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Full Length Research Paper

Response study of canola (*Brassica napus* L.) cultivars to multi-environments using genotype plus genotype environment interaction (GGE) biplot method in Iran

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To study the interaction of genotype and environment in canola crop, a study was carried out in 2010. Ten genotypes (Modena, Okapi, Hyola 401, Licord, Opera, Zarfam, RGS 003, SLM046, Sarigol, and Hyola 308) of canola were studied under normal conditions of irrigation in four locations (Karaj, Birjand, Shiraz, and Kashmar) using randomized complete block design with three replications. Using GGE biplot method, grain yield was investigated for each cultivar. According to analysis of variance, there was a very significant difference among the regions. According to the yield average and genotype stability, Licord, Hyola 308, Modena and Zarfam were the best cultivars. The graphs obtained from GGE biplot software indicated that Hyola 401, Opera, and Sarigol were better than the rest of the genotypes based on stability and yield performance. At location Shiraz, none of the genotype had appropriate stability or yield. Four locations were divided into three mega-environments including Karaj, Kashmar (first mega-environment), Birjand (second mega-environment), and Shiraz (third mega-environment). Moreover, Karaj was recognized as the best region of the classification and ranking of genotypes. The study indicated that the highest and lowest genotypic reaction rates belonged to Licord and SLM 046 cultivars, respectively.

Keywords: Canola, genotype environment interaction, grain yield, GGE biplot.

INTRODUCTION

The concept of biplot was first proposed by Gabriel (1971). Phenotypes are a mixture of genotype (G) and environment (E) components and their interaction (G×E) complicate the process of selecting genotypes with superior performance (Delacy et al., 1996).

Numerous methods have been developed to reveal patterns of G×E interaction, such as joint regression (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966; Perkins and Jinks, 1968), additive main effects and multiplicative interaction (AMMI) (Gauch, 1992) and type B genetic correlation (Burdon, 1977; Yamada, 1962).

The biplot technique was used to display the GGE of METs data, referred to as a GGE biplot (Yan, 2001; Yan et al., 2000). GGE biplot is an effective tool for: 1) mega-environment analysis ("which-won-where" pattern), whereby specific genotypes can be recommended to specific mega-environments; 2) genotype evaluation (the mean performance and stability), and 3) environmental evaluation (the power to discriminate among genotypes in target environments) (Yan and Kang, 2003; Yan and Ma, 2006).

GGE biplot analysis is increasingly being used in G×E interaction data analysis in agriculture (Butron et al., 2004; Crossa, 2002; Dehghani et al., 2006; Kaya et al., 2006; Samonte et al., 2005; Tinker, 2005; Yan et al., 2000; Yan, 2002; Yan and Kang, 2003; Yan and Ma, 2006). Yan (1999) and Yan et al. (2000) presented

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Abbreviations: GGE biplot, Genotype plus genotype environment interaction; **GE,** genotype environment interaction; **AMMI,** additive main effects and multiplicative interaction; **MET,** multi-environmental trials.

Table 1. Summary information of the four sites.

Trial	Karaj (KRJ)	Kashmar (KAM)	Birjand (BIR)	Shiraz (SHZ)
Latitude	35° 49´ N	35° 24´ N	32° 84´ N	29° 61´ N
Longitude	51° E	58° 46´ E	59° 24´ E	52° 53´ E
Elevation (m)	1360	1065	1503	1531

Table 2. Analysis of variance for grain yield of the ten canola genotypes in the four locations of Iran.

Sources of variation	DF	SS	MS
Environment (E)	3	1320177.39	440059.13**
Genotype (G)	9	1060479.44	117831.05**
E × G	27	1683354.39	62346.45**
Error	72	1977732.99	27468.51
Total	111		

** Significant at 1% level of probability.

a versatile graphical approach for analyzing multi environment trials (METs), named as GGE biplot. The term GGE is the abbreviation of G + GE. Indeed, the term GGE refers to the effects of genotypes and inter-actions of genotype and environment (Yan and Kang, 2003).

Gunasekera et al. (2006) studied seven cultivars of canola in three regions, during two consecutive years, within three cropping intervals, under Mediterranean climate of the southwest of Australia. The results showed that grain yield vary significantly among different locations, cultivation time, and genotypes. The grain yield of early cropping in all locations was more than that of late cropping. Based on biplot grain yield, the studied environments were divided into three groups with high, intermediate and low yield. In that research, the genotypes which privately were adaptable to certain regions were identified.

The study was undertaken to know the interaction of genotype and environment graphically and identify the best genotype for specific location and also to indentify the existing mega-environments among the studied regions or classification of regions.

MATERIALS AND METHODS

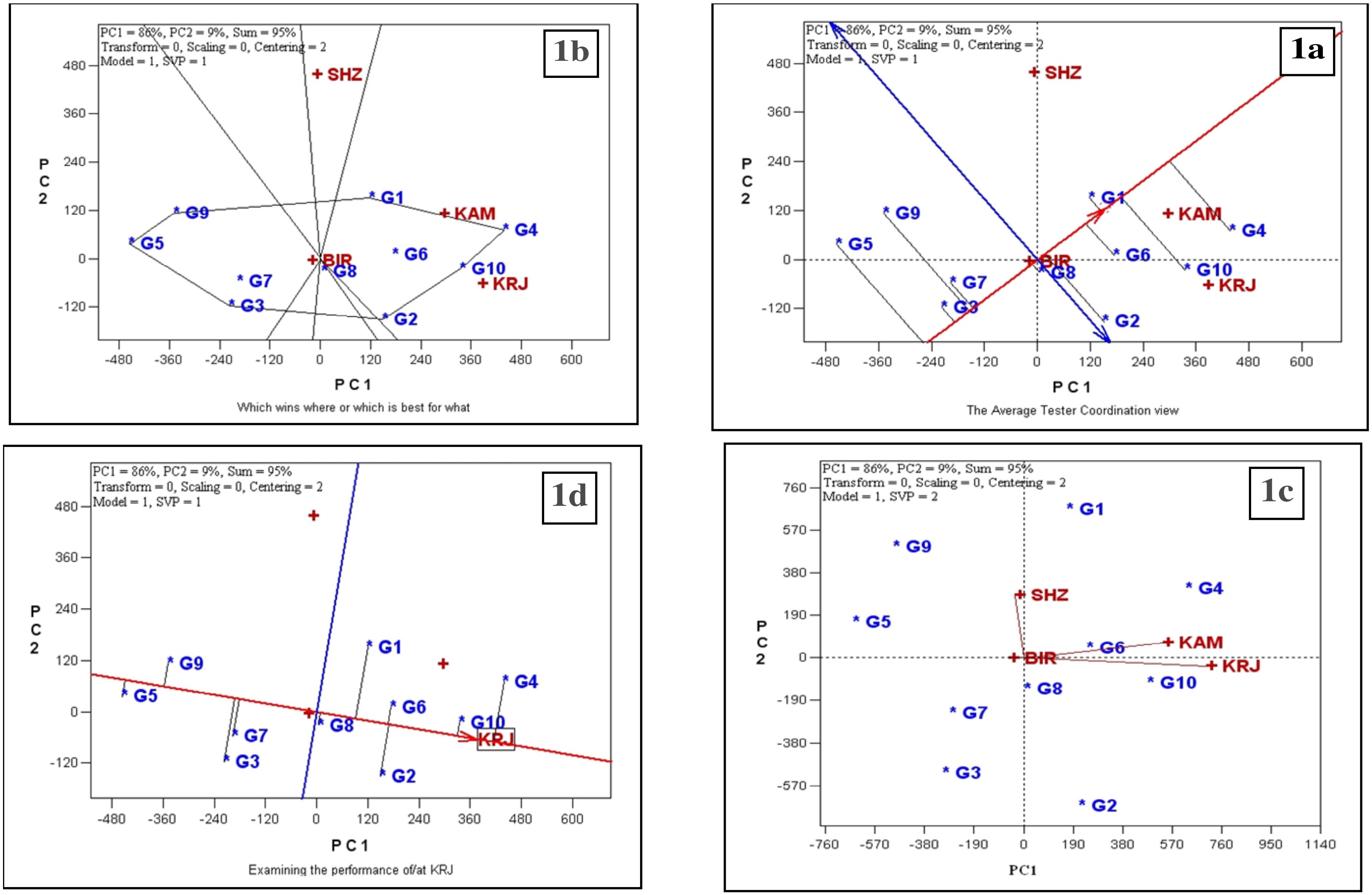
To study the interaction of genotypes with environment in canola cultivars using GGE biplot, a research was carried out in 2009 to 2010. Ten genotypes of canola were studied under normal conditions of irrigation, using randomized complete block design with three replications. The cultivars consisted of Modena, Okapi, Hyola 401, Licord, Opera, Zarfam, RGS 003, SLM046, Sarigol and Hyola 308. Performance trials were conducted in four canola producing areas of Iran including Karaj, Birjand, Shiraz and Kashmar. The geographical longitude and latitude of each region is presented in Table 1. Each entry was allocated to a four row plot, 2 m long and 50 cm wide. Grains were cultivated in the rows with 25 cm plant to plant space. Weeding and thinning were carried out manually. Research plots were irrigated at an interval of ten days. To prevent marginal effects, data were taken on central rows of each experimental unit. Analysis of variance for grain yield was computed using SAS software and GGE biplot software as proposed by Yan, 2001 and Yan and Kang, 2003. Similarly, the graphical interaction of genotypes and environments was based on the method of Yan and Hunt (2001).

RESULTS AND DSCUSSION

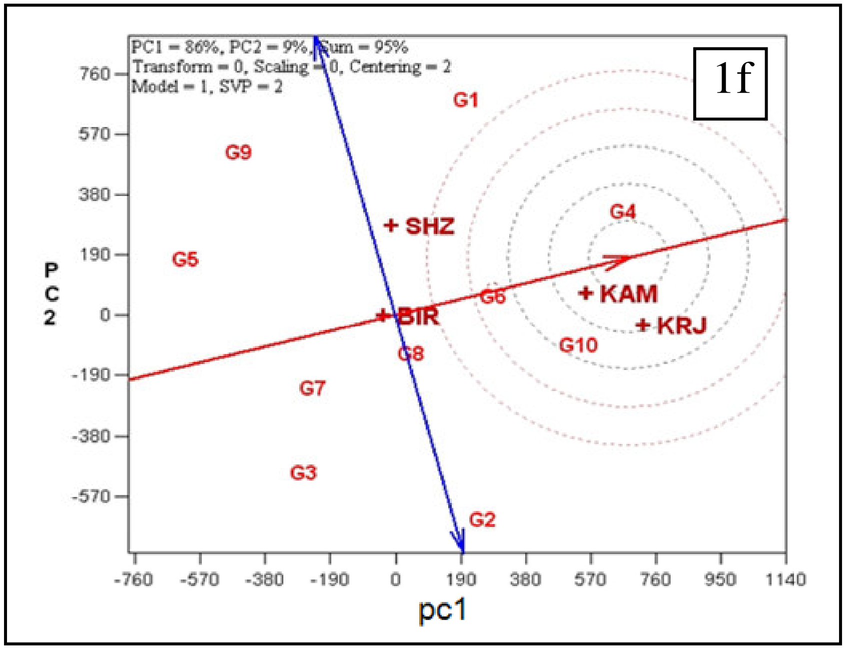
Analysis of variance showed that the grain yield of genotypes was significantly different ($p < 0.01$). The interaction of genotypes with locations was also significant (Table 2). The diversity among the tested cultivars, environments and their interaction are presented in Figure 1. The graph explained 95% of the data variation (PC1= 86%, PC2 = 9%). These results were presented in four different sections to split up the total variation.

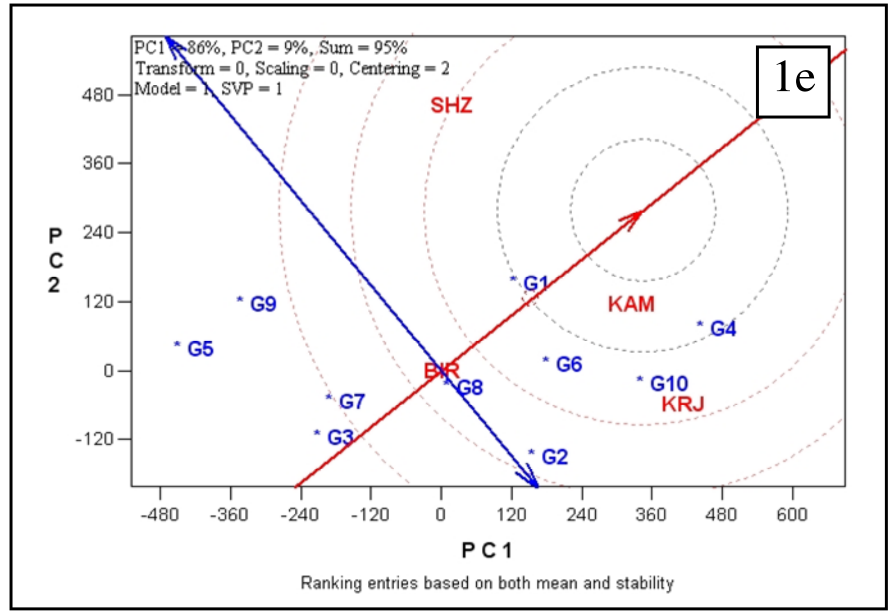
In the 1st section, genotypes yield and their stability were studied (Figure 1a). In the 2nd section, the performance of different genotypes in different regions was shown, which was used to identify the best cultivar for each region (Figure 1b). In the 3rd section, the possible relationship among the locations was studied for classification of the regions on diversification (Figure 1c). The 4th section provided the ranking of the cultivars in superior region (Karaj) (Figure 1d).

Using biplot techniques, the horizontal axis (PC1) indicated the main effect of genotypes while the vertical axis (PC2) showed the interaction of genotypes and environment, which is considering a basic criterion for genotypes instability (Yan, 2002). The line that passed from the origin of the coordinates to the mean of locations (shown by a dotted circle) is referred to as mean axis of locations. The cultivars located on the positive side of the



Figures 1. GGE biplot graph regarding the grain yield of ten cultivars of canola studied in four regions. **a**: The determination of the status of genotypes and their location, as well as location means used to classify cultivars based on the yield and stability mean. **b**: Polygon representation to determine the genotypic reaction of cultivars to the regions**. c:** Location's vector to determine the relation among regions.





Figures 1. Contd.

axis produce higher yield and vice versa. The biplot organized the tested genotypes on the basis of their yield performance as G4>G10>G1>G6>G2>G8>G7>G9>G3>G5 (Figure 1a).

Using the above information as stated by Yan (2002) for stability, the cultivars G1, G3, G7, and G8 were identified as more stable than the rest of the cultivars. In general, cultivars that were standing next to the origin (like G8) was more stable; they react rarely to the changes in environment. An ideal cultivar (G8) should offer firstly a high yield and stability. On the other hand, the optimal cultivar should be located near to the positive end of the mean axis of the locations, and vertical distance of that axis should be low. Based on this particular fact, the cultivar G1 was declared as the best cultivar and can be used for the evaluation of other cultivars; those genotypes located near the ideal cultivar (both stable and high yielding) were more appropriate genotype.

The polygon view (Figure 1b) was used to determine the best genotype for each location. From the origin of each side of the polyhedron, a line stood vertically to divide the Figure 1b into several sectors for the identification of special cultivar with broader adaptability. Thus, the genotype G4 in Karaj and Kashmar, and genotype G5 in Birjand offered better yield. The best genotype was the one located on the apex of the polygon. Genotypes near the origin had less reaction on the changing environment. Similarly, those environments near the origin also showed less reaction on the changing performance of the genotype.

Figure 1c showed the relation among environments. The angle existing between the axes of two environments showed the correlation of two environments. Therefore, the tested environments were divided into three groups based on biplot technique. The first group consisted of Karaj and Kashmar, the second group had Birjand while the third group had Shiraz. Figure 1d addressed the yield of the genotypes in Karaj. For this purpose, a line connected the origin of the coordinates to the intended point; Karaj and it extended from both sides. Those genotypes inclined to the positive end of this axis offer more yields and vice versa. According to Figure 1d, the cultivars order based on their yield in Karaj was as follows: G4>G10>G2≈G6>G1>G8>G7>G3>G9>G5.

Ranking of the genotypes based on the best cultivar is presented in Figure 1e. The most ideal cultivar was the one inclined to the positive end of the axis with least vertical interval from the line.

To identify the best or most discriminative environment ranking is given in Figure 1f. The environment located near the center of the concentric circle was declared as the best. Thus, the biplot placed all the environments in the order of KAM>KRJ>SHZ >BIR.

The study indicate that for the identification of suitable high yielding and stable genotypes based on their yield performance, GGE Biplot technique is one of the best strategy with limited resources. Biplot was also identified as the best tool for screening the high yielding and stable genotypes (Ullah et al. 2011).

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