Study on Spring Type Safflower Lines Suitable for Cold Drylands Using GGE Biplots

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Abstract: Identification of suitable spring safflower cultivars for cold areas is one of the most important breeding objects in dryland conditions. Although the grain yield is a combined result of effects of genotype (G), environment (E) and genotype × environment interaction (G×E), only G and G×E are relevant to cultivar(s) selection. In this study, five advanced lines of safflower were studied in four research stations over two years using GGE biplot which is constructed by two symmetrically scaled principal components. GGE biplot displayed G plus G×E effects, graphically. Lines 333 and 79-299 in Maragheh, 79-299 and 333 in Kurdestan, 79-299 and 333 in Shirvan and PI-537598 and 36 in Zanjan had the highest and poorest performance over two years, respectively. For spring safflower in cold drylands, biplot graphics suggested the existence of three mega-environments including 333 winning area (Maragheh), 79-299 winning area (Shirvan) and PI-537598 winning niche (Kurdestan and Zanjan). It is recommended that mega-environments be determined on the base of safflower data before release of any new cultivar for target area using conventional adaptability trials.

Key words: Biplot · Carthamus tinctorius · Highlands · Rainfed

INTRODUCTION

Approximately 6.2 million hectares of agricultural lands are affected by drought across Iran, which mainly use for wheat and legumes production; and about 2-3 million hectares of dry lands are left as fallow every year [1]. Continuous wheat cultivation without suitable crop rotation has restricted the wheat production in dry lands. Recently, food legumes cultivation areas have been decreased due to the highest cost of legumes production, poor yield and their unstable prices. Developing oilseed crops production in the drylands is important, since about 90% of high-demanded edible oils in the country are imported. Safflower as a native plant of Middle East and Mediterranean areas is a suitable oilseed crop for dry lands of Iran [1,2]. Safflower can improve dry lands rotation due to using fallow and range lands by reducing soil erosion, but present safflower cultivars could not be planted as a winter crop in the cold dry lands [1]. Hence, identification of suitable spring type safflower could be the first priority in the cold dry lands. Previous studies on exotic and local germplasm of safflower as spring crop showed that there are some lines suitable for cold dry lands [3].

Multiple environment trials are conducted to identify superior cultivars for the target region. Although the measured yield is a combined result of effects of genotype, environment and genotype × environment interaction (G×E), only G and G×E are relevant to cultivar evaluation. Conventional methods for stability analysis use G×E or both G and G×E to identify superior cultivars, however, they do not give any sense about target environment. Investigation of mega-environments, which has been an important criterion of multiple environment trials, is a prerequisite for meaningful cultivar evaluation and recommendation [4]. Furthermore, multiple environment trials can develop understanding of the target region especially when the target region can be subdivided into different mega-environments. GGE (i.e., G + GE) biplot, which is constructed by the first two symmetrically scaled principal components derived from singular value decomposition of environment-centered multiple environment trials data, may be useful in the investigation of mega-environments [5]. Each genotype is represented by a point, called a marker, defined by the genotype's scores on all principal components and each environment is represented by a marker defined by the environment's scores on all principal components. Such a plot is called a biplot because both the genotypes and the environments are plotted in a single plot. Biplots can be multidimensional, but two-dimensional biplots, using only the first and the second principal components, are most common, both for biological reasons as well as for easy comprehension [5]. In this paper, the multiple environment trials on promised safflower lines were analyzed using two-dimensional biplot technique.
MATERIALS AND METHODS

Five safflower promised lines (79-299, 333, 36, 336 and PI-537598 from origin of Iran, Turkey, Pakistan, USA and unknown, respectively) were evaluated in two growing seasons (2004 and 2005) at four research stations of Dryland Agricultural Research Institute (DARI) in Iran (Table 1). The individual trials were conducted using a randomized complete block design (RCBD) with three replications. The experiments were planted in the late April in the fields. Each genotype was sown in plots of 6 rows, 5-m long, with spacing of 30-cm between rows. Each plot was harvested leaving 30 cm on both ends of the rows in order to exclude border effects.

The biplot software developed by Yan [6] was used to display the performance of genotypes in a single biplot. In which, according to Gabriel [7] a $g \times e$ matrix of mean yield of $g$ cultivars in $e$ environments can be approximated through singular value decomposition, as the product of a genotype matrix and an environment matrix, so that the yield of genotype $i$ at environment (location) $j$, $Y_{ij}$, is approximated as:

$$Y_{ij} = \sum_{n=1}^{r} \lambda_n e_{in} \eta_{jn} (\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \cdots \geq \lambda_r)$$

where $r$ is the number of PCs required to approximate the original data, with $r=\min(g,e)$; $\lambda$s is the singular value of PC$n$, the square of which is the sum of squares explained by PC$n$, $e_i$ and $\eta_j$ are the $i$th genotype score and the $j$th environment score, respectively, for PC$n$. GGE biplots of sites regression were illustrated, finally [8].

RESULTS

Results of yearly analyses of variance (Table 2) showed location and Genotype × Location interaction effects were significant in both years. However, there was significant genotypic effect only in the first year.

Mean grain yield of lines in locations over years was summarized in Table 3. Lines '79-299' in Shirvan, PI-537598' in Kurdestan, '333' in Maragheh and '336' in Zanjan had the highest grain yield.

Graphic comparison of the relative performance of all genotypes at each location was illustrated in Fig .1. This was done by first drawing a straight line passing through the plot origin and the marker of location, then drawing a perpendicular to this line from each genotype marker. The location-centered yield of each genotype at each particular location was the length of the location vector multiplied by the length of the projection of each genotype onto the location vector which could be positive or negative. The relative yield of the genotypes could be compared simply by the length of their projections. Line '333' had the highest yield at Maragheh,
followed by '36', '336', 'PI537598' and '79-279'. The lines 'PI537598' and '79-279' had lower yield than average, since they were located beyond the thick broken line that was perpendicular to the vector of location Maragheh and passed through the origin. This line separates the cultivars with higher than average yield from those with lower than average yield. Genotype '79-299' was the best line at Shirvan and '333' had the poorest performance in this location (Fig. 1-c). In Zanjan, lines 'PI-537598' and '336' had higher grain yield than average yield and lines 'PI-537598' and '36' were the best and poorest lines in this location, respectively (Fig. 1-d).

In the first year (2004), the locations were divided between two sectors (Fig. 2-a). The first sector contained Zanjan, Kurdestan and Shirvan, with cultivar PI-537598 and '79-299' being the winner. Maragheh made up the second sector, cultivar '333' was the winner. Three sectors were obtained in the second year. The first sector contained Kurdestan and Shirvan with winning line of '79-299'. The second and third sectors included Zanjan and Maragheh, respectively.

**DISCUSSION**

Yearly analysis of variances gave an overall view of the relative magnitudes of the Genotype, Location and Genotype × Location variance terms. The large Genotype × Location effect comparison to Genotype effect in both years (Table 3), suggests the possible existence of different mega-environments that was more
evident in the second year. The large yield variation due to location, which is irrelevant to cultivar evaluation and mega-environment investigation (9, 10), suggests using of GGE biplots of sites regression as the appropriate model for analyzing the multiple environment trials data [8].

On related biplot of each location, some corner genotypes, which were the most responsive ones, could be visually identified (Fig. 2). These were either the best or the poorest genotypes at some or all locations; they could be used to identify possible mega-environments according to Yan et al. [5]. The corner genotypes for the 2004 dataset were all of the studied lines (Fig. 2). By connecting the markers of these corner genotypes a polygon was formed. By drawing perpendiculars to each side of the polygon passing through the origin, the locations were divided among years in several sectors, each with a different corner cultivar. The pattern of the location groupings varied across years. GGE biplot for both years (Fig. 2-c) suggested the existence of three mega-environments for spring safflower in cold drylands, namely 333-winning area including Maragheh, 79-299 winning area including Shirvan and PI-537598 winning niche including Kurdestan and Zanjan. Alizadeh [1] suggested the line 333 for release in all above mentioned areas using conventional stability analysis methods. Ghaffari and Depao [11] grouped Maragheh, Kurdestan and Zanjan different from Shirvan based on biomass production index and meteorological data which supports the results of this study. The identified mega-environments based on the location grouping in this study did not correspond with the other reported results. For example, Roustaii et al. [12] considered all above mentioned locations as one environment for winter wheat production in drylands.

Such a subdivision could be regarded only as a suggestion insofar as it is based solely on two year's data in four locations. It seems that more locations in more years would be considered for reliable subdivision of cold drylands for spring type safflower. Yan et al. [5] used 10 years data on 10 to 33 winter wheat cultivars for subdivision of Ontario winter wheat growing region.

It can be concluded that different cultivars should be deployed for the three mega-environments to achieve optimal safflower adaptation in cold drylands. It
is recommended that mega-environments be determined on the base of safflower data before release of any new cultivar for target area using conventional adaptability trials.

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REFERENCES