{**}	227726.1 ^{ns}	0.817 ^{ns}	9.41 ^{ns}	5.19 ^{ns}	36.1 ^{ns}	259.3 ^{ns}
error	468	190860.8	306914.6	0.759	10.2	10.4	43.9	405.3
C.V		19.5	22.3	22.1	22.9	28.3	26.5	26.5

ns: not significant differences *: significant at the 5% level ** significant at the 1% level.

Figure 1 shows the trends of genotypes performance in different regions. Genotypes 29, 24 and 18 showed the best performance in

Hashemabad, Anbarolum and Gonbad, respectively.

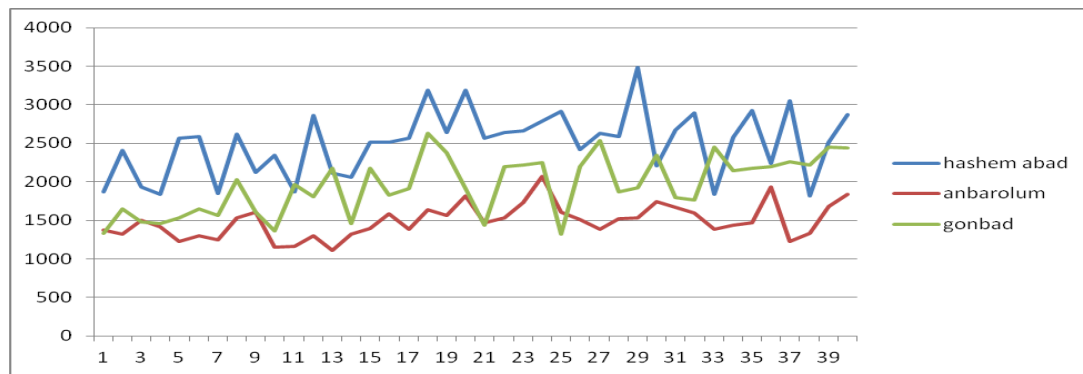


Figure 1. Performance changes trends in cotton genotypes in different areas

According to the results (**Table 2**) the first year was superior to the second year in most of the studied traits. Meanwhile, among regions of

running area, Hashemabad, Gonbad and Anbarolum are placed from first to third for nearly all measured traits, respectively.

Table 2. Comparing the average trait in the years and different areas of the project

		Earliness (%)	Seed Cotton (Kg/ha)	Boll Weight (gr)	Boll Number	Sympodial Number	Sympodial Length (cm)	Plant High (cm)
year	2014	69.1a	2122a	4.44a	8.87a	12.1a	19.4a	82.7a
	2015	69.8a	1705b	3.41b	6.28b	10.6b	16.8b	71.7b
Location	Hashem-Abad	79.7a	2498a	4.83a	12.9a	15.2a	23.5a	97.2a
	Anbarolum	49.2b	1089c	2.65c	4.53b	8.6 c	11.7c	52.7c
	Gonbad	79.5a	1954b	4.31b	5.26b	10.4b	18.9b	81.7b
Interaction Year*Location	Y1 * L1	86.4a	3014a	5.08a	14.1a	14.2b	23.0	97.3a
	Y1 * L2	41.4e	1183e	3.48d	5.7 d	10.5d	15.3d	79.0c
	Y1 * L3	79.4b	2170b	4.78b	6.8 c	11.7c	20.0b	83.0b
	Y2 * L1	73.0c	1982c	4.59b	11.8b	16.2a	24.2a	97.1a
	Y2 * L2	57.1d	1197f	2.83e	3.4e	6.7 f	8.2 e	37.5d
	Y2 * L3	79.5b	1736d	3.83c	3.7e	9.1e	18.0c	80.5b

Comparison of average traits in different genotypes was performed using Duncan method in level 1% (**Table 3**). The tallest plants were belonged to genotype 25 with a height more than 101 cm and the shortest plants were belonged to

genotype 33, with an average of 64 cm. Maximum length and number of sympodial branches was belonged to genotypes 5 and 24, respectively. This morphological characteristic in cotton is very important because of directly

formation of bolls on fruiting branches. Thus, sympodial branches, as components of the performance, can have a positive role in the formation of bolls and increasing yield of cotton.

The highest number of bolls per plant is belonged to the treatment 18. The number of boll in cotton is so important because the cotton plant has a self-regulating mode and in stress conditions can retain the portion of leaf to time by falling flower and boll. In the contrary, if the conditions are provided by increasing the number of bolls per plant, the maximum performance will produce perhaps why treatment 18 has had the most yields among 40 genotypes studied.

In Golestan, the highest produced yield was harvested in first cutting. But overall the yield harvested, the treatment was number 18 that was superior to all treatments and belonged the highest average yield to 2220 kg per hectare. The most important point is that the most performance of single plant was produced with this figure of 50 grams per plant. In terms of earliness that in cotton is calculated from the portion of first cutting to total performance, treatment 39 was earlier than others, because 87 percent of the performance of these genotypes was harvested in the first cutting (**Table 3**).

Table 3. Comparison of mean in the three regions Hashemabad, Anbarolum and Gonbad

Treatment	Genotype	Earliness (%)	Seed Cotton (Kg/ha)	Boll Weight (gr)	Boll Number	Sympodial Number	Sympodial Length (cm)	Plant High (cm)
1	D39	48jkl	1256e	3.54e-i	6.53edf	9.2fg	17.4a-i	67.2efg
2	T52	66b-i	1523c-e	4.05a-i	8.45a-e	11.8a-g	17.8a-i	82.8b-f
3	D38	71a-h	1367de	4.09a-f	6.84b-f	10.3d-g	17.1b-i	67.6efg
4	D8	62d-k	1304de	4.66a	6.44edf	11.4a-g	17.4a-i	68.7efg
5	D26	52i-l	1509c-e	3.74c-j	8.03a-f	10.8b-g	22.9a	70.6d-g
6	D37	60e-k	1578e	3.85b-j	7.30a-f	9.5efg	18.5a-g	67.7efg
7	D7	55h-k	1285b-e	4.01a-i	7.19a-f	10.1d-g	15.2f-i	66.4ef
8	D9	59f-k	1794b-e	4.20a-f	7.68a-f	11.6a-g	16.6d-i	87.8a-d
9	D13	64c-j	1511c-e	4.33a-d	6.92a-f	10.8b-g	18.5a-g	75.5c-g
10	D25	42 l	1355de	3.01 j	6.96a-f	9.1 g	18.3a-i	66.3ef
11	T51	58g-k	1396de	4.01a-i	7.98a-f	12.5a-d	22.4ab	79.1c-g
12	T41	68b-h	1721b-e	4.51ab	6.69c-f	13.5ab	21.9abc	90.4abc
13	D10	54h-k	1532c-e	3.98a-i	5.51 f	9.7efg	19.1a-g	67.4efg
14	D36	46kl	1347de	3.82b-j	6.96a-f	11.2a-g	20.7a-f	80.8b-g
15	TJ8	79a-d	1759b-e	4.05a-i	7.01a-f	10.3d-g	17.1b-i	74.4c-g
16	TJ20	71a-h	1708b-e	3.49f-i	7.28a-f	10.7c-g	16.2d-i	75.7c-e
17	TJ57	68b-i	1688b-e	3.77b-j	7.03a-f	10.8b-g	16.5d-i	67.9efg
18	TJ82	76a-f	2220a	4.27a-e	9.72a	13.1abc	20.6a-f	91.1abc
19	TJ124	79a-d	1942a-c	3.93a-i	8.02a-f	12.2a-e	16.3d-i	87.2a-d
20	TJ135	66b-i	2040ab	3.92a-i	9.19abc	11.5a-g	21.6a-d	84.1a-e
21	TJ139	72a-g	1555c-e	3.87b-i	7.18a-f	12.3a-e	20.9a-e	85.8a-d
22	TJ168	68b-i	1857b-e	4.25a-e	7.53a-f	10.6c-g	16.6d-i	77.8c-g
23	TJ169	75a-g	1938a-c	3.37c-j	7.18a-f	12.8a-d	17.3a-i	88.9abc
24	TJ174	77a-e	2103ab	4.09a-f	7.31a-f	13.9a	17.2b-i	97.1ab
25	TJ178	70a-g	1680b-e	4.23a-e	8.41a-e	13.1abc	19.6a-h	101.3a
26	TJ183	73a-g	1774b-e	3.63d-j	7.34a-f	11.1b-g	19.4a-g	83.3b-f
27	TJ185	74a-g	1914a-d	3.93a-i	8.52a-d	12.3a-e	20.3a-f	84.4a-e
28	TJ189	77a-e	1727b-e	4.47abc	6.16ef	10.6c-g	18.7a-h	74.1c-g
29	SB26	77a-e	2044ab	3.32ij	9.42abc	10.5c-g	12.6 i	74.2c-g
30	SB8	73a-g	1831b-e	4.22a-e	7.21a-f	10.9b-g	18.6a-g	80.9b-g
31	SB22	69a-h	1777b-e	3.62d-j	6.59edf	9.4fg	13.3h-i	67.9efg
32	SB38	83ab	1817b-e	3.65d-j	7.72a-f	11.9a-f	16.6d-i	77.1c-g
33	SB36	75a-f	1625b-e	3.34hij	8.45a-d	11.1b-g	17.8a-i	64.4g
34	SB7	83ab	1785b-e	3.89b-i	7.56a-f	11.6a-g	16.9b-i	75.1c-g
35	SB9	79a-d	1922a-c	4.33a-d	8.03a-f	13.5ab	18.4a-g	80.3b-g
36	SB34	73a-e	1858b-e	3.81b-j	8.83a-d	11.1b-g	19.7a-g	70.5d-g
37	SB29	73a-e	1913a-d	3.37h-i	7.70a-f	12.7a-d	20.2a-f	73.7c-g
38	Sepid	77a-e	1522c-e	3.91a-i	7.03a-f	11.5a-g	18.3a-g	77.1c-g
39	SB33	87a	1949a-c	4.02a-i	7.58a-f	11.5a-g	15.8e-i	70.8d-g
40	Golestan	81abc	2116ab	4.06a-g	9.51ab	11.4a-g	13.9g-i	65.1g

Stability analysis

Based on how to do statistical analysis, there are a lot of methods to evaluate the genotype \times environment interaction that usually divided it into two major groups of parametric and non-parametric. Versus genotypes and environment interaction, the stability subject is raised. Term stability is used about genotypes that have a relatively stable performance and the minimal variance in different environmental conditions. This aspect of stability called static or biological stability. Of course, such genotype is not always the best genotype because not responds to improve environmental conditions.

Romer environmental variance

Phenotypic stability according to the concept of static stability (stable) by Romer (10) using variance of a genotype in different

environments is calculated and measures deviation of a genotype from average of that genotype in all environments. A genotype that not responds to changing environmental conditions is more stable. The standard is an independent model of other genotypes. According to environmental variance, a genotype is stable that its environmental variance is less. Of course, this stability should not be generalized i.e. a genotype that with a group of genotypes seems stable may be unstable with another group of genotypes. Based on this, according to the results in **Table 4 and 5**, genotype 1 which has the lowest yield, also has had the lowest environmental variance and is considered as the most stable genotype. In contrast, genotype 29 that was part of yielding genotypes has had the highest variance and from this point is accounted as an unstable genotype.

Table 4. Average cotton seed yield of 40 genotypes in different environments (Kg/ha)

A	y1*L1	y1*L2	y1*L3	y2*L1	y2*L2	y2*L3	mean
1	1729	1109	1479	2010	831	1183	1390.1
2	2368	967	1833	2438	867	1467	1656.7
3	2682	1257	1642	1174	934	1314	1500.6
4	2396	993	1626	1272	1039	1301	1437.7
5	2657	698	1708	2484	944	1366	1642.9
6	3195	857	1833	1973	946	1466	1711.5
7	2715	824	1733	984	872	1386	1418.9
8	3141	1267	2252	2105	1001	1801	1927.8
9	2610	1396	1781	1644	1015	1424	1645.0
10	1919	704	1518	2773	807	1214	1489.0
11	2388	621	2183	1342	897	1747	1529.6
12	3157	729	2009	2566	1062	1607	1855.0
13	2297	626	2414	1927	800	1931	1665.8
14	2499	976	1620	1625	869	1296	1480.7
15	3333	1005	2421	1688	976	1937	1893.2
16	2968	1441	2030	2059	932	1624	1842.3
17	3389	1091	2129	1748	867	1703	1821.4
18	3663	1522	2924	2725	947	2340	2353.4
19	3181	1400	2635	2098	924	2108	2057.8
20	3505	1844	2128	2865	995	1703	2173.4
21	3219	880	1601	1906	1248	1281	1689.3
22	3102	1188	2446	2169	1082	1957	1990.8
23	3008	1682	2461	2323	985	1969	2071.4
24	3371	2184	2502	2199	1162	2002	2236.8
25	3289	1332	1471	2532	1086	1176	1814.3
26	3095	1321	2439	1734	906	1951	1907.8
27	3278	821	2813	1975	1153	2250	2048.2
28	3071	1345	2082	2111	893	1666	1861.2
29	3985	1068	2132	2980	1196	1705	2177.7
30	3093	1727	2608	1317	961	2087	1965.3
31	3236	1599	1993	2113	932	1594	1911.1
32	3714	1207	1961	2073	1179	1569	1950.5
33	2900	1073	2727	776	897	2182	1759.2
34	3415	1081	2382	1737	994	1906	1919.1
35	3321	987	2422	2522	1149	1937	2056.2
36	2941	2173	2441	1544	899	1953	1991.8
37	3638	803	2514	2463	850	2011	2046.5
38	2720	887	2462	915	983	1970	1656.2
39	3097	1423	2725	1936	1135	2180	2082.7
40	3276	1216	2708	2474	1657	2167	2249.8
mean	3219	880	1601	1906	1248	1281	1846.981

Table 5. Calculation of performance stability parameters of cotton genotypes in different environments

A	mean	S ²	Cv	Wi ²	δ ²	b	S ² d	R ²
1	1390.1	188477.5	31.2	1216037.0	252844.2	0.4485	101847.8	0.5677
2	1656.7	456546.8	40.8	656439.9	135034.3	0.8055	139134.7	0.7562
3	1500.6	387651.8	41.5	509898.9	104183.6	0.7685	91763.1	0.8106
4	1437.7	271085.7	36.2	405574.2	82220.5	0.6786	32608.4	0.9038
5	1642.9	639907.1	48.7	717304.1	147847.8	0.9664	178765.4	0.7765
6	1711.5	731901.2	50.0	217944.6	42719.5	1.1468	40206.2	0.9561
7	1418.9	524193.6	51.0	444974.7	90515.3	0.9091	105580.6	0.8389
8	1927.8	583925.3	39.6	9927.6	-1073.6	1.0469	1040.4	0.9986
9	1645.0	291407.8	32.8	326694.1	65614.1	0.7125	26692.0	0.9267
10	1489.0	598130.3	51.9	2018787.7	421844.4	0.6824	437934.4	0.4143
11	1529.6	494741.5	46.0	523924.7	107136.4	0.8666	118948.2	0.8077
12	1855.0	836628.0	49.3	613826.3	126063.0	1.1708	134206.2	0.8717
13	1665.8	585538.5	45.9	767081.8	158327.3	0.9062	185815.8	0.7461
14	1480.7	348228.4	39.9	143383.8	27022.5	0.8003	9342.7	0.9785
15	1893.2	805037.6	47.4	310881.7	62285.2	1.1982	51454.8	0.9489
16	1842.3	477571.4	37.5	110444.1	20087.8	0.9280	24236.9	0.9594
17	1821.4	803053.6	49.2	219610.6	43070.2	1.2135	24566.8	0.9755
18	2353.4	969613.5	41.8	484436.4	98823.0	1.3201	53012.4	0.9563
19	2057.8	663462.7	39.6	182494.5	35256.3	1.0893	40278.8	0.9514
20	2173.4	794814.1	41.0	822682.7	170032.8	1.0923	200001.3	0.7987
21	1689.3	682122.6	48.9	583843.2	119750.8	1.0313	145308.6	0.8296
22	1990.8	588991.8	38.5	51273.6	7630.9	1.0439	11537.1	0.9843
23	2071.4	486933.3	33.7	202940.5	39560.7	0.9195	46422.5	0.9237
24	2236.8	514603.9	32.1	474311.1	96691.4	0.8945	111171.6	0.8272
25	1814.3	795396.2	49.2	1203870.4	250282.8	1.0212	300667.9	0.6976
26	1907.8	614165.3	41.1	192102.5	37279.0	1.0411	46903.3	0.9389
27	2048.2	890203.4	46.1	659761.9	135733.7	1.2126	134881.8	0.8788
28	1861.2	563176.2	40.3	68464.2	11249.9	1.0164	16937.2	0.9759
29	2177.7	1266050.8	51.7	1337823.0	278483.4	1.4384	206655.9	0.8694
30	1965.3	637434.5	40.6	976795.3	202477.5	0.9155	239445.7	0.6995
31	1911.1	591906.1	40.3	270114.2	53702.6	1.0055	67508.5	0.9088
32	1950.5	884201.5	48.2	539337.5	110381.1	1.2296	99778.1	0.9097
33	1759.2	919276.4	54.5	1952056.7	407795.7	0.9970	488008.3	0.5753
34	1919.1	808698.2	46.9	273970.8	54514.5	1.2085	39578.1	0.9608
35	2056.2	786142.4	43.1	288497.8	57572.8	1.1846	49465.3	0.9497
36	1991.8	506337.4	35.7	1181872.4	245651.7	0.7537	255127.4	0.5969
37	2046.5	1180705.3	53.1	741773.8	152999.3	1.4702	38413.6	0.9740
38	1656.2	694661.8	50.3	1233637.9	256549.7	0.9210	304255.3	0.6496
39	2082.7	561118.4	36.0	257557.8	51059.1	0.9789	64094.1	0.9086
40	2249.8	547962.7	32.9	249791.6	49424.1	0.9680	61767.8	0.9098

Coefficient of genotypic variations of Francis and Kanenberg

Francis and Kanenberg (11) to determine the stability of corn varieties used the coefficient of variations of a genotype that measures the share of genotype I in the interaction between genotype and environment and is independent from the other tested genotypes. In fact, CV_i measures deviation of a genotype from average genotypes in all environments. According to this criterion, a genotype is more stable when genotype variation coefficient is less. As it is shown in **Table 5**, genotype 1 was the most stable genotype but genotype 33 has more coefficient of variation and was more unstable than the other tested genotypes.

Wricke equivalence

Wricke (12) suggested that the interaction of genotype and environment for each genotype can be used as a parameter of stability, as this effect be squared for any genotype and added up in all environments. Genotypes that have small equivalence have less volatility and they are more stable. This parameter is directly related to the genotype × environment interaction and its calculation is simple. Considering that equivalence measures the contribution of each genotype in the interaction. Thus, a genotype with Wi² = 0 is considered as stable. According to data in **Table 5**, genotype 8 has had more stability but genotypes 29, 33 and 10 were the most unstable genotypes.

Shukla stability variance

Shukla (13) proposed variance estimate of genotype i in different environments based on remainder of the mutual classification of genotype and environment. Stability variance is linear combinations of equivalence so rating genotypes were similar in both models. Because the stability variance is based on the remaining of matrix of interaction of genotype and environment, so the more the variance, indicates less the main effect of genotype is considering as more stable genotype. Ranking of genotypes based on Shukla stability variance is somewhat similar to Rick equivalence. Thus, the most stable genotype was genotype number 8. However, genotypes 29, 33 and 10 were the most unstable genotypes.

Finlay and Wilkinson

In this method, two parameters of regression coefficient and deviation from regression as stable parameters are used and regression of genotype and environment interaction on environmental index is calculated, the difference is that before calculating the regression coefficient not needs to correct the environmental effects on values. Also, the performance of genotypes as main effects for genotype and environment and product of main effects of environment in regression coefficients is expressed. With this parameter, a genotype that has a gradient of 1 ($b = 1$) has the highest stability than the other genotypes. Finlay and Wilkinson (14) demonstrated that b parameter in addition to stability represents compatibility. Genotypes that significantly have regression coefficient greater than one have special compatibility for environments with high performance. However, according to the results in **Table 5** genotype 33 with $b = 0.997$ was the most stable genotype and genotypes number 29 and 37 were more unstable than the other genotypes and also genotype 29 is suitable for environments with good performance like Hashemabad.

Eberhart and Russell

Eberhart and Russell (15) measured varieties respond to environmental changes with coefficient of linear regression and deviations from the regression and grouped varieties based on regression coefficient less or more than one and variance of deviation equal to or different from zero. In this method the linear regression coefficient is accounted as the compatibility parameter and the deviation from regression is considered as the parameter of stability and nonlinear component. If the regression coefficient has not a significant difference with one, it should be benefitted as

the deviation of regression and average of yield because yield is associated with the linear response of varieties. This analysis is useful only if at least 50% of total sum of squares is expressed by sum of squares of interaction between genotype and environment. According to Eberhart and Russell (15), a genotype is stable when mean of squares of deviation is smaller than its regression. In **Table 5**, this specification is shown by genotype 8 while in genotype 33 the regression coefficient was near one but its sum of squares for regression deviation was higher than the other genotypes.

Determination Coefficient of Pintus

Pintus (16) proposed determination coefficient instead of mean of squares for regression deviation to be used in calculating the genotype stability. This parameter strongly depends on the studied genotypes and deviation from regression. A genotype with more coefficient of determination is more stable. Basically, genotype 8 showed a good stability, however genotypes 10 and 33 were unstable. Finally, after calculating the stability parameters and according to regression slope near one, it can be introduced that genotype 8 as the most stable genotype among all 40 studied genotypes since it has smaller share in the interaction of genotype and environment according to Wricke (12) ecovalans parameter and Shukla (13) stability variance. Genotypes 10 and 33 were the most unstable genotypes in terms of performance.

Determining the compatibility and yield stability

Determining the compatibility and yield stability is one of the most important and costly stages in reform program of crops. This issue is important because of the genotype interaction on the environment simply is not possible. The genotype interaction on the environment will be important when the interaction is significant and various genotypes show their superiority in different environments. The performance of a genotype in each environment consisting of the main effect of environment (E), the main effect of genotype (G), and the genotype \times environment (GE) interaction. Yan (17) stated that despite the effect of environment allocated a major role from changes of the whole performance and the effects of genotype and genotype \times environment interaction are small but these two effects were involved in assessment tests of genotypes and at time of selection of superior genotypes, genotype effect and genotype interaction on the environment must be considered simultaneously. Three methods

of statistical analysis include principal components analysis (PCA), additive main effects and multiplicative interaction (AMMI) and GGE biplot analysis based on singular value decomposition (SVD) are established and often used for the analysis of experimental data comparing the performance in area.

Analysis in AMMI method

AMMI method justifies the main part of the sum of squares of genotype \times environment interaction. In contrast to the regression methods that is not able to predict the nonlinear of response of genotypes to the environment, separate main and interaction effects and estimates performance. Also, it makes possible interpretation of analyzed data. This model uses incremental analysis for the main effects and multiplicative analysis for interactions and is a combination of variance analysis and analysis to principal component.

AMMI model reduces errors and its statistical benefit is equal to add 1 to 3 replications in a testing experiment. IPCA is stability score of

genotype that scores more negative or positive indicates compatibility to a particular environment and scores close to zero means greater stability. It may be obtained a large number of IPC in analysis of AMMI but much IPC causes error and two IPC seem to be enough for analysis.

In **Figure 2**, diagram of analysis by AMMI method based on two components IPC1, IPC2 is shown. Share of the first component explained 49%, the second component explained 22% and overall they explained 71% of the variance. The first group that have IPC1 positive are appropriate for Hashemabad region, includes genotypes TJ82, SB29, Sb9, SB26 and Golestan commercial cultivars which are high yielding varieties. The second group includes genotypes DB19, DB22, and SB34, which are unstable cultivars and are suitable for Anbarolum region. The third group includes genotypes SB36, TJ8, TJ185 that with the commercial cultivars of Sepid has special are compatible to Gonbad region.

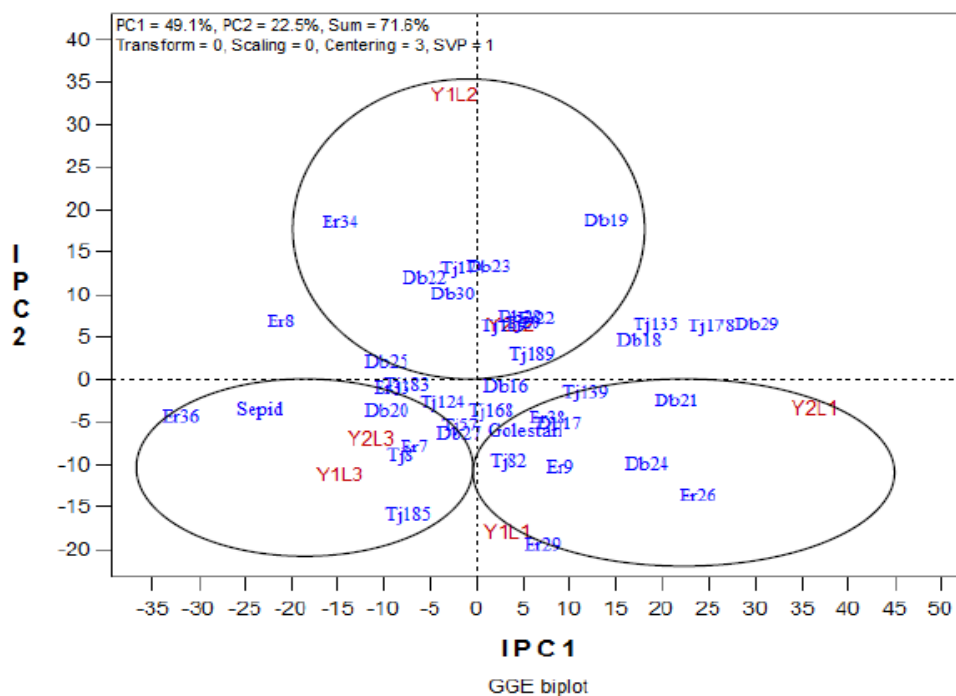


Figure 2. Diagram of analysis by the AMMI method based on two components

Biplot analysis

Biplot technique was first proposed by Gabriel (18) and then was developed by Kempton (19) and Zobl et al (20), but its widespread use in examining the genotype (G) and genotype \times environment (GE) recently (21). In the GGE biplot main effects of genotype (G) and genotype \times environment (GE) are not separated from each other. Base on view of breeders and producers genotypes selection on G or GE crops alone is not considered. So

study these effects have to be done simultaneously. That's why Yan et al (17) believe that GGE biplot analysis is more successful than genotypic data in the AMMI method.

There are many ways to characterize the interaction of G \times E. Charts that simultaneously show genotypes reaction in different environments (biplot) have much important and wide uses. GGE biplot is a tool

for data visualization because shows interaction between genotype and environment in a bilateral graph. Hens, to determine the stability of various products such as rice (22), barley (23), wheat (24) and lentils (25) have been used.

To identify superior genotypes and environments, polygon graph was plotted by software GGE biplot. The corresponding polygon is obtained from connection of genotypes that have the maximum distance from the origin. On this basis, superior genotypes included TJ82, ER26, DB29, DB19, DB25, and ER36 that are placed at the head of the polygon. Using vertical lines on the sides

of the polygon, larger environments were identified that in this figure, Hashemabad environment placed in one group and Anbarolum and Gonbad regions placed in another group. Another consequence is that because of placing genotype ER26 in top of the first group of environments is suitable for Hashemabad and genotype TJ82 is appropriate for second group of areas. Other genotypes were not placed in any environment, which indicates that these genotypes showed no superiority in none of environments. Of course, two components specified in this figure justify totally 74% of the variations (**Figure 3**).

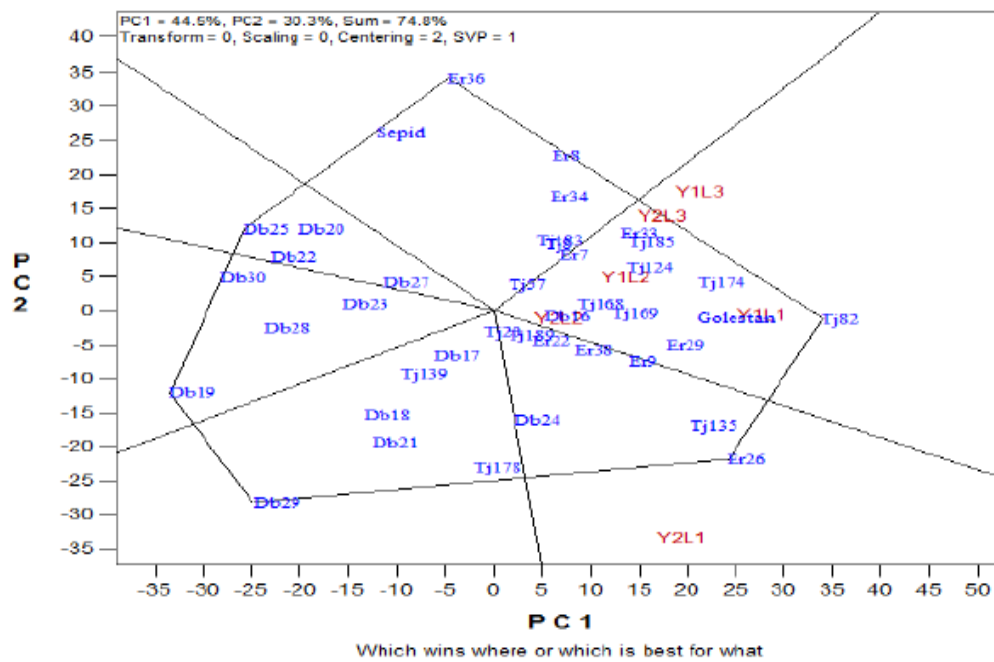


Figure 3. Graphical representation of compliance of 40 cotton genotypes with three regions Hashemabad, Anbarolum and Gonbad in two years (2015-2014)

If the sum of the first and second principal component fails most of the variation, that reflects the complex nature of the interaction between genotype environment and biplot not necessarily mean invalid.

In **Figure 4**, the average of performance of genotypes and their stability is simultaneously studied. Genotypes that are placed in positive side of X axis i.e. genotype TJ82 had the highest performance and in contrast, genotypes in left side of X axis, such as DB19 had the lowest performance. Genotypes ER36, DB29 in addition to low yield, had the most instability. Because the more the length of the perpendicular line on the horizontal axis is more, it represents the instability of the genotype. Finally, genotype TJ82 was selected as the best and most stable while Golestan

cultivar also had a good performance and stability (**Figure 4**).

Survey results showed that the GGE biplot an easy way to evaluate the effect of genotype on the environment and useful information about the genotypes and environments provides under review. Other researchers have reported similar results (5-26-27).

Abbreviation

- AMMI: Additive main effects and multiplicative interaction;
- GEI: Genotype-environment interaction;
- GGE: Genotype main effects and genotype × environment interaction effects;
- AEC: average environment coordinate;
- PCA: Principal components analysis;
- SVD: Singular value decomposition;
- IPCA: interaction principal component axis;
- HVI: High Volume Instrumentation.

ACKNOWLEDGMENTS:

I would like to express appreciation to my advisor Dr. Ranjbar and Dr. Zangi, who's theirs, guidance in my professional and

personal life will last a lifetime. I would also like to thank Dr. Roshani, head of Research Cotton Institute of Iran for providing financial support during the course of this research.

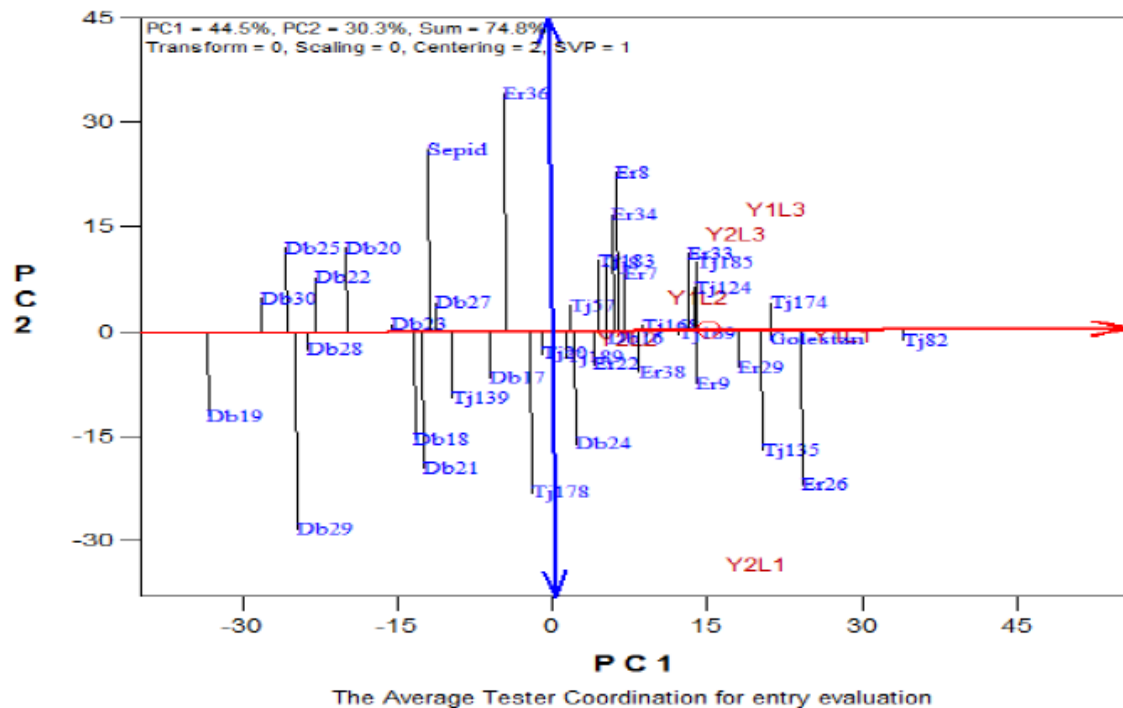


Figure 4. Evaluate cotton genotypes in 6 environments based on yield and stability simultaneously

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