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Full Length Research Paper

A study on genotype x environment interaction in chickpea cultivars (*Cicer arietinum* L.) grown in arid and semi-arid conditions

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The study was carried out to identify stability and adaptability of 19 chickpea (*Cicer arietinum* L.) cultivars grown in arid and semi arid conditions at three locations (Field Crops Central Research Institute in Ankara, Bahri Dağdaş International Agricultural Research Institute in Konya and Research Farms of Agriculture Faculty of Suleyman Demirel University in Isparta) for two years (2005 and 2006 years). Experiments was set up as randomized complate block design with three replications. Studied parameters were plant height, first pod height, 100 - grain weight and grain yield and stability parameters were calculated according to Finlay-Wilkinson and Ketata methods. Results showed (confirmed) that Menemen 92 (4) and İzmir 92 (6) were the highest yielding and stable cultivars at three locations during the study period in terms of plant height, first pod height and grain yield. For the 100 grain weight, Çağatay (2), Akçin 91 (9) and Er 99 (13) cultivars performed better than other cultivars.

Key words: Chickpea, cultivar, genotype x environment interaction.

INTRODUCTION

Chickpea is an important nutrition source for its dry grains containing around 20% raw protein and 6% leucine (Cinsoy et al., 2005). Variability of ecological conditions, inappropriate production methods and insufficient numbers of stable types may cause fluctuations in the production of chickpea. Production efficiency, suitable place and conditions for the production of developed types should be determined by the plant breeders (Yilmaz and Tugay, 1999).

In general, stability is defined as the practicable performance of genotypes under changing environmental conditions. In biological sense, stability is the fixed production efficiency of the species under different environmental conditions, while in agricultural sense, it means whether species display the same production efficiency as predicted. Reliable stability of production efficiency under changing conditions of environment is very important. For this reason, plant breeders desire for the general adaptation capability in the species they develop. Adaptation demonstrates the high production efficiency of the species in a given region, on the other hand, stability indicates the constant mean efficiency in different environments (Gencer and Killi, 1994; Altinbaş, 2003; Atta et al., 2009).

To implement stability analysis, variance values of the genotype x environment interaction must be statistically significant. Selection of the species would be easier in the studies carried out to determine adaptation of species in different environmental conditions if the variance were statistically insignificant. When the interaction is significant and rank of species performance changes, species should be bred for each location. Significance of genotype x year interaction can't be easily interpreted, and since it is not possible to apply different breeding programs every year, the best way is to select lines that show higher performance annually. When the genotype x

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location x year interaction is significant, plant breeders should select the lines with the highest average efficiency. Stable lines have low variance, similar performance to their experimental performance average and low mean square for deviation from regression. In addition, if a genotype shows constant performance in different environments, it is defined as biologically stable and if it reaches the desired efficiency level in a given region, it is defined as agronomically stable (Yilmaz and Tugay, 1999; Bozoğlu and Gülümser, 2000; Özberk et al., 2004; Özcan et al., 2005). In plant breeding studies, genotype performance in terms of yield and yield components and the effects of environmental factors could be determined through variance analysis methods. However, the significance of genotype x year and genotype x location interactions complicates interpretation of the results. Therefore, selection of candidate lines and breeding species for certain ecologies could be accomplished using stability statistics (Zencirci et al., 1990; Dehghani et al., 2010). Stability parameters can be used alone and with various parameters to determine performance in different locations and periods. Widely used stability parameters are variation coefficient (VC), determination coefficient (R^2), regression coefficient (b), regression constant (a), mean square of errors and standard deviation. Genotype x environment interaction is more important for selection efficiency in plant breeding. Stability characteristics of genotypes grown in different environments could be determined by regression analysis. Mean square of deviation from regression (Sdi^2) is also an important method used in the determination of adaptation characteristics. As the regression coefficient gets closer to 1, stability of species or lines becomes higher. Genotypes with low (closer to 0) deviation from regression and high (above average) mean efficiency are accepted as stable. Besides, positive regression constant, high coefficient of determination and low variation coefficient are desired criteria in stability analysis. (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Ozdemir and Engin, 1996; Ozdemir et al., 1999; Kara, 2000; Özberk and Özberk, 2002; Albayrak et al., 2005; Duzdemir and Akdag, 2007).

In a study investigating the stability characteristics and environmental adaptation of the species, employed stability parameters developed by Finlay and Wilkonson (1963), Perkins and Jinks (1968), Wricke (1962), Eberhart and Russell (1966), Shukla (1972), Francis and Kannenberg (1978), Baker (1969) and Ketata (1984), stated that Finlay and Wilkinson (1963) method was easier but incomplete and Ebehart and Russell (1966) method including mean square of deviation from regression would be more suitable. Çaylak et al. (1994) carried out a study on soybean and defined the genotype average higher than general average and regression coefficient equal to 1 as good adaptation to all environments and genotype average lower than general average and regression coefficient equal to 1 as bad adaptation to all environments. Researchers estimated regression coefficient higher than 1 as special adaptation to favorable environments and regression coefficient lower than 1 as special adaptation to unfavorable environments. This study was carried out to determine certain stability parameters of 19 chickpea genotypes grown in Ankara, Konya and Isparta province of Turkey in for two years.

MATERIALS AND METHODS

Study was carried out during two years (2005 - 2006) in the experiment fields of Field Crops Central Research Institute in Ankara, Bahri Dağdaş International Agricultural Research Institute in Konya and Research Farms of Agriculture Faculty of Süleyman Demirel University. Study material was composed of 19 registered chickpea cultivars [Damla 89 (1), Çağatay (2), Gülümser (3), Menemen 92 (4), Aydin 92 (5), İzmir 92 (6), Cevdetbey (7), Sari 98 (8), Akçin 91 (9), Gökçe (10), Küsmen 99 (11), Uzunlu 99 (12), Er 99 (13), İnci (14), Canitez 87 (15), Aziziye 94 (16), Diyar 98 (17), ILC 482 (18), Eser 87 (19)]. Sowing were done made manually on plots composed of 4 rows, 5m long with 30 cm spacing between rows and 10 cm within rows. Experiment was set up as randomized complate block design with three repetitions. Sowings were made at the end of March in all locations and harvests were done the end of July. In the study, stability of the cultivars were investigated by two methods. Plant height, first pod height, 100-grain weight and grain yield were used to calculate stabilty parameters of the chickpea cultivars. In the first method, Finlay and Wilkinson (1963) formula was used:

$$bi=[\Sigma^{m}_{j=1} Y_{ij}X_j - (Y_i.)\ (X.) / m] / [\ \Sigma^{m}_{j=1} X_j^2 - X^2. / m]$$

i: genotypes (1 - 19), J: environments (1 - 3), m: number of environments

$[\Sigma^{m}_{j=1} Y_{ij}X_j - (Y_i.)\ (X.) / m]$: Sum of the observed values of genotypes multiplied by the average of environments

$[\Sigma^{m}_{j=1} X_j^2 - X^2. / m]$: Sum of Squares of independent variables (environments)

Regression coefficients were calculated by this formula and genotypes with genotype average higher than general average and regression coefficient equal or close to 1 were accepted as stable (Yilmaz and Tugay, 1999; Turan and Göksoy, 2002; Kumeagac and Sağlam, 2005; Ozcan et al., 2005). Figure 1 is used in the classification of species in terms of stability.

In the second method, mean rank and rank standard deviation model was used to evaluate low number of genotypes. For the determination of highly efficient and stable genotypes, “mean rank values” and “rank standard deviations” were calculated using rank values of genotypes in each environment (Hühn, 1979; Ketata, 1984; Ketata et al., 1989; Huehn, 1990; Özberk et al., 2004). For this reason, cultivars were grouped as the rank values in X axis and rank standard deviations in Y axis. As can be seen in (Figure 2), genotypes with low rank and low rank standard deviation were found highly efficient and stable (I. Region), genotypes with low rank and high rank standard deviation were highly efficient but unstable (II. Region), genotypes with high rank and low rank standard deviation were efficient but stable (III. Region) and the genotypes with high rank and high rank standard deviation were classified as low efficient and unstable (IV. Region) (Özberk et al., 2004). Analyses were carried out using Totemstat and Tarpopgen

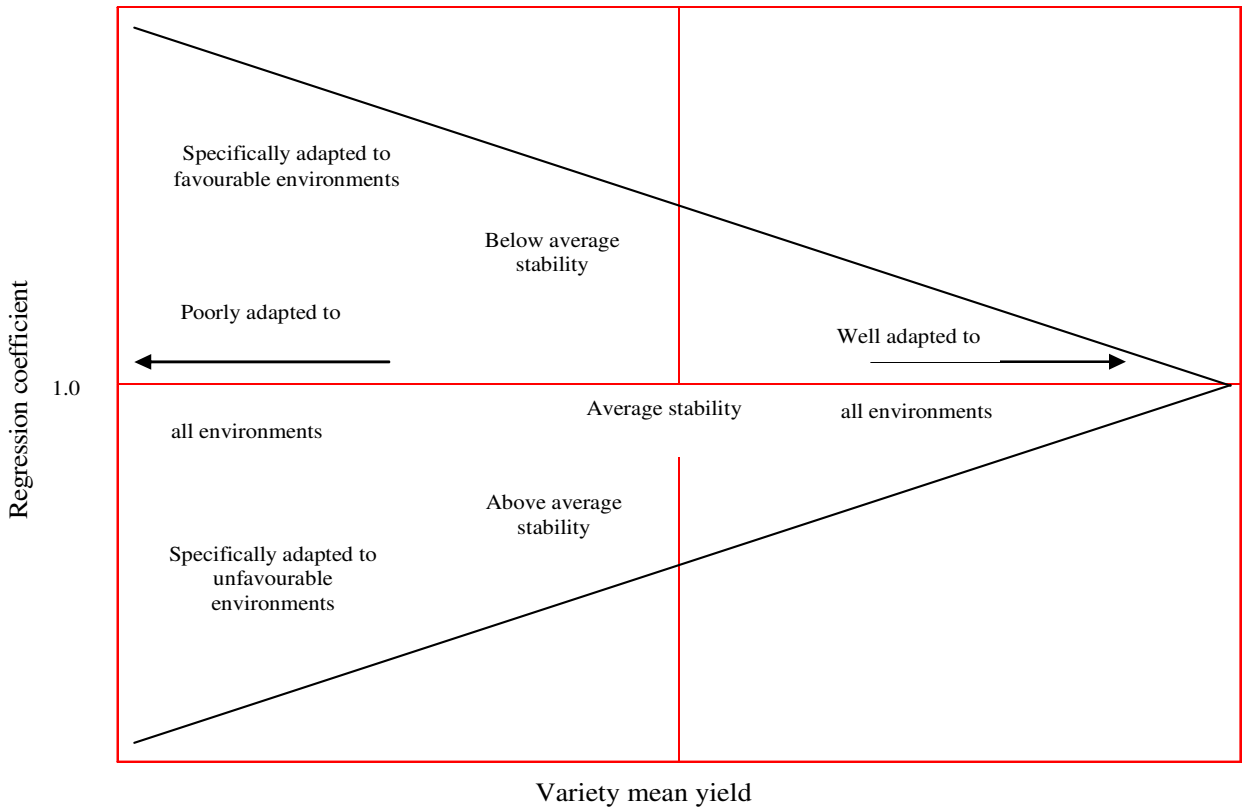

Figure 1. Grouping of cultivars according to regression coefficient and general average yield (Finlay and Wilkinson, 1963).

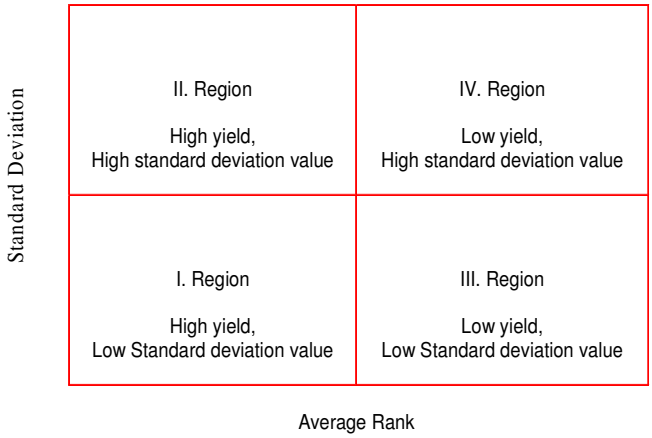

Figure 2. Grouping of cultivars according to average rank and standart deviation values (Ketata, 1984; Ozberk et al, 2004).

statistic programs (Özcan, 1999; Açikgöz et al., 1994).

RESULTS AND DISCUSSION

In this study, 19 chickpea cultivar were studied in three different locations for 2 years. Variance analysis was performed using plant height, first pod height, 100 grain weigth and grain yield. Year x location x genotype interaction and the difference between the regression coefficients of genotypes were found to be statistically significant. Therefore, annual stability graphics were prepared according to the methods of Finlay and Wilkinson (1963) and Ketata (1984). In the studies on different plants, variances of genotype x environment interaction should be statistically significant for the stability analysis and for this reason, experiments repeated in different locations and years should be combined and mean squares of genotype x location, genotype x year and genotype x location x year interactions should be determined with F test. In addition, when the genotype x year interaction is significant, annually separate breeding programs could not be applied therefore, superior genotypes should be selected each year and genotypes that have suitable stability parameters in terms of genotype x location x year interaction and higher efficiency than general average should be selected (Arshad, 1990; Friman 1990; Yilmaz and Tugay 1999; Bozoğlu and Gülümser, 2000; Özberk et al., 2004; Cinsoy et al., 2005).

Stability levels of chickpea species considering plant heigth, first pod height, 100 grain weigth and grain yield according to Finlay and Wilkonson (1963) were given annually in (Figure 3). In terms of plant heigth, Sari 98, Gökçe, Küsmen 99, Er 99, İnci, Canitez 87, ILC 482 and

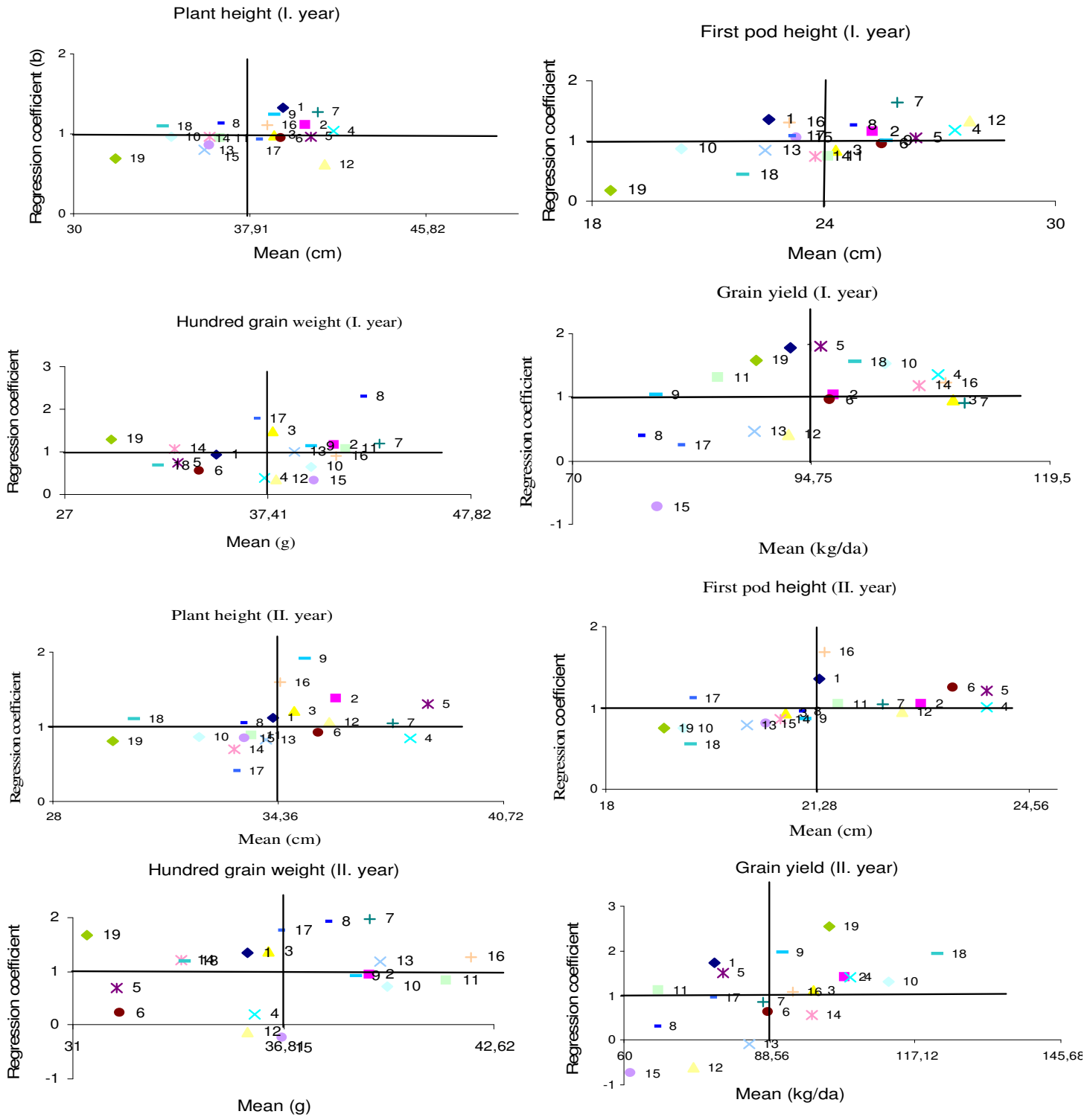

Figure 3. Stability analysis according to Finlay and Wilkinson (1963) in plant height, first pod height, 100 grain weight and grain yield properties on chickpea varieties grown in three locations. (Numbers represents the chickpea cultivars).

Eser 87 had lower averages than the general average in the first year and Sari 98, Gökçe, Küsmen 99, Er 99, İnci, Diyar 95, ILC 482 and Eser 87 had lower avarages than general average in the second year, therefore, these cultivars were determined as unstable. At both years, Damla 89, Çağatay Gülümser, Menemen 92, Aydin 92, İzmir 92, Cevdetbey, Akçin 91, Uzunlu 99 and Aziziye 94 had higher plant heigth than general average. Menemen

92 and İzmir 92 were the most stable cultivars based on regression coefficient for both years (Figure 3).

In terms of first pod height, Çağatay, Gülümser, Menemen 92, Aydin 92, İzmir 92, Cevdetbey, Sari 98, Akçin 91, Küsmen 99 and Uzunlu 99 had higher values than the general average in the first year and Damla 89, Çağatay Menemen 92, Aydin 92, İzmir 92, Cevdetbey, Küsmen 99, Uzunlu 99 and Aziziye 94 had in the second second year. Regression coefficient of Menemen 92, Aydin 92, İzmir 92 and Akçin 91 in the first year and Çağatay Menemen 92, Cevdetbey and Küsmen 99 in the second year were close to 1. Menemen 92 was the most stable cultivar in terms of first pod height in both years. 100 grain weigth of Çağatay Cevdetbey, Sari 98, Akçin 91, Gökçe, Küsmen 99, Er 99, Canitez 87 and Aziziye 94 cultivars were higher than the general average. Regression coefficients of Çağatay, Akçin 91 and Er 99 were close to 1, therefore, these cultivars were accepted as stable and highly efficient. In terms of grain yield; Çağatay, Gülümser, Menemen 92, Aydin 92, İzmir 92, Cevdetbey, Gökçe, İnci, Aziziye 94 and ILC 482 were higher than the general average (94.75 kg/da) in the first year and Çağatay, Menemen 92, İzmir 92 and İnci were determined as the most stable species in all conditions according to regression coefficients. In the second year, Çağatay Gülümser Menemen 92, İzmir 92, Akçin 91, Gökçe, İnci, Aziziye 94, ILC 482 and Eser 87 had higher grain yields, and Gülümser and Aziziye 94 were determined as the most stable species (Figure 3). According to the stability parameters, following criteria were taken into consideration to determine whether a cultivar is highly efficient in all conditions: (1) regression coefficient should be equal or close to 1, (2) coefficient of determination should be close to 1 and (3) sum of square of deviation from regression should theoretically be equal to 0 (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Püskülcü, 1974). All cultivars with higher genotype average than general and regression coeffcient equal to 1 were reported to demonstrate good adaptation ability in all environments in the experiments carried out with different species (Bilbro and Ray, 1976; Çaylak et al., 1994; Turan and Göksoy, 2002; Özberk et al., 2004; Albayrak et al., 2005; Cinsoy et al., 2005; Özcan et al., 2005).

Stability parameters of chickpea cultivars were prepared according to the mean rank and standard deviation model developed by Ketata (1984) and the results were evaluated using the scale reported by Özberk et al. (2004), then the cultivars were grouped (Figure 4). Results of the chickpea cultivars in both years were similar and in general, Çağatay Gülümser Menemen 92, Aydin 92, İzmir 92, Cevdetbey, Akçin 91 and Uzunlu 99 demonstrated high peformance in mean rank value. On the other hand, Çağatay, Menemen 92, Aydin 92 and Cevdetbey were determined as stable cultivars according to the mean standard deviation values. In the first year, Damla 89, Gülümser, Akçin 91 and Uzunlu 99 and in the second year, Gülümser, İzmir 92 and Aziziye 94 had high plant heigth, but they lost their stability (Figure 4). In general, cultivars with high plant heigth had the highest mean of first pod height, as well. In the first year, Çağatay, Gülümser, Menemen 92, Aydin 92, Sari 98, Akçin 91 and Uzunlu 99 and in the second year, Çağatay, Menemen 92, Aydin 92, İzmir 92 and Küsmen 99 were determined as the most stable cultivars considering stability parameters. However, Damla 89, İzmir 92, Cevdetbey and Aziziye 94 that had high mean of first pod height were not determined as stable.

Cevdetbey, Sari 98, Akçin 91, Gökçe, Küsmen 99, Er 99 and Aziziye 94 were the primary cultivars for 100 grain weigth. Cevdetbey, Akçin 91 and Küsmen 99 were the stable cultivars in the first year, and Çağatay, Akçin 91, Gökçe, Küsmen 99, Er 99 and Aziziye 94 were in the second year. Despite their high values of 100-grain weigth, Çağatay, Sari 98, Gökçe, Canitez 87 and Aziziye 94 in the first year, and Cevdetbey, Sari 98 and Canitez 87 in the second year lost their stability (Figure 4). In terms of grain yield; Çağatay, Gülümser, Menemen 92, İzmir 92, Cevdetbey, Gökçe, İnci, Aziziye 94 and ILC 482 had the highest values in the first year. Despite their high grain yields, Çağatay, Cevdetbey, Gökçe, Aziziye 94 and ILC 482 were not found to be stable. On the other hand, Gülümser, Menemen 92, İnci and İzmir 92 had high grain yield and were determined as stable. And in the second year; Çağatay, Gülümser, Menemen 92, Akçin 91, Gökçe, İnci, Aziziye 94, ILC 482 and Eser 87 had the highest grain yield values, and other cultivars exhibited low efficiency. Çağatay, Gülümser, Menemen 92, Gökçe, ILC 482, İnci and Aziziye 94 had high grain yield and were stable (Figure 4).

Ketata (1984) and Özberk et al. (2004) reported that Çağatay and Menemen 92 had the highest efficiency in all examined parameters including plant heigth, first pod height and grain yield and were more stable according to the results of stability analysis. On the other hand, Akçin 91 and Küsmen 99 were more efficient and more stable in both years in terms of 100 grain weigth.

If genotype x environment interaction causes differences in yield rank of cultivars in different locations, it becomes more important for the plant breeders in terms of selection efficiency and species suggestions for different locations. If genotype x environment interaction does not change yield rank of genotypes in different regions, it does not cause any problem in the suggestion of cultivars (Kara, 2000). Hühn (1979) developed nonparametric stability methods by using yield rank of genotypes in different locations. According to this approach, cultivars that demonstrate similar yield rank in different locations are accepted as stable. Variance and standard deviation of yield rank of a genotype in different locations were used as a stability parameter by researchers (Nassar and Hühn, 1987; Huehn, 1990; Kara, 2000; Özberk et al., 2004).

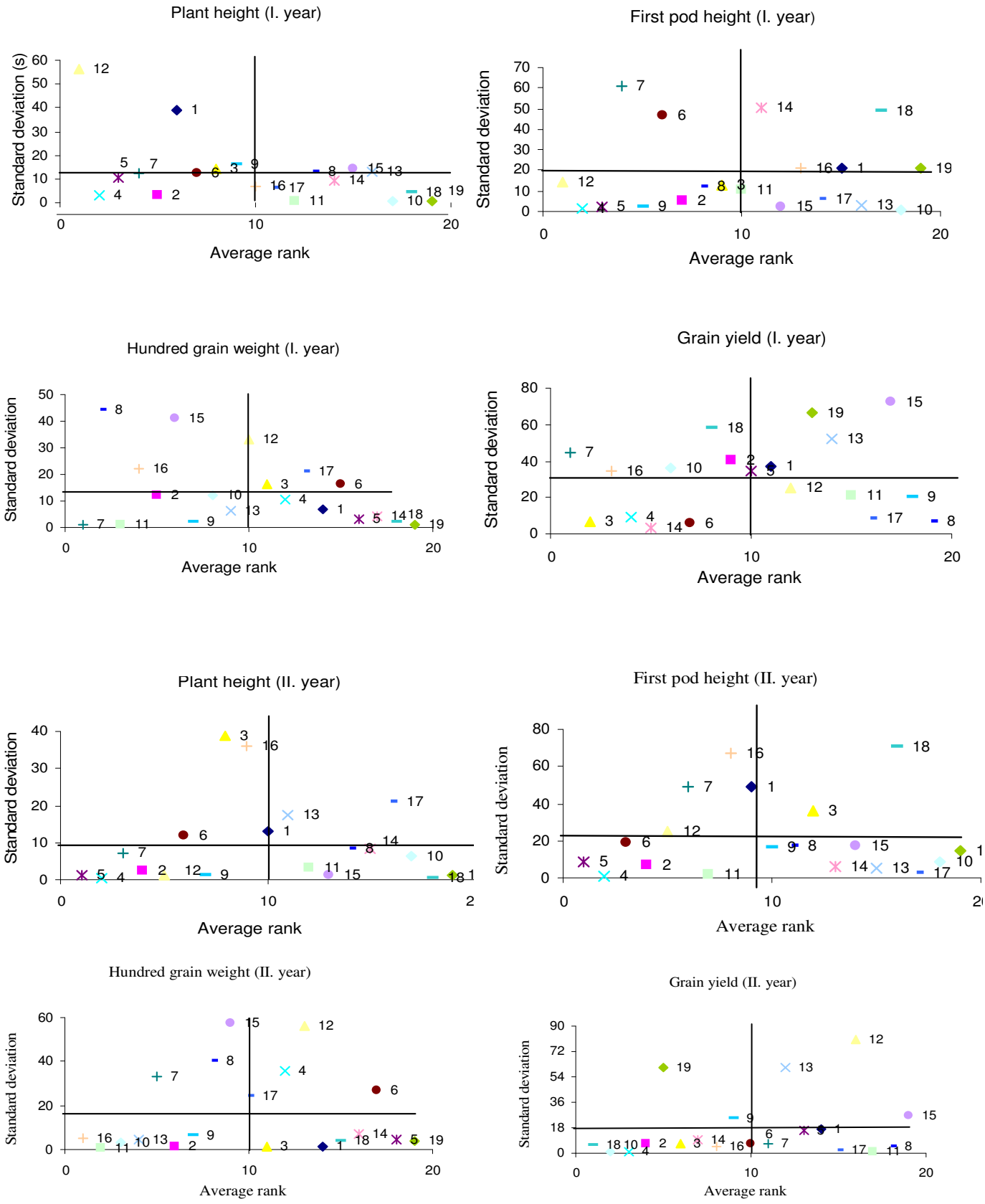

Figure 4. Stability analysis according to Ketata (1984) in plant height, first pod height, 100 grain weight and grain yield properties on chickpea varieties grown in different locations. (Numbers represents the chickpea cultivars).

For plant breeders, the main problem in selection efficiency is genotype x environment interaction that causes yield rank to change in different locations. Methods based on the yield rank parameters of genotypes in different locations could be alternative to parametric methods widely used by plant breeders since they do not depend on any assumption and permit easy calculation and interpretation (Becker, 1981; Kang, 1990; Kara, 2000; Özberk et al., 2004). A method that ranks genotypes according to their yields in each location. Selection of genotypes with low variance and mean rank values could be reliable in many applications for plant breeders.

Conclusion

In the present study, 19 different chickpea genotypes in three different locations were grown and some stability parameters were calculated using regression coefficient and mean rank and deviation from regression models in plant heigth, first pod height and 100 grain weigth.

According to the results of both models, Menemen 92 and İzmir 92 were determined as the most stable and the most efficient cultivars in all locations. And in terms of 100 grain weigth; Çağatay, Akçin 91 and Er 99 were determined as stable with high yield potentials. Consequently, both methods appears to be suitable for plant breeders and could be used in stability analysis.

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