Selcuk J Agr Food Sci, 30(1):39-43

Selcuk Journal of Agriculture and Food Sciences

# Drought Resistance Indices of Chickpea (*Cicer arietinum* L.) Germplasm

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**ARTICLE INFO**

Article history:
Received 07 March 2016
Accepted 24 April 2016

Keywords:
Drought tolerance
Drought stress
Stress tolerance index
Yield index
Yield-stress index

**ABSRACT**

Drought is a major and wide-spread reducer of production and quality in chickpea-growing regions. Identification and selection of drought resistant genotypes is possible by using of several indices. A total of 96 chickpea genotypes were evaluated in randomized complete block design with three replications under non-stress and stress conditions in Konya ecological conditions for two years (2010 and 2011 spring growing seasons). Several selection indices, such as stress drought susceptibility index, drought tolerance, average yield, decreasing ratio of yield, yield index, stress tolerance index, harmonic mean, geometric mean, yield-stress index were used to evaluation of the chickpea germplasm to drought. Results of the mentioned indices showed that “Cumra” could be considered superior beside Derebucak, Hadim, Aziziye, Ahirli and Canitez local genotypes together with 22261, 22213, 22243, ILC, 222147 and 22128 germplasm. These germplasm may be considered as promising genotypes for drought tolerance.

## 1. Introduction

Chickpea is one of the most important pulse crops in the world. It contains higher quantities of vitamin B, P, K, Ca, Fe and S. Using areas of the chickpeas are quite wide such as roasting (confectionary), medicine (used for tiredness of brain and nervous system, anorexia, stomach weakness, urine problems, congestion on the channels of liver and spleen, intestine problems, chickpea powder is used for lesions and itching on skin, chickpea soup is used for impotence, chickpea oil is used for acne, teeth and also for the lesions on the stroke patients, flour (gluten free). Many of those make chickpea as an important food source in human nutrition (Anonymous 2014).

Drought is one of the main -limiting factors in agricultural production (Kahraman and Onder 2010) which cause to more than 50% decrease in the crops. Drought which reaches to terminal degrees cause to yield loss by 58-95% by comparing of irrigated plants (Leport et al. 1999; 2006). There is a big demand to investigation the response of plant to drought which can be reached by developing of new cultivars (Ceyhan et al. 2012a). Plants are able to change several metabolic activities in case of the changing of environmental conditions. Depending on genetic variation, some of the plants can adopt easily while some of them are affected negatively (Ceyhan et al. 2012b). In dry lands, there is a growing attention to development of drought tolerant plants by international scientific and policy foundations. In Mediterranean Region, chickpea is usually sown in the spring; therefore the crop is under the effects of heat and drought stress from flowering period to maturity which cause to reducing of yields (Ceyhan et al. 2013).

Understanding of drought tolerance and selection of the tolerant genotypes in the breeding works can begin by determination of the characteristics related to drought which are based on yield related traits (Clarke et al. 1992). It is much needed to selection of the intended stress status (Ceccarelli 1987; Ceccarelli and Grando 1991; Rathjen 1994) to success in breeding programs.

There are several selection indices that are based on mathematical equations to determination of drought resistant genotypes (Clarke et al. 1984; Huang 2000). It was reported that (Fisher and Maurer 1978) a genotype could be accepted as drought resistant which has a stress

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susceptibility index value of less than a unit due to reduction of yield under drought conditions is less than mean of the yield (Bruckner and Frohberg 1987).

In the drought conditions, the selection indices for drought resistance depend on the duration, severity, plant growing period and the genetic structure of the genotype. Many studies have pointed that researches should be done under both optimum and stress conditions to reach reliable results (Fischer and Maurer 1978; Clarke et al. 1992; Nasir Ud-Din et al. 1992; Fernandez 1992; Byrne et al. 1995; Rajaram and Van Ginkle 2001; Kahraman et al. 2015). From this point, aim of the present research was to determination of drought tolerant chickpea genotypes under both non-stress (YP) and stress (YS) conditions.

## 2. Materials and Methods

The field trials were conducted at "Konya Directorate of Research Station of Soil Water and Combating Desertification" in Konya-Turkey. Konya (1020 m above sea level) has 11.4$^0$C temperature, 281 mm annual rainfall and 52.5 % relative humidity on a long-term average. The soil characteristics had clay loam structure, lower level of organic matter (1.49 %), a higher level of lime (17.14 %) and alkaline (pH = 8.40). There was not salinity (0.05 %) problem, and the soil had a rich content of available potassium (51.60 kg da$^{-1}$) besides lower phosphorus (4.01 kg da$^{-1}$) level.

A total of 96 chickpea genotypes were entered in two trials (Table 1). Trials were set up according to randomized complete blocks design with three replications. Plots consisted from 2 m long, rows spaced 20 cm and 5 cm distance between the seeds. Fertilizer was applied before sowing (150 kg ha$^{-1}$ DAP: 18% N and 46% P) for both of the years. Sowing was done on 1$^{st}$ of April 2010 and 4$^{th}$ of April 2011 on 4-5 cm of soil depth by hand. The trial years (2010 and 2011) were not recorded as a factor. Hoeing was made twice and harvest was made by hand after whole of the pods were matured.

In the non-stress (YP) condition, a total of two irrigations were made - once during pre-flowering period and once at pod-filling period. During these irrigation periods, an amount of 73 mm sprinkler irrigation in total was made by checking the soil humidity (Leport et al. 1999; 2006) in first year of the trial. In the second year of the trial, irrigations were made on 17$^{th}$ of June (50 mm) and 8$^{th}$ of July (75 mm). There was not any irrigation in the stress (YS) conditions (Leport et al. 2006). In the first trial year, the total water consumption was 270 mm in the stress application while that value was 343 mm in the control. In the second trial year, the water consumption values were 251 mm and 376 mm for the stress application and control, respectively. These results showed that water consumption increases by increasing of irrigation.

A total of nine parameters related to drought index - Drought susceptibility index-**DSI** (Fisher and Maurer 1978), Drought tolerance-**DT** (Rosielle and Hamblin 1981), Average yield-**AY** (Rosielle and Hamblin 1981), Decreasing ratio of yield-**DRY** (Golestani and Assad 1998), Yield index-**YI** (Gavuzzi et al. 1997), Stress tolerance index-**STI** (Fernandez 1992), Harmonic mean-**HM** (Kristin et al. 1997), Geometric mean-**GM** (Kristin et al. 1997), Yield-stress index-**YSI** (Kristin et al. 1997) were determined by using mean of the trial years (2010 and 2011).

## 3. Results and Discussion

The results of analyses of variance for the investigated drought related indices were presented in Table 2. Significant differences were found for all the investigated characteristics. The investigated data for the drought indices and discussion were summarized in the below.

Drought susceptibility index was significant in the level of $p<0.01$. The most susceptible genotype was 22121 (1.500) while the genotype Derebucak (0.600) showed the most tolerant which was followed by the genotypes Hadim and Aziziye. The tolerant genotypes for DSI are the common cultivars for the region. This situation can be explained by the adaptation (Austin 1987; Van Ginkel et al. 1998). This criteria (DSI) has been also widely used to determination of the tolerant genotypes (Clarke et al. 1984, 1992; Fischer and Maurer 1978).

Drought tolerance showed significant difference ($p<0.05$) among the genotypes. This variation may also be due to the fact that characteristics eligible for an adapted environment. The lowest value (204.11) for DT was on the genotype 22151 while the most drought tolerant genotype was Derebucak. A similar and previously made research that was used a total of 482 chickpea genotypes investigated that only 18 of the used genotypes were drought tolerant that can be reach 10% more seed yield at least (Anbessa and Bejiga 2002).

Analysis of variance for average yield is presented in Table 2. Significant difference was found among the genotypes on the level of 1%. The highest AY was 904.3 kg ha$^{-1}$ on the Cumra genotype. The other promising genotypes for the drought tolerance based breeding works can be 22261, 22213, 22243, ILC, 22235, 22258, 22147 and Kusmen (Table 3). Selection based on average yield will result by increased seed yield on well-watered conditions as it was reported by many researches (Rosielle and Hamblin 1981; Clarke et al. 1992; Mardeh et al. 2006). Toker and Cagirgan (1998) were investigated the effect of drought stress and non-stress applications on a total of 64 chickpea genotypes. They reported that seed yield showed a difference ratio of 53% between the applications. In the other similar studies, the changing ratios of seed yield were determined as 90% (Silim and Saxena 1993) and 50-80% (Leport et al. 1999).

Decreasing ratio of yield was about tweny times differed (0.0300-0.6417) among the genotypes. The lowest DRY values were on the genotypes Derebucak, 22124, Aziziye, Hadim, Ahirli, Canitez and 22147, respectively. As it seen on the previous sentence, most of the promising genotypes are landraces. These results are similar with previous related researches which were reported that landraces were more productive under stress conditions (Bruckner and Frohberg 1987; Ceccarelli and Grando 1991).

Yield index was statistically significant ($p<0.01$) among the used genotypes. The values for YI was ranged from 0.487 (Cumra) to 1.420 (22213). 22213, Akoren, 22128, Guneysinir, Ilgin and 22101 genotypes can be used for the breeding works in the future (Table 3). The genotypes that were investigated as low-valued for yield index might gave a less response to drought due to lower adaptation to those conditions (Clarke et al. 1992). Furthermore, former researches reported that semi-dwarf genotypes are preferred for drought on the late season (Fischer and Maurer 1978; Richards 1996; Van Ginkel et al. 1998). It was stated that yield index was significantly correlated with the yield under stress (Gavuzzi et al. 1997) and this index is an indicator for drought resistance of the genotypes (Bouslama and Schapaugh 1984).

There was a significant difference ($p<0.01$) for stress tolerance index of the genotypes. In the present research, the highest STI value (0.0091) was investigated on the 22261 genotype while the lowest value (0.0048) was on Derbent genotype. Similar to the present findings, Siashar et al. (2010) screened drought tolerance in lentil lines based on yields of non-stress and stress conditions by using several indices of drought tolerance such as mean productivity, geometric mean productivity, harmonic mean, tolerance index, yield index, yield stability index, stress susceptibility index and stress tolerance index. They reported that the values of geometric mean productivity, harmonic mean and stress tolerance indices were considered as the best criteria to selection the genotypes under drought stress.

Harmonic mean of the genotypes was statistically significant on the level of $p<0.01$. The lowest value (73.31 kg $ha^{-1}$) was on Cumra genotype while the highest value (196.83 kg $ha^{-1}$) was on 22213 genotype. 22261, Akoren, 22243 and Doganhisar genotypes also showed a high value for HM respectively. Evaluation of HM is accepted as a good indicator to identification of drought tolerant genotypes (Siashar et al. 2010).

A significant difference was determined among the genotypes in the view of geometric mean. The lowest value (81.02 kg $ha^{-1}$) for GM was on Cumra genotype while the highest value (202.74 kg $ha^{-1}$) was on 22261 genotype that was followed by 22213, Akoren, 22243 and Doganhisar, respectively. It was pointed that selection which based on the both combination of geometric mean and stress susceptibility index can provide a better selection for drought tolerance (Vallejo and Kelly 1998).

Yield-Stress Index values of the used genotypes was significant on the level of 1%. The lowest value (0.2867) was investigated on 22121 genotype. The highest value (0.9701) for YSI was shown on Derebucak genotype. The genotypes Hadim, Canitez, Ahirli and Aziziye were also listed as drought tolerant, respectively. Previously made studies have also been reported that changing of environmental conditions cause to several effects on plants by depending on local conditions and type of crops (Yazar et al. 1999; Irmak et al. 2000; Orta et al. 2003; Simsek et al. 2005; Kirnak and Dogan 2009; Erdem et al. 2010; Al-Kayssi et al. 2011; Candogan et al. 2013; Kahraman and Ozkan 2015; Yavuz et al. 2015).

Ganjeali et al. (2011) used a total of 150 chickpea genotypes to compare the stress and non-stress applications of drought. Results were implicated that six of the used genotypes were promising by means the view of drought stress. Additionally, both of the applications (stress and non-stress applications) showed highly significant and positive correlations between mean of the seed yield and geometric mean, stress tolerance index and harmonic mean, stress susceptibility index and drought response index values.

## 4. Conclusions

Results of the present study highlighted that, drought susceptibility index showed that the most tolerant genotypes were Derebucak (0.060), Hadim (0.280), Aziziye (0.340), Ahirli, Canitez (0.393), 22147 (0.477) and 22128 (0.570) while the most sensitive gentoypes were 22121 (1.500), 22207 (1.413), Derbent (1.390) and 22114 (1.373), respectvely.

According to the results of the present research, drought index values showed that the most drought tolerant genotypes are Cumra, Derebucak, Hadim, Aziziye, Ahirli and Canitez local genotypes beside 22261, 22213, 22243, ILC, 222147 and 22128 germplasm which can be used for the breeding works that are focused on drought tolerance.

## 5. Acknowledgements

Present research was supported by TUBİTAK (Project no: 108O742). The authors declare that they have no conflict of interest.

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