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# Evaluation on drought and heat tolerance capacity of chickpea

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## Abstract

Chickpea (*Cicer arietinum* L.) is one of the important legumes widely grown for dietary proteins in semi-arid Mediterranean climatic conditions. To evaluate the genetic diversity with improved heat and drought tolerance capacity in chickpea, thirty-four selected chickpea genotypes were tested under different field-growing conditions (rain fed winter sowing, irrigated-late sowing and rain fed-late sowing) in 2015 and 2016 growing seasons. A factorial experiment in randomized complete block design with 3 reps was conducted at the Eastern Mediterranean Research Institute Adana, Turkey. Based on grain yields under different growing conditions, the values of tolerance index, mean productivity, yield index, yield stability index, stress tolerance index, stress susceptibility index, and geometric mean productivity were calculated to identify economically higher-yielding chickpea genotypes with greater heat and drought tolerance capacity. There were highly significant differences observed among the tested chickpea genotypes response to drought and heat stresses. Besides, in both non-stress and stress conditions mean productivity, yield index, stress tolerance index, and geometric mean productivity, which highly positively significantly correlated with seed yields, were the best indices. Among the chickpea genotypes, the Aksu, Arda, Çakır, F4 09 (X 05 TH 21-16189), FLIP 03-108 were identified with a higher drought and heat tolerance capacity. Based on our field studies, it is suggested that the drought and heat tolerance indicators of plants can be used by breeders to select stress-resistant economically productive chickpea genotypes suitable to grow under Mediterranean climatic conditions.

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## Introduction

Chickpea with nearly 3.600.000 da sowing area and 460.000 ton production in Turkey is the second important pulses after peas (TUIK, 2015). Due to high protein content, it has become an important component of human diet in the developing country. It is grown in semi-arid or arid regions and sown in autumn or spring and grows during the cool wet months of winter and spring in Mediterranean-climatic regions. It is mainly grown in rainfed condition in Mediterranean area of TURKEY. Mediterranean area alone contributes about 23% of chickpea production of the country (TUIK, 2013).

Abiotic stress is the most significant limiting factor in agriculture production in arid and semi-arid areas. Sensitivity to stress is often measured in terms of lower yields under stress conditions. Quantifying the degree of tolerance or resistance of crops to stress requires several indices. Several researchers suggested that screening should be performed under favorable conditions (Rajaram and Van Ginkle, 2001; Betran *et al.*, 2003). However, selection in the stressed conditions has been emphasized as well (Ceccarelli and Grando, 1991; Rathjen, 1994).

Chickpea is considered one of the most stresses tolerant of the cool season food legumes. The basis of its tolerance is unknown (Singh, 1993). For improving productivity in stressed condition, development of new chickpea cultivars with high yield potential through identifying tolerance mechanism is of great important (Rajaram *et al.*, 1996). However, there is a greater variability for yield performance of different chickpea genotypes in stress conditions. Attempts to measure the degree of tolerance with single parameter have limited value because of the confounding effect of the various factors to drought and heat tolerance in field condition.

Different workers used different methods to evaluate genetic differences in stress tolerance (Farshadfer *et al.*, 2012; Zebarjadi *et al.*, 2011; Anwar *et al.*, 2011). Some screening indices for evaluating genotypes have been stressed based on a mathematical relationship between non-stress and stress conditions.

Most of these indices such as tolerance (TOL), mean productivity (MP), stress susceptibility index (SSI), geometric mean productivity (GMP) and stress tolerance index (STI) have been used in various crops.

Fernandez (1992) used stress tolerance index (STI) and geometric mean productivity (GMP) and suggested that STI is the best criteria for screening drought resistance in bean (*Phaseolus vulgaris*). Mean Productivity (MP), GMP and STI have been all considered as the most suitable indices for screening stress resistance of various crop cultivars such as chickpea (*Cicer arietinum*) (Ganjeali *et al.*, 2005; Ganjeali *et al.*, 2011), wheat (*Triticum aestivum*) (Sio-Se Mardeh *et al.* 2006), durum wheat (*Triticum durum*) (Golabadi *et al.*, 2006), Rice (*Oryza sativa*) (Abbasi and Sepaskhah, 2011).

Field performance is the standard to assess plant response in stress. Field screening is a powerful tool for evaluation of genotypes for effective breeding to develop new crop varieties prone to stress (Yücel and Mart, 2014). The aim of the present study was to evaluate the tolerance chickpea genotypes to drought and heat stress as well as to identify a suitable index for further screening and to select chickpea genotypes tolerant to drought and heat stress.

## Materials and methods

*Plant Material and Experimental Design*

Thirty four chickpea genotypes that are high yielding and seen promising in carried out research in our region along with four control varieties (FLIP 87-59 C, drought tolerant; ILC 8617, drought susceptible; ICC 1205; heat tolerant and ICC 4567, heat susceptible) were used as material. They were assessed in factorial randomized complete block design with 3 replications under winter sowing, irrigated-late sowing and non-irrigated- late sowing conditions. The experiment plots consisted of two rows of 4 m length with inter and intra-row spacing of 45 and 10 cm, respectively.

Fertilization was applied at a rate of 30 kg nitrogen and 60 kg phosphorus per ha before sowing. Sowing was performed in December, 01 2014 and 21 2015 for winter treatment, March 4 2015 and February 28 2016 for late treatments.

*Experimental Site and Conditions*

This experiment took place at the Eastern Mediterranean Research Institute, Adana, TURKEY (35° 18'E, 37°01'N; 23 m above the sea level) during 2014-15 and 2015-2016 growing seasons. Winter sowing was evaluated as control (non-drought stress), irrigated late sowing was evaluated as control (non-heat stress), while non-irrigated late sowing was evaluated both drought and heat stress conditions. The soil of the research area is clay that has a pH of 6.7, 1.2% organic matter, 23.6% $CaCO_3$ and 0.09% salt content. The research region has a Mediterranean climate with wet winters and hot dry summers. According to the long-term average from four decades of records, there is early total precipitation of 625mm and mean temperature 18.7 °C.

Mean temperature relative humidity (%) and total precipitation of Adana during December 2014 to July 2015 are presented in Table 1.

**Table 1.** Monthly mean temperature (°C), Relative Humidity (%) and total precipitation (mm) of Adana during December 2014 to July 2016.

| Months | Years | Temperature (°C) | | | Relative humidity (%) | | | Total precipitation (mm) |
|---|---|---|---|---|---|---|---|---|
| | | Max. | Mean | Min. | Max. | Mean | Min. | |
| December | 2014 | 22 | 13.0 | 2 | 100 | 71.6 | 17 | 50.05 |
| | 2015 | 22 | 11.0 | -1 | 93 | 48.4 | 4 | 2.03 |
| January | 2015 | 21 | 8.9 | -3 | 100 | 66.3 | 13 | 56.39 |
| | 2016 | 19 | 8.0 | -4 | 100 | 57.5 | 4 | 42.17 |
| February | 2015 | 22 | 10.9 | -1 | 100 | 70.1 | 7 | 90.68 |
| | 2016 | 28 | 14.0 | 1 | 100 | 62.4 | 9 | 43.18 |
| March | 2015 | 28 | 13.9 | 3 | 96 | 64.6 | 13 | 115.81 |
| | 2016 | 27 | 16.0 | 3 | 94 | 57.1 | 9 | 36.83 |
| April | 2015 | 28 | 13.9 | 3 | 96 | 64.6 | 13 | 115.81 |
| | 2016 | 34 | 20.0 | 8 | 100 | 56.1 | 4 | 8.89 |
| May | 2015 | 38 | 21.7 | 11 | 100 | 64.3 | 8 | 81.02 |
| | 2016 | 33 | 26.0 | 20 | 94 | 67.2 | 8 | 26.7 |
| June | 2015 | 33 | 24.2 | 15 | 100 | 69.1 | 11 | 9.5 |
| | 2016 | 39 | 32.0 | 25 | 100 | 69.0 | 12 | 1.5 |
| July | 2015 | 36 | 28.0 | 18 | 100 | 69.3 | 19 | 8.8 |
| | 2016 | 37 | 31.0 | 26 | 100 | 70.9 | 18 | 0.0 |

*Calculation of Stress Indices*

After harvest, seed yield of each genotypes was recorded in grams after threshing and then converted into kg per decar. Drought and heat resistance indices were calculated using the following relationships:

1. Tolerance Index (TI) = $Y_p$-$Y_s$ (Rosielle and Hamblin, 1981)
2. Mean Productivity (MP) = ($Y_p$ + $Y_s$)/2 (Rosielle and Hamblin, 1981)
3. Yield Index (YI) = $Y_s/X_s$ (Lin *et al.,* 1986)
4. Yield Stability Index (YSI) = $Y_s/Y_p$ (Bouslama and Schapaugh, 1984)
5. Stress Tolerance Index (STI) = ($Y_s$ x $Y_p$) / $(X_P)^2$ (Fernandez, 1992)
6. Stress Susceptibility Index (SSI) = (1-($Y_s/Y_p$))/(1-($X_s/X_p$)) (Fischer and Maurer, 1978)
7. Tolerance Efficiency (TE) = ($Y_p/Y_s$) x 100 (Deshmukh *et al.,* 2004)
8. Geometric Mean Productivity (GMP) = $(Y_p \text{ x } Y_s)^{1/2}$ (Fernandez, 1992)
9. Stress Intensity (SI) I= ($X_p$-$X_s$)/$X_p$

In the above formulas Ys, Yp, Xs and Xp represent yield under stress, yield under non-stress for each genotype, yield mean in stress and non-stress conditions for all genotypes, respectively. As a result of the screening at different growing terms (seedling, flowering, podding and maturity) of each plot, drought and heat tolerance of chickpea genotypes were evaluated with 1 to 9 scale (1- No damage; 9-All plants killed) according to Wery *et. al.,* 1993. The evaluation was done after the susceptible check shows % 100 mortality. In 2015, the evaluation was not done because of non-mortality in check.

*Statistical Analysis*

The statistically study focused on correlations between grain yield under two stress and non-stress conditions by using JMP software program.

**Results and discussion**

Data concerning yields under two different conditions (Yp and Ys) and drought stress indices in 2015 and 2016 were calculated for all the genotypes and given in Table 2 and Table 3. In drought stress condition, results of two years experiment showed that TI values ranged from 1.1 to 217.63 in 2015 and from 55.7 to 243.57 in 2016 regarding to chickpea genotypes. In the first year ENA 8-2, ILC 8617, İzmir-92, ENA 144-10, F4 09 (X 05 TH 80-16105-31-2), EN 1750, ICC 4567, Dikbaş, ICC 1205, EN 766 and EN 952 chickpea genotypes had lower value than investigated genotypes. Besides, in the second year, Seçkin cultivar had the lowest value and followed by İzmir-92, ICC 1205, Dikbaş, ILC 8617, F4 09 (X 05 TH 80-16105-31-2), Çağatay, ICC 4567, EN 952 and EN 808.

As a result of two years research, according to TI ILC 8617, İzmir-92, F4 09 (X 05 TH 80-16105-31-2), ICC 4567, ICC 1205, Dikbaş and EN 952 were the most tolerant genotypes. Results of 2015 and 2016 experiments showed that TI values in heat stress condition ranged from 3.33 to 54.27 and 6.9 to 59.77, respectively. In the first year, Hasanbey and FLIP 03-126 C cultivars ranged as first, and followed by FLIP 05-170 C, Azkan, ILC 8617, F4 09 (X 05 TH 69-16124-8), FLIP 05-150 C, ICC 4567, ENA 8-2 and EN 952.In 2016, ICC 1205 cultivar ranged as first, and followed by F4 09 (X 05 TH 69-16124-8), Aksu, ICC 4567, Azkan, EN 766, FLIP 87-59 C, Dikbaş, ENA 8-2, Çakır and EN 952. As to TI, Azkan, F4 09 (X 05 TH 69-16124-8), ICC 4567, ENA 8-2 and EN 952 were the most tolerant genotypes for both years. The study conducted by Yucel and Mart (2014) in Turkey evaluating drought tolerance in chickpea genotypes showed lower value of TI found the suitable parameter for screening for stress tolerant lines. Similarly, Sio-Se Mardeh *et al.* (2006) showed that a selection based on TI is superior in wheat.

**Table 2.** Drought Stress Indices in 2015.

| Genotypes | TI | MP | YI | YSI | STI | SSI | TE | GMP |
|---|---|---|---|---|---|---|---|---|
| Aksu | 175.2 (31) | 182.2 (2) | 1.5 (4) | 0.4 (21) | 1.1 (2) | 1.1 (21) | 285.14 (14) | 159.79 (2) |
| Arda | 217.6 (33) | 201.8 (1) | 1.5 (5) | 0.3 (25) | 1.2 (1) | 1.2 (25) | 334.09 (9) | 169.93 (1) |
| Azkan | 218.4 (34) | 160.2 (4) | 0.8 (21) | 0.2 (33) | 0.6 (9) | 1.4 (33) | 528.90 (1) | 117.13 (9) |
| Çağatay | 97.0 (20) | 113.2 (14) | 1.1 (14) | 0.4 (18) | 0.4 (13) | 1.0 (18) | 250.15(17) | 102.22 (13) |
| Çakır | 87.9 (19) | 144.2 (9) | 1.6 (3) | 0.5 (11) | 0.8 (5) | 0.8 (11) | 187.75(24) | 137.3 (5) |
| Dikbaş | 36.1 (8) | 40.8 (33) | 0.4 (33) | 0.4 (19) | 0.1 (33) | 1.0 (19) | 258.67(16) | 36.62 (33) |
| EN 1685 | 60.4 (12) | 107.6 (18) | 1.3 (7) | 0.6 (6) | 0.5 (12) | 0.7 (6) | 177.97(29) | 103.29 (12) |
| EN 1750 | 33.3 (6) | 55.9 (31) | 0.6 (30) | 0.5 (10) | 0.1 (30) | 0.8 (10) | 184.87(25) | 53.39 (30) |
| EN 766 | 53.3 (10) | 70.2 (26) | 0.7 (28) | 0.5 (17) | 0.2(26) | 0.9 (17) | 222.54(18) | 64.94 (26) |
| EN 808 | 102.2 (21) | 110.7 (16) | 1.0 (18) | 0.4 (20) | 0.4 (15) | 1.1 (20) | 271.53 (15) | 98.21 (15) |
| EN 952 | 58.1 (11) | 92.2 (23) | 1.0 (15) | 0.5 (12) | 0.3 (21) | 0.8 (12) | 192.10(23) | 87.5 (21) |
| ENA 144-10 | 27.2 (4) | 61.6 (28) | 0.8 (23) | 0.6 (3) | 0.2 (28) | 0.6 (3) | 156.70(32) | 60.05 (28) |
| ENA 8-2 | 1.1 (1) | 75.9 (25) | 1.2 (9) | 1.0 (1) | 0.2 (25) | 0.0 (1) | 101.46(34) | 75.92 (25) |
| F4 09 (X 05 TH 21 16189-12-4) | 86.3 (17) | 150.0 (5) | 1.7 (1) | 0.6 (7) | 0.9 (4) | 0.7 (7) | 180.71(28) | 143.67 (4) |
| F4 09 (X 05 TH 69-16124-8) | 78.3 (16) | 58.3 (30) | 0.3 (34) | 0.2 (32) | 0.1 (31) | 1.3 (32) | 509.95 (3) | 43.13 (31) |
| F4 09 (X 05 TH 80-16105-31-2) | 29.6 (5) | 42.4 (32) | 0.5 (31) | 0.5 (15) | 0.1 (32) | 0.9 (15) | 207.36(20) | 39.74 (32) |
| FLIP 01-24 C | 120.2 (24) | 104.4 (20) | 0.7 (27) | 0.3 (30) | 0.3 (24) | 1.2 (30) | 371.43 (5) | 85.32 (24) |
| FLIP 01-39 C | 127.6 (26) | 117.3 (13) | 0.9 (19) | 0.3(26) | 0.4 (14) | 1.2 (27) | 338.31 (8) | 98.46 (14) |
| FLIP 01-54 C | 114.1 (22) | 110.2 (17) | 0.9 (20) | 0.3 (23) | 0.4 (18) | 1.1 (23) | 314.52 (12) | 94.3 (18) |
| FLIP 03-108 C | 168.8 (30) | 169.4 (3) | 1.4 (6) | 0.3 (22) | 0.9 (3) | 1.1 (22) | 298.61(13) | 146.83 (3) |
| FLIP 03-126 C | 66.1(14) | 96.0 (22) | 1.0 (16) | 0.5 (14) | 0.3 (20) | 0.9 (14) | 205.02(21) | 90.16 (20) |
| FLIP 03-21 C | 87.5 (18) | 120.6 (11) | 1.3 (8) | 0.5 (16) | 0.5 (10) | 0.9 (16) | 213.85(19) | 112.35 (10) |
| FLIP 03-28 C | 143.3 (27) | 119.3 (12) | 0.8 (24) | 0.3 (31) | 0.4 (17) | 1.3 (31) | 401.05 (4) | 95.32 (17) |
| FLIP 03-42 C | 117.2 (23) | 104.5 (19) | 0.8 (26) | 0.3 (29) | 0.3 (23) | 1.2 (28) | 355.17 (6) | 86.56 (23) |
| FLIP 05-150 C | 125.8 (25) | 113.1 (15) | 0.8 (22) | 0.3 (28) | 0.4 (19) | 1.2 (29) | 350.67 (7) | 93.95 (19) |
| FLIP 05-170 C | 66.0 (13) | 103.5 (21) | 1.2 (10) | 0.5 (13) | 0.4 (16) | 0.8 (13) | 193.53(22) | 98.12 (16) |
| FLIP 87-59 C | 77.0 (15) | 142.1 (10) | 1.7 (2) | 0.6 (5) | 0.8 (6) | 0.7 (5) | 174.41(30) | 136.73 (6) |
| Hasanbey | 154.8 (28) | 147.4 (7) | 1.1 (11) | 0.3 (24) | 0.7 (7) | 1.1 (24) | 321.14 (11) | 125.44 (7) |
| ICC 1205 | 42.6 (9) | 90.0 (24) | 1.1 (12) | 0.6 (4) | 0.3 (22) | 0.6 (4) | 162.01(31) | 87.44 (22) |
| ICC 4567 | 34.4 (7) | 58.7 (29) | 0.7 (29) | 0.6 (8) | 0.1 (29) | 0.8 (9) | 182.89(26) | 56.12 (29) |
| ILC 8617 | 5.3 (2) | 63.8 (27) | 1.0 (17) | 0.9 (2) | 0.2 (27) | 0.1 (2) | 108.74(33) | 63.74 (27) |
| İnci | 200.5 (32) | 147.5 (6) | 0.8 (25) | 0.2 (34) | 0.5 (11) | 1.4 (34) | 524.60 (2) | 108.18 (11) |
| İzmir-92 | 21.8 (3) | 38.0 (34) | 0.4 (32) | 0.6 (9) | 0.1 (34) | 0.7 (8) | 180.80(27) | 36.34 (34) |
| Seçkin | 155.2 (29) | 144.8 (8) | 1.1 (13) | 0.3 (27) | 0.6 (8) | 1.2 (26) | 330.95 (10) | 122.25 (8) |

TI: Tolerance index, MP: Mean productivity, YI: Yield index (YI), YSI: Yield stability index, STI: Stress tolerance index (STI), SSI: Stress susceptibility index, TE: Tolerance efficiency, GMP: Geometric mean productivity (GMP)

**Table 3.** Drought Stress Indices in 2016.

| Genotypes | TI | MP | YI | YSI | STI | SSI | TE | GMP | DSS |
|---|---|---|---|---|---|---|---|---|---|
| Aksu | 213.83 (32) | 184.52 (2) | 1.31 (7) | 0.27 (22) | 0.59 (3) | 1.05 (24) | 375.55 (10) | 150.38 (2) | 3 |
| Arda | 220.47 (33) | 181.67 (3) | 1.21 (12) | 0.24 (29) | 0.55 (5) | 1.08 (27) | 408.65 (69) | 144.40 (4 ) | 3 |
| Azkan | 197.4 (30) | 137.47 (14) | 0.65 (31) | 0.16 (34) | 0.24 (19) | 1.19 (33) | 609.16 (1) | 95.69 (19) | 6 |
| Çağatay | 86.7 (7) | 91.82 (27) | 0.82 (25) | 0.36 (8) | 0.17 (27) | 0.92 (8) | 278.87 (27) | 80.94 (27) | 5 |
| Çakır | 125.9 (17) | 140.35 (13) | 1.31 (8) | 0.38 (6) | 0.41 (12) | 0.88 (6) | 262.66 (29) | 125.44 (11) | 3 |
| Dikbaş | 80.8 (4) | 78.37 (34) | 0.64 (32) | 0.32 (14) | 0.12 (32) | 0.97 (14) | 312.80 (20) | 67.15 (32) | 6 |
| EN 1685 | 110.4 (13) | 108.17 (21) | 0.89 (22) | 0.32 (15) | 0.23 (20) | 0.97 (15) | 308.42 (21) | 93.03 (23) | 6 |
| EN 1750 | 107.73 (11) | 82.04 (32) | 0.48 (33) | 0.21 (30) | 0.10 (34) | 1.13 (30) | 482.43 (4) | 61.87 (34) | 7 |
| EN 766 | 147.96 (21) | 122.55 (16) | 0.82 (26) | 0.25 (26) | 0.25 (17) | 1.08 (28) | 404.63 (8) | 97.70 (18) | 3 |
| EN 808 | 101.8 (10) | 106.83 (23) | 0.94 (18) | 0.35 (10) | 0.23 (21) | 0.92 (9) | 282.01 (25) | 93.92 (21) | 7 |
| EN 952 | 90.8 (9) | 99.53 (26) | 0.91 (19) | 0.37 (7) | 0.21 (24) | 0.90 (7) | 267.74 (28) | 88.57 (25) | 5 |
| ENA 144-10 | 107.77 (12) | 107.72 (22) | 0.91 (20) | 0.33 (12) | 0.23 (22) | 0.95 (12) | 300.20 (22) | 93.27 (22) | 3 |
| ENA 8-2 | 117.5 (14) | 117.72 (19) | 1.00 (16) | 0.33 (13) | 0.27 (16) | 0.95 (13) | 299.25 (23) | 102.01 (16) | 4 |
| F4 09 (X 05 TH 21 16189-12-4) | 152.87 (22) | 159.24 (7) | 1.40 (3) | 0.35 (11) | 0.51 (7) | 0.93 (11) | 284.63 (24) | 139.69 (7) | 3 |
| F4 09 (X 05 TH 69-16124-8) | 130.6 (18) | 91.40 (28) | 0.44 (34) | 0.17 (33) | 0.11 (33) | 1.19 (34) | 600.38 (2) | 63.95 (33) | 8 |
| F4 09 (X 05 TH 80-16105-31-2) | 82.5 (6) | 87.15 (30) | 0.77 (27) | 0.36 (9) | 0.15 (29) | 0.92 (10) | 279.74 (26) | 76.77 (29) | 7 |
| FLIP 01-24 C | 163.33 (24) | 121.57 (17) | 0.67 (28) | 0.20 (32) | 0.21 (25) | 1.15 (32) | 509.35 (3) | 90.05 (24) | 5 |
| FLIP 01-39 C | 139.27 (20) | 126.07 (15) | 0.95 (17) | 0.29 (21) | 0.29 (15) | 1.02 (21) | 346.80 (14) | 105.09 (15) | 6 |
| FLIP 01-54 C | 122.17 (15) | 100.99 (25) | 0.67 (29) | 0.25 (27) | 0.17 (28) | 1.08 (29) | 406.19 (7) | 80.42 (28) | 5 |
| FLIP 03-108 C | 178.54 (26) | 169.30 (6) | 1.35 (5) | 0.31 (17) | 0.54 (6) | 0.99 (19) | 323.09 (16) | 143.85 (5) | 3 |
| FLIP 03-126 C | 138.14 (19) | 120.30 (18) | 0.86 (23) | 0.27 (23) | 0.25 (18) | 1.04 (22) | 369.65 (12) | 98.50 (17) | 7 |
| FLIP 03-21 C | 122.43 (16) | 149.89 (11) | 1.50 (2) | 0.42 (5) | 0.49 (9) | 0.83 (5) | 238.07 (30) | 136.81 (8) | 3 |
| FLIP 03-28 C | 192.37 (29) | 147.12 (12) | 0.86 (24) | 0.21 (31) | 0.32 (13) | 1.13 (31) | 477.71 (5) | 111.32 (13) | 4 |
| FLIP 03-42 C | 159.27 (23) | 153.24 (10) | 1.24 (9) | 0.32 (16) | 0.45 (11) | 0.98 (16) | 316.40 (19) | 130.92 (10) | 3 |
| FLIP 05-150 C | 170.7 (25) | 157.72 (8) | 1.22 (10) | 0.30 (20) | 0.46 (10) | 1.00 (20) | 335.87 (15) | 132.63 (9) | 2 |
| FLIP 05-170 C | 187.56 (28) | 156.25 (9) | 1.05 (13) | 0.25 (28) | 0.41 (1) | 1.07 (26) | 400.24 (9) | 124.98 (12) | 5 |
| FLIP 87-59 C | 183 (27) | 174.03 (4) | 1.39 (4) | 0.31 (18) | 0.57 (4) | 0.98 (17) | 321.74 (17) | 148.03 (3) | 1 |
| Hasanbey | 198.07 (31) | 171.34 (5) | 1.22 (11) | 0.27 (24) | 0.51 (8) | 1.05 (25) | 373.96 (11) | 139.81 (6) | 2 |
| ICC 1205 | 74.83 (3) | 116.82 (20) | 1.34 (6) | 0.51 (1) | 0.32 (14) | 0.69 (1) | 194.24 (34) | 110.66 (14) | 1 |
| ICC 4567 | 87.1 (8) | 83.15 (31) | 0.67 (30) | 0.31 (19) | 0.13 (31) | 0.98 (18) | 319.95 (18) | 70.83 (31) | 8 |
| ILC 8617 | 81.57 (5) | 102.79 (24) | 1.05 (14) | 0.43 (4) | 0.23 (23) | 0.81 (4) | 231.56 (31) | 94.35 (20) | 8 |
| İnci | 243.57 (34) | 212.69 (1) | 1.53 (1) | 0.27 (25) | 0.80 (2) | 1.04 (23) | 367.95 (13) | 174.37 (1) | 2 |
| İzmir-92 | 61.47 (2) | 90.77 (29) | 1.01 (15) | 0.49 (2) | 0.19 (26) | 0.72 (2) | 202.40 (33) | 85.40 (26) | 4 |
| Seçkin | 55.2 (1) | 81.23 (33) | 0.90 (21) | 0.49 (3) | 0.15 (30) | 0.72 (3) | 202.93 (32) | 76.40 (30) | 4 |

TI: Tolerance index, MP: Mean productivity, YI: Yield index (YI), YSI: Yield stability index, STI: Stress tolerance index (STI), SSI: Stress susceptibility index, TE: Tolerance efficiency, GMP: Geometric mean productivity (GMP).

In 2015 and 2016, MP values in drought stress condition ranged from 37.95 to 201.79 and 78.37-212.69, respectively. The highest value was obtained from Arda followed by Aksu, FLIP 03-108 C, Azkan, F4 09 (X 05 TH 21 16189-12-4), İnci, Hasanbey, Seçkin, Çakır and FLIP 87-59 C in 2015. At the second research year, the highest value was obtained from İnci followed by Aksu, Arda, FLIP 87-59 C, Hasanbey, FLIP 03-108 C, F4 09 (X 05 TH 21 16189-12-4), FLIP 05-150 C,FLIP 05-170 C and FLIP 03-42 C. For MP, Aksu, Arda, FLIP 03-108 C and F4 09 (X 05 TH 21 16189-12-4) were tolerant genotypes in both research years. In heat stress condition, MP values ranged from 23.35 to 118.44 and 29.82-120.79 in 2015 and 2016. In terms of MP, F4 09 (X05 TH 21 16189-12-4), FLIP 87-59 C, Aksu, Çakır, Arda, Seçkin, FLIP 03-108 C, EN 1685, FLIP 03-21 C and ENA 8-2 cultivars in 2015 as well as İnci, F4 09 (X05 TH 21 16189-12-4), FLIP 03-21 C, FLIP 03-108 C, FLIP 03-42 C, FLIP 87-59 C, Hasanbey, FLIP 05-150 C, Çakır, Arda cultivars in 2016 had higher value. Similar result was reported by Bellague *et al.* (2016), Farshadfer *et al.* (2012) and Ali and El-Sadek (2016). In drought stress condition, YI values ranged from 0.31 to 1.74 and from 0.44 to 1.53 in 2015 and 2016, respectively. The highest value was obtained from F4 09 (X 05 TH 21 16189-12-4) followed by FLIP 87-59 C, Çakır, Aksu, Arda, FLIP 03-108 C, EN 1685, FLIP 03-21 C, ENA 8-2, FLIP 05-170 C and Hasanbey cultivars in 2015. The highest value was obtained from İnci and followed by FLIP 03-21 C, F4 09 (X 05 TH 21 16189-12-4), FLIP 87-59 C, FLIP 03-108 C, ICC 1205, Aksu, Çakır, FLIP 03-42 C, Hasanbey and FLIP 05-150 C in 2016. As to YI, F4 09 (X 05 TH 21 16189-12-4), FLIP 87-59 C, FLIP 03-108 C, Aksu, Çakır were drought tolerant genotypes for both research years. YI values ranged from 0.31 to 1.74 and 0.44-1.53 in 2015 and 2016 in heat stress condition.

In 2015, the highest YI value was obtained from F4 09 (X05 TH 21 16189-12-4) cultivar and followed by FLIP 87-59 C, Çakır, Aksu, Arda, FLIP 03-108 C, EN 1685, FLIP 03-21 C, ENA 8-2, FLIP 05-170 C and Hasanbey. In 2016, the highest YI value was obtained from İnci cultivar and followed by FLIP 03-21 C, F4 09 (X05 TH 21 16189-12-4), FLIP 87-59 C, FLIP 03-108 C, ICC 1205, Aksu, Çakır, FLIP 03-42 C, FLIP 05-150 C and Hasanbey. For YI, F4 09 (X 05 TH 21 16189-12-4), FLIP 87-59 C, Aksu, Çakır and FLIP 03-108 C were the desirable heat tolerant genotypes in 2015 and 2016. The genotypes which possess high value of YI can be considered tolerant to heat and drought stresses. These results are in agreement with Moein *et al.* (2015), Yucel and Mart (2014). Regarding the drought stress condition, YSI values ranged from 0.19 to 0.99 and from 0.16 to 0.51 in 2015 and 2016, respectively.

In the first year ENA 8-2, ILC 8617, ENA 144-10, ICC 1205, FLIP 87-59 C, EN 1685, F4 09 (X 05 TH 21 16189-12-4), ICC 4567, İzmir-92 and EN 1750 cultivars registered as first. In 2016, the highest YSI value was obtained from ICC 1205 and followed by İzmir-92, Seçkin, ILC 8617, FLIP 03-21 C, Çakır, EN 952, Çağatay, F4 09 (X 05 TH 80-16105-31-2), F4 09 (X 05 TH 21 16189-12-4) and EN 808.

Averaged across chickpea genotypes, in 2015 and 2016 growing seasons, grain yields in response to drought stress were significantly decreased by 39% and 30 %, respectively. The results indicated that crop yields under drought stress were lower in all genotypes than under non-stressed conditions in 2015 and 2016 (Fig. 1 and Fig. 2).

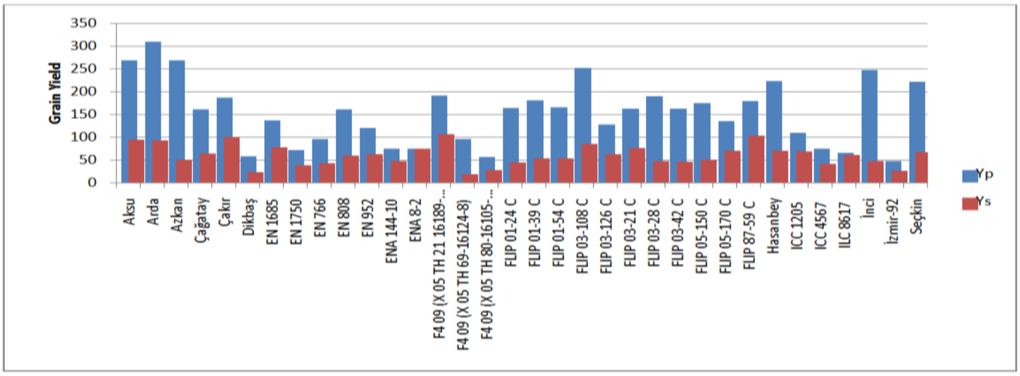


**Fig. 1.** Grain yield of chickpea genotypes under drought stressed and non-stressed conditions in 2015.

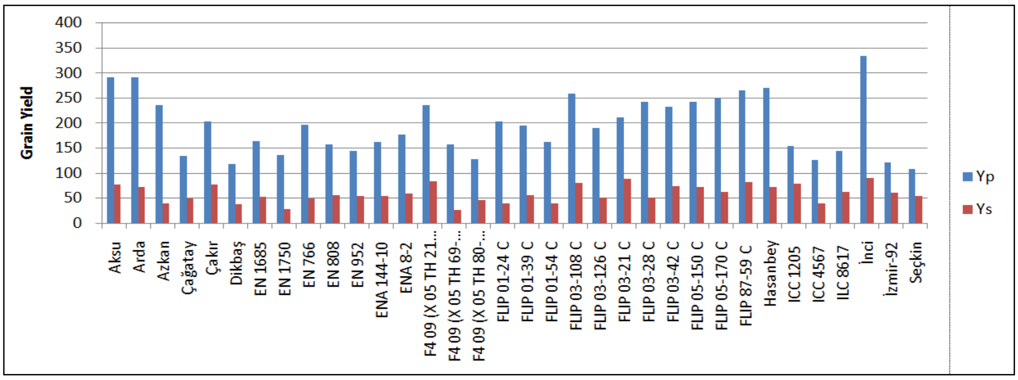


**Fig. 2.** Grain yield of chickpea genotypes under drought stressed and non-stressed conditions in 2016.

According to YSI, the desirable drought tolerant genotypes were ILC 8617, ICC 1205, İzmir-92 for two research years. In heat stress condition, YSI values ranged from 0.43 to 0.95 and 0.47 to 0.92 in 2015 and 2016. FLIP 03-126 C, Hasanbey, FLIP 05-170 C, ILC 8617, Azkan, ENA 8-2, FLIP 03-108 C, Çakır, EN 952 and FLIP 03-21 C cultivars had higher value than other cultivars value in the first year.

In 2016, ICC 1205, Aksu, FLIP 87-59 C, Çakır, ICC 4567, EN 766, ENA 8-2, Azkan, F4 09 (X 05 TH 69-16124-8) and FLIP 03-21 C cultivars had higher value. According to YSI ENA 8-2 and FLIP 03-21 C were relatively heat tolerant genotypes in both 2015 and 2016 growing season. YSI has been considering the most suitable indices for screening drought and heat resistant genotypes of chickpea. Similar result was reported by Farshadfer *et al.* (2012), Moein *et al.* (2015), Yucel and Mart (2014).

With regard to drought stress, STI values ranged from 0.07 to 1.21 and ranged from 0.1 to 0.8 in 2015 and 2016, respectively. The highest STI value was obtained from Arda and followed by Aksu, FLIP 03-108 C, F4 09 (X 05 TH 21 16189-12-4), Çakır, FLIP 87-59 C, Hasanbey, Seçkin, Azkan and FLIP 03-21 C in 2015. The highest STI value was obtained from Inci and followed by Aksu, FLIP 87-59 C, Arda, FLIP 03-108 C, F4 09 (X 05 TH 21 16189-12-4), Hasanbey, FLIP 03-21 C, FLIP 05-150 C, FLIP 03-42 C and Çakır in 2016. According to STI indices selected genotypes Arda, FLIP 03-108 C, Aksu, Çakır, F4 09 (X 05 TH 21 16189-12-4), Hasanbey and FLIP 03-21 C as the most drought tolerant genotypes.

Data concerning yields under two different conditions (Yp and Ys) and heat stress indices in 2015 and 2016 were calculated for all the genotypes and given in Table 4 and Table 5.

**Table 4.** Heat stress indices in 2015.

| Genotypes | TI | MP | YI | YSI | STI | SSI | TE | GMP |
|---|---|---|---|---|---|---|---|---|
| Aksu | 39.27 (29) | 114.27 (3) | 1.54 (4) | 0.71 (20) | 1.89 (3) | 1.18 (20) | 141.50(20) | 112.57(3) |
| Arda | 27.40 (23) | 106.67 (5) | 1.51 (5) | 0.77 (17) | 1.67 (5) | 0.91 (17) | 129.47(17) | 105.79(5) |
| Azkan | 7.04 (4) | 54.45 (27) | 0.83 (21) | 0.88 (5) | 0.44(26) | 0.49 (7) | 113.82(7) | 54.34(27) |
| Çağatay | 31.50 (27) | 80.38 (11) | 1.05 (14) | 0.67 (23) | 0.92 (11) | 1.32 (23) | 148.74(23) | 78.82(11) |
| Çakır | 18.13 (17) | 109.27 (4) | 1.63 (3) | 0.85 (8) | 1.77 (4) | 0.62 (12) | 118.09(12) | 108.89(4) |
| Dikbaş | 29.63 (25) | 37.59 (33) | 0.37 (33) | 0.43 (34) | 0.18 (33) | 2.27(34) | 230.13(34) | 34.54(33) |
| EN 1685 | 17.20 (16) | 86.03 (8) | 1.26 (7) | 0.82 (13) | 1.09 (8) | 0.73 (15) | 122.21(15) | 85.60(8) |
| EN 1750 | 19.43 (18) | 48.99 (29) | 0.64 (30) | 0.67 (24) | 0.34(29) | 1.33 (24) | 149.48(24) | 48.01(29) |
| EN 766 | 14.07 (14) | 50.57 (28) | 0.71 (28) | 0.76 (18) | 0.37(28) | 0.98 (19) | 132.32(19) | 50.07(28) |
| EN 808 | 40.20 (30) | 79.70 (12) | 0.97 (18) | 0.60 (26) | 0.89(12) | 1.62(26) | 167.45(26) | 77.12(12) |
| EN 952 | 10.74 (10) | 68.50 (19) | 1.03 (15) | 0.85 (9) | 0.69(18) | 0.58 (8) | 117.01(8) | 68.29(18) |
| ENA 144-10 | 14.83 (15) | 55.39 (25) | 0.78 (23) | 0.76 (19) | 0.45(25) | 0.95 (18) | 130.92(18) | 54.89(25) |
| ENA 8-2 | 10.20 (9) | 80.47 (10) | 1.22 (9) | 0.88 (6) | 0.96 (10) | 0.48 (6) | 113.53(5) | 80.31(10) |
| F4 09 (X 05 TH 21 16189-12-4) | 23.13 (20) | 118.44 (1) | 1.74 (1) | 0.82 (14) | 2.07 (1) | 0.71 (14) | 121.64(14) | 117.87(1) |
| F4 09 (X 05 TH 69-16124-8) | 8.50 (6) | 23.35 (34) | 0.31 (34) | 0.69 (21) | 0.08 (34) | 1.24 (21) | 144.50(21) | 22.96(34) |
| F4 09 (X 05 TH 80-16105-31-2) | 30.93 (26) | 43.07 (31) | 0.45 (31) | 0.47 (32) | 0.24(31) | 2.12(32) | 212.07(32) | 40.19(31) |
| FLIP 01-24 C | 32.23 (28) | 60.39 (23) | 0.72 (27) | 0.58 (27) | 0.50(23) | 1.69(27) | 172.80(27) | 58.19(23) |
| FLIP 01-39 C | 25.37 (21) | 66.22 (20) | 0.87 (19) | 0.68 (22) | 0.63(20) | 1.29(22) | 147.39(22) | 64.99(20) |
| FLIP 01-54 C | 44.43 (31) | 75.39 (13) | 0.86 (20) | 0.54 (29) | 0.77(15) | 1.83(29) | 183.56(29) | 72.04(15) |
| FLIP 03-108 C | 11.66 (11) | 90.80 (7) | 1.38 (6) | 0.88 (7) | 1.22 (7) | 0.48 (5) | 113.72(6) | 90.61(7) |
| FLIP 03-126 C | 3.33(1) | 64.64 (22) | 1.02 (16) | 0.95 (1) | 0.62(21) | 0.20 (2) | 105.29(2) | 64.61(22) |
| FLIP 03-21 C | 13.54 (13) | 83.60 (9) | 1.25 (8) | 0.85 (10) | 1.03 (9) | 0.60 (9) | 117.62(10) | 83.33(9) |
| FLIP 03-28 C | 47.03 (32) | 71.12 (18) | 0.77 (24) | 0.50 (31) | 0.67 (19) | 2.00(31) | 198.80(31) | 67.11(19) |
| FLIP 03-42 C | 25.74 (22) | 58.80 (24) | 0.75 (26) | 0.64 (25) | 0.49 (24) | 1.44 (25) | 156.04(25) | 57.37(24) |
| FLIP 05-150 C | 8.73 (7) | 54.54 (26) | 0.82 (22) | 0.85 (11) | 0.44 (27) | 0.60 (10) | 117.40(9) | 54.36(26) |
| FLIP 05-170 C | 6.14 (3) | 73.60 (16) | 1.15 (10) | 0.92 (3) | 0.80 (14) | 0.32 (3) | 108.71(3) | 73.54(14) |
| FLIP 87-59 C | 27.94 (24) | 117.50 (2) | 1.68 (2) | 0.79 (16) | 2.03 (2) | 0.85 (16) | 126.99(16) | 116.67(2) |
| Hasanbey | 3.33 (2) | 71.67 (17) | 1.14 (11) | 0.95 (2) | 0.76 (16) | 0.18 (1) | 104.76(1) | 71.65(16) |
| ICC 1205 | 12.23 (12) | 74.82 (14) | 1.12 (12) | 0.85 (12) | 0.83 (13) | 0.61 (11) | 117.80(11) | 74.56(13) |
| ICC 4567 | 8.83 (8) | 45.92 (30) | 0.67 (29) | 0.82 (15) | 0.31 (30) | 0.70 (13) | 121.28(13) | 45.70(30) |
| ILC 8617 | 7.20 (5) | 64.73 (21) | 0.99 (17) | 0.89 (4) | 0.62 (22) | 0.42 (4) | 111.78(4) | 64.63(21) |
| İnci | 54.27 (32) | 74.37 (15) | 0.77 (25) | 0.47 (33) | 0.71 (17) | 2.15(33) | 214.91(33) | 69.24(17) |
| İzmir-92 | 22.20 (19) | 38.13 (32) | 0.44 (32) | 0.55 (28) | 0.20 (32) | 1.81(28) | 182.13(28) | 36.48(32) |
| Seçkin | 58.63 (34) | 96.52 (6) | 1.09 (13) | 0.53 (30) | 1.26 (6) | 1.87(30) | 187.25(30) | 91.96(6) |

**Table 5.** Heat stress indices in 2016.

| Genotypes | TI | MP | YI | YSI | STI | SSI | TE | GMP | DSS |
|---|---|---|---|---|---|---|---|---|---|
| Aksu | 7.7 (3) | 81.45 (12) | 1.31 (7) | 0.91 (2) | 0.92 (12) | 0.30 (2) | 109.92 (33) | 81.36 (12) | 3 |
| Arda | 25.8 (20) | 84.33 (10) | 1.21 (12) | 0.73 (15) | 0.96 (10) | 0.88 (15) | 136.12 (20) | 83.34 (10) | 3 |
| Azkan | 10.76 (5) | 44.15 (31) | 0.65 (31) | 0.78 (8) | 0.27 (30) | 0.72 (8) | 127.75 (27) | 43.82 (31) | 4 |
| Çağatay | 24.56 (16) | 60.75 (27) | 0.82 (25) | 0.66 (24) | 0.49 (26) | 1.12 (24) | 150.67 (11) | 59.50 (26) | 3 |
| Çakır | 14.7 (10) | 84.75 (9) | 1.31 (8) | 0.84 (4) | 0.99 (7) | 0.53 (4) | 118.99 (31) | 84.43 (8) | 3 |
| Dikbaş | 14.13 (8) | 45.04 (30) | 0.64 (32) | 0.73 (16) | 0.27 (31) | 0.90 (17) | 137.21 (17) | 44.48 (30) | 4 |
| EN 1685 | 25.16 (18) | 65.55 (23) | 0.89 (22) | 0.68 (19) | 0.57 (23) | 1.07 (20) | 147.50 (14) | 64.33 (23) | 3 |
| EN 1750 | 24.5 (15) | 40.42 (33) | 0.48 (33) | 0.53(32) | 0.21 (33) | 1.55 (32) | 186.97 (3) | 38.52 (33) | 6 |
| EN 766 | 11.63 (6) | 54.39 (29) | 0.82 (26) | 0.81 (6) | 0.40 (28) | 0.64 (6) | 123.94 (29) | 54.07 (28) | 5 |
| EN 808 | 20.3 (13) | 66.08 (22) | 0.94 (18) | 0.73 (17) | 0.59 (22) | 0.89 (16) | 136.30 (19) | 65.30 (22) | 5 |
| EN 952 | 18.34 (11) | 63.30 (24) | 0.91 (19) | 0.75 (12) | 0.54 (24) | 0.84 (13) | 133.88 (22) | 62.63 (24) | 4 |
| ENA 144-10 | 26.1 (21) | 66.88 (20) | 0.91 (20) | 0.67 (23) | 0.60 (20) | 1.09 (23) | 148.49 (12) | 65.59 (21) | 2 |
| ENA 8-2 | 14.63 (9) | 66.29 (21) | 1.00 (16) | 0.80 (7) | 0.60 (21) | 0.66 (7) | 124.81 (28) | 65.88 (20) | 2 |
| F4 09 (X 05 TH 21 16189-12-4) | 38.3 (29) | 101.95 (2) | 1.40 (3) | 0.68 (20) | 1.39 (3) | 1.05 (19) | 146.26 (16) | 100.14 (3) | 2 |
| F4 09 (X 05 TH 69-16124-8) | 7.43 (2) | 29.82 (34) | 0.44 (34) | 0.78 (9) | 0.12 (34) | 0.74 (9) | 128.47 (26) | 29.58 (34) | 5 |
| F4 09 (X 05 TH 80-16105-31-2) | 32.87 (25) | 62.34 (25) | 0.77 (27) | 0.58 (28) | 0.50 (25) | 1.39 (28) | 171.61 (7) | 60.13 (25) | 2 |
| FLIP 01-24 C | 44.83 (32) | 62.32 (26) | 0.67 (28) | 0.47 (33) | 0.47 (27) | 1.76 (33) | 212.36 (1) | 58.14 (27) | 2 |
| FLIP 01-39 C | 41.67 (30) | 77.27 (15) | 0.95 (17) | 0.58 (29) | 0.77 (15) | 1.42 (29) | 173.84 (6) | 74.40 (15) | 2 |
| FLIP 01-54 C | 31.17 (24) | 55.49 (28) | 0.67 (29) | 0.56 (30) | 0.39 (29) | 1.46 (30) | 178.12 (5) | 53.25 (29) | 2 |
| FLIP 03-108 C | 24.04 (14) | 92.05 (4) | 1.35 (5) | 0.77 (11) | 1.15 (4) | 0.77 (11) | 130.04 (24) | 91.26 (4) | 1 |
| FLIP 03-126 C | 34.6 (26) | 68.53 (19) | 0.86 (23) | 0.60 (26) | 0.61 (19) | 1.34 (27) | 167.54 (8) | 66.31 (19) | 2 |
| FLIP 03-21 C | 25.66 (19) | 101.50 (3) | 1.50 (2) | 0.78 (10) | 1.40 (2) | 0.75 (10) | 128.94 (25) | 100.69 (2) | 1 |
| FLIP 03-28 C | 57.1 (33) | 79.48 (14) | 0.86 (24) | 0.47 (34) | 0.76 (16) | 1.76 (34) | 212.11 (2) | 74.18 (16) | 2 |
| FLIP 03-42 C | 34.7 (27) | 90.95 (5) | 1.24 (9) | 0.68 (21) | 1.10 (5) | 1.07 (21) | 147.15 (15) | 89.28 (5) | 1 |
| FLIP 05-150 C | 24.86 (17) | 84.80 (8) | 1.22 (10) | 0.74 (14) | 0.97 (9) | 0.85 (14) | 134.35 (21) | 83.88 (9) | 2 |
| FLIP 05-170 C | 34.76 (28) | 79.85 (13) | 1.05 (13) | 0.64 (25) | 0.84 (13) | 1.19 (25) | 155.64 (10) | 77.94 (13) | 3 |
| FLIP 87-59 C | 11.9 (7) | 88.48 (6) | 1.39 (4) | 0.87 (3) | 1.08 (6) | 0.42 (3) | 114.42 (32) | 88.28 (6) | 3 |
| Hasanbey | 26.9 (22) | 85.75 (7) | 1.22 (11) | 0.73 (18) | 0.99 (8) | 0.90 (18) | 137.21 (18) | 84.69 (7) | 2 |
| ICC 1205 | 6.9 (1) | 82.85 (11) | 1.34 (6) | 0.92 (1) | 0.95 (11) | 0.27 (1) | 108.69 (34) | 82.78 (11) | 1 |
| ICC 4567 | 7.97 (4) | 43.59 (32) | 0.67 (30) | 0.83 (5) | 0.26 (32) | 0.56 (5) | 120.13 (30) | 43.40 (32) | 7 |
| ILC 8617 | 29.67 (23) | 76.84 (16) | 1.05 (14) | 0.68 (22) | 0.79 (14) | 1.08 (22) | 147.85 (13) | 75.39 (14) | 5 |
| İnci | 59.77 (34) | 120.79 (1) | 1.53 (1) | 0.60 (27) | 1.90 (1) | 1.32 (26) | 165.75 (9) | 117.03 (1) | 2 |
| İzmir-92 | 19.57 (12) | 69.82 (18) | 1.01 (15) | 0.75 (13) | 0.66 (18) | 0.82 (12) | 132.60 (23) | 69.13 (18) | 3 |
| Seçkin | 42 (31) | 74.63 (17) | 0.90 (21) | 0.56 (31) | 0.71 (17) | 1.46 (31) | 178.31 (4) | 71.61 (17) | 5 |

TI: Tolerance index, MP: Mean productivity, YI: Yield index, YSI: Yield stability index, STI: Stress tolerance index, SSI: Stress susceptibility index, TE: tolerance efficiency, GMP: Geometric mean productivity.

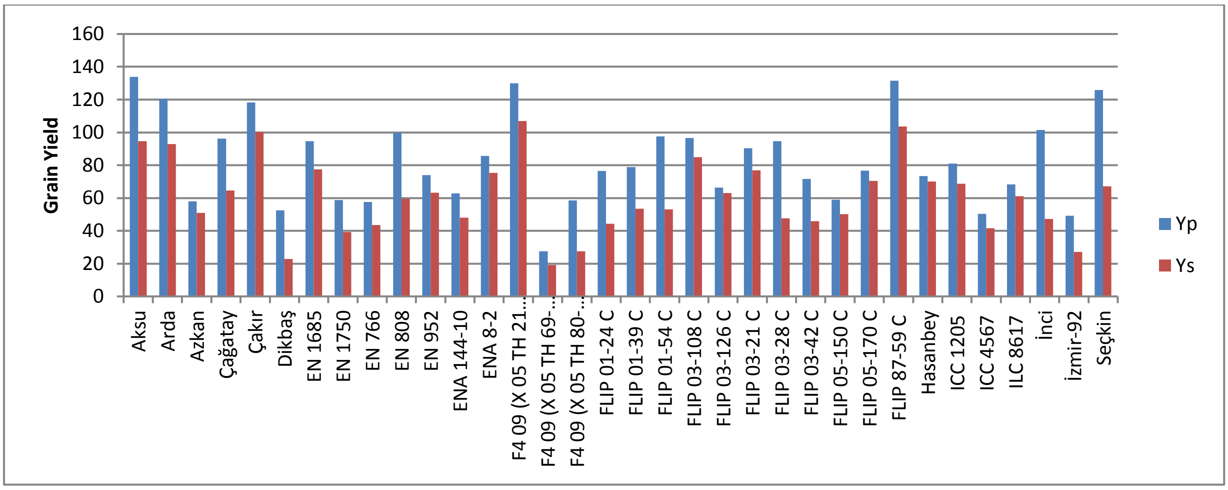


**Fig. 3.** Grain Yield of Chickpea Genotypes under heat stressed and non-stressed conditions in 2015.

In heat stress, STI values ranged from 0.18 to 2.03 and 0.12-1.90 in 2015 and 2016. The highest STI value was obtained from F4 09 (X05 TH 21 16189-12-4) cultivar and followed by FLIP 87-59 C, Aksu, Çakır, Arda, Seçkin, FLIP 03-108 C, EN 1685, FLIP 03-21 C and ENA 8-2 in 2015. In 2016, the highest STI value was obtained from Inci cultivar and followed by FLIP 03-21 C, F4 09 (X05 TH 21 16189-12-4), FLIP 03-108

C, FLIP 03-42 C, FLIP 87-59 C, Çakır, Hasanbey, FLIP 05-150 C, Arda and ICC 1205. As to STI indices selected F4 09 (X05 TH 21 16189-12-4), FLIP 03-21 C, FLIP 03-108 C as the best heat tolerant genotypes. Our result are consistent with the findings of Naderi and Emam (2014), Pireivatlou *et al.* (2014) who reported that STI is useful criteria for identifying drought and heat tolerant chickpea genotypes. In drought stress condition, SSI values ranged from 0.02 to 1.35 and from 0.69 to 1.19 in 2015 and 2016, respectively.

In 2015, ENA 8-2, ILC 8617, ENA 144-10, ICC 1205, FLIP 87-59 C, EN 1685, F4 09 (X 05 TH 21 16189-12-4), İzmir-92, ICC 4567 and EN 1750 have lower SSI value than other cultivars STI value, as well as in 2016 ICC 1205, İzmir-92, Seçkin, ILC 8617, FLIP 03-21 C, Çakır, EN 952, Çağatay, EN 808 and F4 09 (X 05 TH 80-16105-31-2) cultivars had lower SSI value than other cultivars values. SSI selected genotypes ILC 8617, ICC 1205, İzmir-92 as the best relatively drought tolerant genotypes.

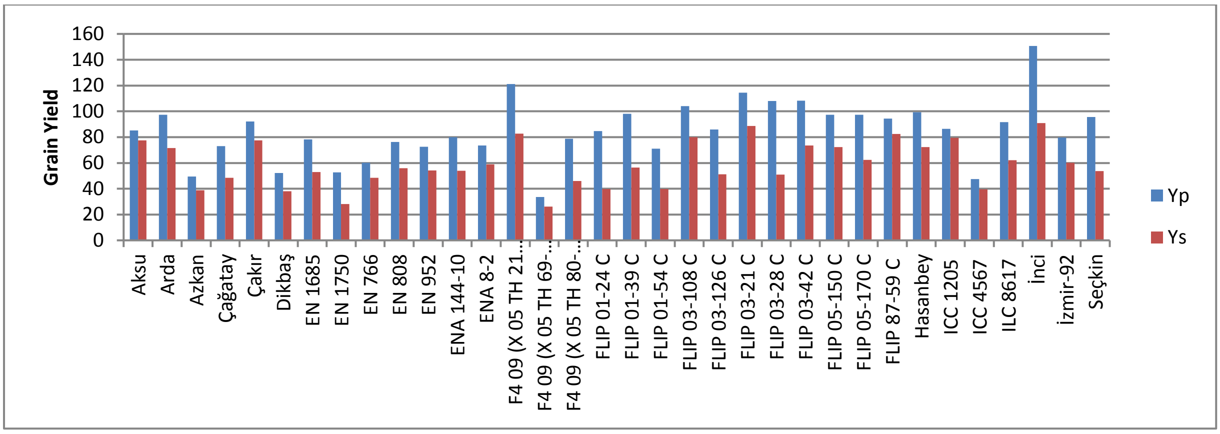


**Fig. 4.** Grain Yield of Chickpea Genotypes under heat stressed and non-stressed conditions in 2016.

**Table 6.** Drought and heat stress indices correlation coefficients between Yp, Ys and tolerance indices in 2015.

| Stress indices | Yp | Ys | TI | MP | YI | YSI | STI | SSI | TE | GMP |
|---|---|---|---|---|---|---|---|---|---|---|
| Yp | | 0.84** | 0.52** | 0.97** | 0.83** | 0.002 | 0.93** | 0.002 | -0.03 | 0.95** |
| Ys | 0.56** | | -0.04 | 0.95** | 1.00** | 0.53** | 0.95** | -0.53** | -0.54** | 0.97** |
| TI | 0.95** | 0.26 | | 0.28 | -0.03 | -0.82** | 0.22 | 0.82** | 0.79** | 0.23 |
| MP | 0.97** | 0.73** | 0.85** | | 0.95** | 0.26 | 0.98** | -0.25 | -0.28 | 0.99** |
| YI | 0.56** | 1.00** | 0.27 | 0.85** | | 0.53** | 0.95** | -0.53** | -0.54** | 0.97** |
| YSI | -0.60** | 0.23 | -0.78** | 0.27 | 0.23 | | 0.27 | -0.99** | -0.98** | 0.31 |
| STI | 0.88** | 0.84** | 0.70** | -0.78** | 0.84** | -0.26 | | -0.27 | -0.29 | 0.98** |
| SSI | 0.59** | -0.24 | 0.78** | 0.70** | -0.23 | -0.99** | 0.25 | | 0.98** | -0.31 |
| TE | 0.57** | -0.30 | 0.78** | 0.80** | -0.30 | -0.88** | 0.16 | 0.88** | | -0.33 |
| GMP | 0.90** | 0.86** | 0.72** | 0.78** | 0.86** | -0.27 | 0.98** | 0.26 | 0.18 | |

Represent the result of the drought and heat stress correlations coefficients

**Table 7.** Drought and heat stress indices correlation coefficients between Yp, Ys and tolerance indices in 2016.

| Stress indices | Yp | Ys | TI | MP | YI | YSI | STI | SSI | TE | GMP |
|---|---|---|---|---|---|---|---|---|---|---|
| Yp | | 0.82** | 0.67** | 0.97** | 0.83** | -0.20 | 0.94** | 0.20 | 0.19 | 0.95** |
| Ys | 0.64** | | 0.13 | 0.94** | 0.99** | 0.38** | 0.94** | -0.38** | -0.38** | 0.96** |
| TI | 0.97** | 0.40** | | 0.46** | 0.13 | -0.84** | 0.41** | 0.84** | 0.82** | 0.41** |
| MP | 0.98** | 0.77** | 0.89** | | 0.94** | 0.05 | 0.98** | -0.05 | -0.06 | 0.99** |
| YI | 0.64** | 0.99** | 0.40** | 0.77** | | 0.38** | 0.94** | -0.38** | -0.39** | 0.96** |
| YSI | -0.44** | 0.39** | -0.66** | -0.27 | 0.39** | | 0.11 | -0.99** | -0.98** | 0.11 |
| STI | 0.91** | 0.89** | 0.77** | 0.96** | 0.88** | -0.06 | | -0.11 | -0.12 | 0.98** |
| SSI | 0.44** | -0.39** | 0.66** | 0.27 | -0.39** | -0.99** | 0.07 | | 0.98** | -0.11 |
| TE | 0.32 | -0.49** | 0.55** | 0.15 | -0.49** | -0.94** | -0.07 | 0.93** | | -0.12 |
| GMP | 0.91** | 0.90** | 0.76** | 0.97** | 0.90** | -0.04 | 0.99** | 0.04 | -0.10 | |

Represent the result of the drought and heat stress correlations coefficients.

Regarding the heat stress, SSI values ranged from 0.18 to 2.27 and 0.27-1.76 in 2015 and 2016. In 2015 Hasanbey cultivars had the least SSI value and followed by FLIP 03-126 C, FLIP 05-170 C, ILC 8617, ENA 8-2, FLIP 03-108 C, Azkan, EN 952, FLIP 03-21 C, FLIP 05-150 C and ICC 1205 cultivars. In 2016, ICC 1205, Aksu, FLIP 87-59 C, Çakır, ICC 4567, EN 766, ENA 8-2, Azkan, F4 09 (X 05 TH 69-16124-8), FLIP 03-21 C, FLIP 03-108 C cultivars had lower SSI value. For SSI, in both research years, ENA 8-2, FLIP 03-108 C, Azkan and FLIP 03-21 C were desirable heat tolerant genotypes. Screening based on SSI will lead to reduced yield under well-conditions. These results are accordance with those of Naderi and Emam (2014) and Yucel and Mart (2014). However, the results of many researchers have found that SSI is not very suitable for identifying stress tolerant genotypes (Sio-Se Mardeh *et al.*, 2006; Bazrafsham *et al.*, 2008; Clarke *et al.*, 1992).

In drought stress, TE values ranged from 101.46 to 509.95 and from 194.24 to 609.16 in 2015 and 2016, respectively. In terms of TE value, Azkan, İnci, F4 09 (X 05 TH 69-16124-8), FLIP 03-28 C, FLIP 01-24 C, FLIP 03-42 C, FLIP 05-150 C, FLIP 01-39 C, Arda and Seçkin cultivars had higher value in 2015. Also, the highest TE value was obtained from Azkan and followed by F4 09 (X 05 TH 69-16124-8), FLIP 01-24 C, EN 1750, FLIP 03-28 C, Arda, FLIP 01-54 C, EN 766, FLIP 05-170 C, Aksu, Hasanbey and FLIP 03-126 C in 2016. In both research years, Azkan was the most drought tolerant genotypes as to TE indices. TE values ranged from 104.76 to 230.13 and 108.69-212.36 in 2015 and 2016 in heat stress condition. Dikbaş, İnci, F4 09 (X 05 TH 80-16105-31-2), FLIP 03-28 C, Seçkin, FLIP 01-54 C, İzmir-92, FLIP 01-24 C, EN 808 and FLIP 03-42 C cultivars had high TE value in the first year. In 2016, FLIP 01-24 C, FLIP 03-28 C, EN 1750, Seçkin, FLIP 01-54 C, FLIP 01-39 C, F4 09 (X 05 TH 80-16105-31-2), FLIP 03-126 C, İnci and FLIP 05-170 C had high TE value in heat stress condition.

Averaged across Chickpea genotypes, in 2015 and 2016 growing seasons, grain yields in response to heat stress were significantly decreased by 73 % and 69 %, respectively.

The results indicated that crop yields under heat stress were lower in all genotypes than under non-stressed conditions in 2015 and 2016 (Fig. 3 and Fig. 4).

Regarding the drought stress, GMP values ranged from 36.34 to 169.93 and from 61.87 to 174.37 in 2015 and 2016, respectively. In 2015, the highest value was obtained from Arda cultivar and followed by Aksu, FLIP 03-108 C, F4 09 (X 05 TH 21 16189-12-4), Çakır, FLIP 87-59 C, Hasanbey, Azkan, FLIP 03-21 C, İnci and EN 1685. In 2016, the highest value was obtained from Inci cultivar and followed by Aksu, FLIP 87-59 C, Arda, FLIP 03-108 C, Hasanbey, F4 09 (X 05 TH 21 16189-12-4), FLIP 03-21 C, FLIP 05-150 CFLIP 03-42 C and Çakır.

According to GMP, the desirable drought genotypes were Arda, Aksu, FLIP 03-108 C, Çakır, F4 09 (X 05 TH 21 16189-12-4), Hasanbey and FLIP 03-21 C. In heat stress condition, GMP values ranged from 22.96 to 117.87 and 29.58-117.03 in 2015 and 2016. In 2015, F4 09 (X05 TH 21 16189-12-4), FLIP 87-59 C, Aksu, Çakır, Arda, Seçkin, FLIP 03-108 C, EN 1685, FLIP 03-21 C and ENA 8-2 had high GMP value. In 2016, İnci, FLIP 03-21 C, F4 09 (X05 TH 21 16189-12-4), FLIP 03-108 C, FLIP 03-42 C, FLIP 87-59 C, Hasanbey, Çakır, FLIP 05-150 C and Arda cultivars had high GMP value. According to GMP, F4 09 (X05 TH 21 16189-12-4), FLIP 87-59 C, FLIP 03-21 C and Arda were heat tolerant genotypes in both research years. Many studies (Ali and El-Sadek, 2016; Moein *et al.*, 2015; Bellague *et al.*, 2016) indicated that GMP is useful for identifying stress-tolerant genotypes that perform well in stress environment Therefore, the genotypes with high GMP can be considered as tolerant. Drought stress intensity was calculated as 0.61 and 0.69 for 2015 and 2016 growing season. Besides, heat stress intensity was calculated as 0.27 and 0.30 in 2015 and 2016.

Correlation co efficient between yield and drought and heat stress indices in 2015 and 2016 are presented in Table 6 and 7. In drought and heat stress conditions of two research years, there was a significantly positive correlation between (Yp) and (Ys).

This indicates that high yield performance under favorable condition resulted in relatively high yield under stress condition.

In drought stress conditions of 2015 and 2016, Yield under non-stress conditions (Yp) was well correlated with all indices, except for TE in the second year. As seen Table 6 and 7, highly significantly positive correlation indicated that in heat stress conditions, yield under stress conditions (Ys) was significantly correlated with all indices, except for YSI, SSI and TE in both years. In drought stress condition, Yp and Ys were significantly positively correlated with TI, MP, YI, STI and GMP in two research years.

Besides, in heat stress conditions, Yp and Ys were significantly positively correlated with MP, YI, STI and GMP in two research years. In terms of drought and heat tolerance, highly positively significantly correlation under stress as well as non-stress conditions indicated that these indices were more suitable for selection stress tolerant genotype. These results are accordance with those of Ali and Sadek (2016); Bellague *et al.* (2016) and Farshadfar *et al.* (2012).

## Conclusion

In conclusion, there were highly significant differences observed among the tested chickpea genotypes response to drought and heat stresses. Significantly higher values of MP, YI, YSI, TE and GMP with an associated decrease in TI and SSI values suggested that, Aksu, Arda, Çakır, F4 09 (X 05 TH 21-16189), FLIP 03-108 were the most drought and heat tolerant genotypes, respectively. Besides, in both non-stress and stress conditions MP, YI, STI and GMP, which highly positively significantly correlated with seed yields, were the best indices. Based on our field studies, it is suggested that the drought and heat tolerance indicators of plants can be used by breeders to select stress-resistant economically productive chickpea genotypes suitable to grow under Mediterranean climatic conditions.

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## References

**Abbasi MR, Sepaskhah AR.** 2011. Response of different rice cultivars (*Oryza sativa* L.) to water-saving irrigation in greenhouse conditions. Int J Plant Product **5,** 1735-8043.

**Ali MB, El-Sadek AN.** 2016. Evaluation of drought tolerance indices for wheat (*Triticum aestivum* L.) under irrigated and rainfed conditions. Communications in Biometry and Crop Science **11,** 77-89.

**Anwar J, Subhanı GM, Hussaın M, Ahmad J, Hussaın, Munır M.** 2011. Drought Tolerance Indices and Their Correlation with Yield in Exotic Wheat Genotypes. Pak. J. Bot **43(3),** 1527-1530.

**Bazrafshan M, Matlubi F, Mesbah M, Joukar L. 2008.** Evaluations of drought tolerance of sugar beet genotypes using drought tolerance indices. J Sugar beet **24,** 15-35.

**Bellague D, Hammedi-Bouzina MM, Abdelguerfi A.** 2016. Measuring the performance of perennial alfalfa with drought tolerance indices. Chilean J of Agricultural Research **76(3),** 273-284.

**Betran FJ, Beck D, Banziger M, Edmeades GO.** 2003. Genetic analysis of inbred and hybrid grain yield under stress and non-stress environments in tropical maize. Crop. Sci. **43,** 807-817.

**Bidinger FR, Mahalakshmi V, Rao GDP.** 1987. Assessment of drought resistance in pearl millet (*Pennisetum americanum* (L.) Leeke) Estimation of genotype response to stress. Crop and Pasture Sci **38,** 49-59.

**Bouslama M, Schapaugh WT.** 1984. Evaluation of Three Screening Techniques for Heat and Drought Tolerance. Crop Sci **24,** 933-937.

**Ceccarelli S, Grando S.** 1991. Selection environment and environmental sensitivity in barley. Euphytica **57,** 157-167.

**Clarke JM, De Pauw RM, Townley-Smith TM.** 1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Science **32,** 728-732.

**Deshmukh DV, Mhase LB, Jamadagni BM.** 2004. Performance of Desi and Kabuli Chickpea Genotypes under Irrigated and Rainfed Conditions. Indian J. Pulses Res. **17(2),** 181-182.

**Farshadfar E, Jamshidi1 B, Aghaee M.** 2012. Biplot analysis of drought tolerance indicators in bread wheat landraces of Iran. Intl J Agri Crop Sci **4(5),** 226-233.

**Fernandez, GCJ.** 1992. Effective selection criteria for assessing plant stress tolerance. Proceedings of the international Symposium on Adaptation of Vegetable and Other Food Crops in Temperature and Water Stress 257-270.

**Fischer RA, Maurer R.** 1978. Drought Resistance in Spring Wheat Cultivars. Aust. J. Agric. Res **29,** 897-912.

**Ganjeali A, Kafi M, Bagheriv F, Shahriyari F.** 2005. Screening for drought tolerance on Chickpea genotypes. Iran J Field Crops Res **3,** 122-127.

**Ganjeali A, Porsa H, Bagheri A.** 2011. Assessment of Iranian chickpea (*Cicer arietinum* L.) germplasms for drought tolerance. Agr Water Manage **98,** 1477-1484.

**Gavuzzi P, Rizza F, Palumbo M, Campaline RG, Ricciardi GL, Borghi B.** 1997. Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can. J. Plant Sci **77,** 523-531.

**Golabadi M, Arzani A, Mirmohammadi Maibodi SAM.** 2006. Assessment of drought tolerance in segregating populations in durum wheat. Afr J Agric Res **1,** 162-171.

**Lin CS, Binns MR, Lefkovitch LP.** 1986. Stability analysis: where do we stand. Crop Sci **26,** 894-900.

**Moein R, Akbar S, Shahram N, Alireza Z.** 2015. Screening Drought Tolerant Genotypes in Chickpea using Tolerance Score Method. Int. J of Advanced Biological Research **3.**

**Naderi R, Emam Y.** 2014. Evaluation of rapeseed (*Brassica napus* L.) cultivars performance under drought stress. AJCS **8(9),** 1319-1323.

**Pireivatlou AS, Masjedlou BD, Aliyev RT.** 2010. Evaluation of yield potential and stress adaptive trait in wheat genotypes under post an thesis drought stress conditions, Afric J of Agric Res **5,** 2829-2836.

**Rajaram S, Braun HJ, Ginkel MV.** 1996. CIMMYT's approach to breed for drought tolerance. Euphytica **92,** 147-153.

**Rajaram S, Van Ginkle M.** 2001. Mexico, 50 years of international wheat breeding. In: Bonjean, A.P., Angus, WJ. (Eds.), The World Wheat Book: A History of Wheat Breeding. Lavoisier Publishing, Paris, France pp. 579-604.

**Rathjen AJ.** 1994. The biological basis of genotype - environment interaction: its definition and management. In: Proceedings of the Seventh Assembly of the Wheat Breeding Society of Australia, Adelaide, Australia.

**Rosielle AA, Hamblin J.** 1981. Theoretical Aspects of Selection for Yield in Stress and Non- stress Environment Crop Sci **21,** 943-946.

**Singh KB.** 1993. Problems and Prospects of Stress Resistance Breeding in Chickpea. Editör: Singh, K.B., Saxena, M.C. p. 17-35.

**Sio-Se Mardeh A, Ahmadi A, Poustini K, Mohammadi V.** 2006. Evaluation of drought resistance indices under various environmental conditions. Field Crops Research **98,** 222-229.

**Wery J, Turc O, Lecoeur J.** 1993. Mechanism of Resistance to Cold, Heat and Drought in Cool-Season Legumes, with Special Reference to Chickpea and Pea. In 'Food Legumes'. (Eds: Singh, KB., MC., Saxena) Wiley Publishing, Chichester, UK 271-291.

**Yücel D, Mart D.** 2014. Drought Tolerance in chickpea Genotypes. Turkish J of Agriculture and Natural Sci **1,** 1299-1303.

**Zebarjadi AR, Chaghakaboodi Z, Kahrizi D.** 2011. Evaluation of Rapeseed Genotypes (*Brassica napus* L.) under Drought Stress Conditions. Researches of the First International Conference. Babylon and Razı Uni.