Research Journal of Agricultural Sciences
An International Journal

*Res. Jr. of Agril. Sci.* **12**(2): 597–600

**P**- ISSN: 0976-1675 | **E**- ISSN: 2249-4538

www.rjas.org

*Research Paper*

# Heat Tolerance Indices and their Role in Selection of Heat Stress Tolerant Chickpea (*Cicer arietinum* L.) Genotypes

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Received: 05 Jan 2021 | Revised accepted: 31 Mar 2021 | Published online: 01 Apr 2021
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## A B S T R A C T

A field experiment was carried out in factorial randomized block design to evaluate six chickpea genotypes for high temperature tolerance. High temperature was imposed by delaying sowing dates i.e., October 5th, November 5th and December 5th. 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 tolerance capacity. There were highly significant differences observed among the tested chickpea genotypes to heat stresses. Significantly higher values of mean productivity (2062), yield index (1.184), Yield stability index (0.643), and geometric mean productivity (1842) with an associated decrease in tolerance efficiency (155.5) and stress susceptibility index (0.646) values suggested that, JAKI-9218, JG-14 and JG-11 were the most heat tolerant genotypes, whereas, BGD-128, KAK-2 and Annigeri-1 genotypes showed susceptible to heat stress.

***Key words*:** Chickpea, Yield indices, Temperature stress, Genotypes

Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops of dry lands in the world. For a wide range of agro-ecological environments, it is also an alternative pulse crop for increasing the diversification of different cropping systems [1]. Chickpea yield affected by biotic stresses is quite low, and yield is below its potential [2]. Abiotic stress is the most significant limiting factor in agriculture production in arid and semi-arid areas. Sensitivity to heat stress is often measured in terms of lower yields under heat stress conditions [3]. Quantifying the degree of tolerance or resistance of crops to stress requires several indices. Chickpea is considered one of the most stresses tolerant of the cool season food legumes. Chickpea area under late sown high temperature condition is increasing particularly in N Northern and Central region due to inclusion of chickpea in new cropping system and intense in sequential cropping practice leading to prolonged exposure of chickpea to high temperature stress [4]. Field performance is the standard to assess plant response in stress. The genotypes yield performance in drought stressed and favourable environments seems to be a common starting point in the identification of traits related to drought resistance and the selection of genotypes for breeding programmes [5]. Field screening is a powerful tool for evaluation of genotypes for effective breeding to develop new crop varieties prone to heat stress. The aim of the present study was to evaluate the tolerance chickpea genotypes to heat stress as well as to identify a suitable index for further screening and to select chickpea genotypes tolerant to heat stress.

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## MATERIALS AND METHODS

*Plant material and experimental design*

Six chickpea genotypes that are high yielding were used as material. Among six genotypes 4 desi genotypes (Annigeri-1, JAKI-9218, JG-11 and JG-14) and 2 kabuli genotypes (BGD-128 and KAK-2). They were assessed in factorial randomized complete block design with 3 replications under winter sowing. The experiment plots consisted of 14 rows of 4 m length with 4 m wide inter and intra-row spacing of 30 and 10 cm, respectively.

Calculation of stress indices after harvest, seed yield of each genotype was recorded in grams after threshing and then converted into kg per hectare. Heat resistance indices were calculated using the following relationships:

1. Tolerance Index (TI) = Yp – Ys [6]
2. Mean Productivity (MP) = (Yp + Ys)/2 [6]
3. Yield Index (YI) = Ys/Xs [7]
4. Yield Stability Index (YSI) = Ys/Yp [8]
5. Stress Tolerance Index (STI) = (Ys × Yp) / (XP) 2 [9]
6. Stress Susceptibility Index (SSI) = (1 – (Ys/Yp)) / (1 – (Xs/Xp)) [10]
7. Tolerance Efficiency (TE) = (Yp/Ys) × 100 [11)
8. Geometric Mean Productivity (GMP) = (Yp × Ys) 1/2 [9]
9. Stress Intensity (SI) I = (Xp-Xs) / Xp

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.

*Climate and weather*

The mean monthly maximum and minimum temperatures show a wide range of fluctuations during the year. The maximum temperature sometimes exceeds 37°C during summer, less than 15°C recorded during winter. Great variation in temperature entire year. The average annual rainfall is about 625.9 mm and the total rain as well as its distribution is subjected to great variations. During 2018-19 the total rainfall was 891.2 mm whereas, during 2019-20 the total rainfall was 1316.2 mm.

## RESULTS AND DISCUSSION

Significant genetic variability for various morpho-physiological traits was recorded for the given set of six genotypes grown under both high temperature stress and normal conditions.

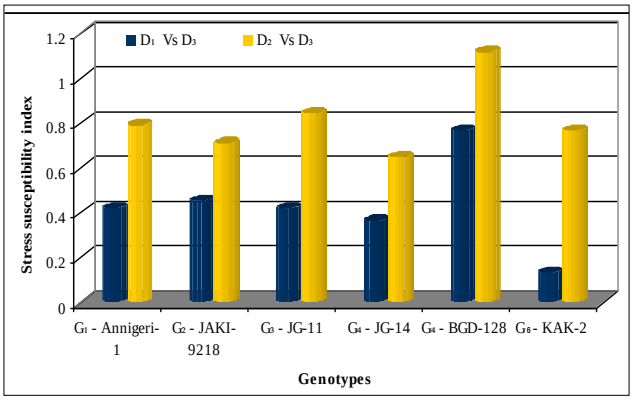


Fig 1 Effect of temperature regimes on stress susceptibility index of chickpea genotypes

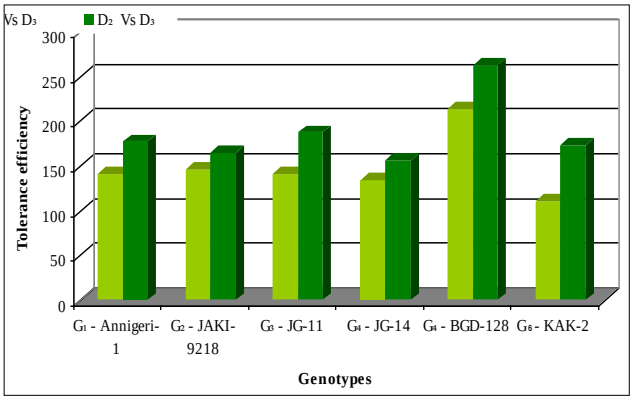


Fig 2 Effect of temperature regimes on tolerance efficiency of chickpea

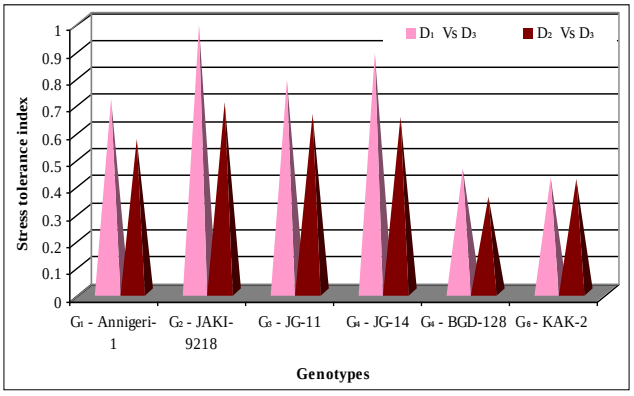


Fig 3 Effect of temperature regimes on stress tolerance index of chickpea

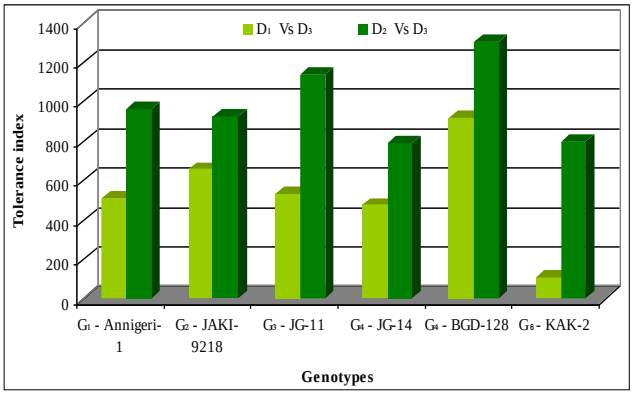


Fig 4 Effect of temperature regimes on tolerance index of chickpea genotypes

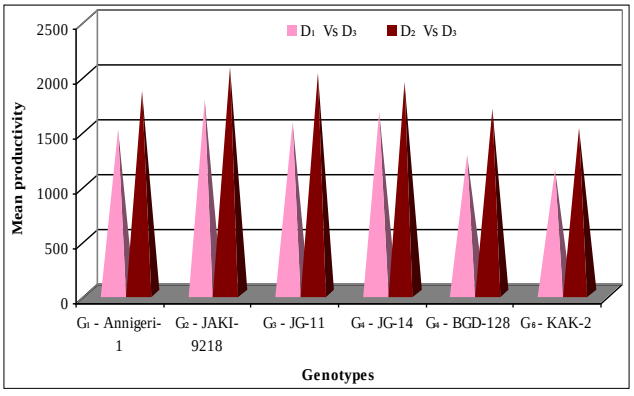


Fig 5 Effect of temperature regimes on mean productivity of chickpea genotypes

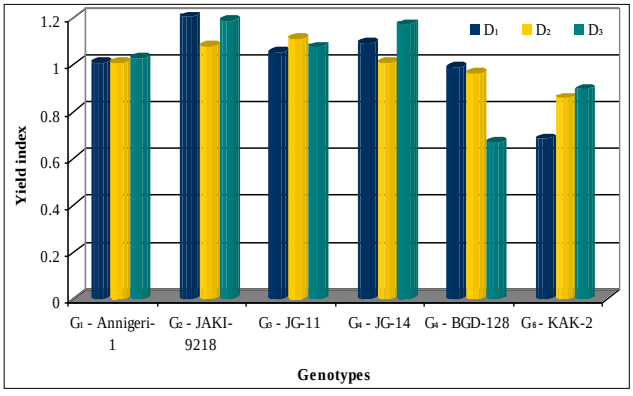


Fig 6 Effect of temperature regimes on yield index of chickpea genotypes

The result indicated that in $D_1$ temperature regime, the maximum stress susceptibility index was observed in BGD-128 (0.764) genotype followed by JAKI-9218 (0.449), Annigeri-1(0.416) and JG-11 (0.416). The lowest stress susceptibility index was observed in KAK-2(0.128) genotype in $D_1$ temperature regime (Fig 1). In $D_2$ temperature regime, stress susceptibility index ranged from 0.646 to 1.117. In $D_2$ temperature regime, the maximum stress susceptibility index was observed in BGD-128 (1.117) genotype followed by JG-11 (0.842), Annigeri-1 (0.787) and KAK-2 (0.764). The lowest stress susceptibility index was observed in JG-14 (0.646) genotype. In $D_1$ temperature regime, tolerance efficiency ranged from 109.8 to 213.6. In $D_1$ temperature regime, the maximum tolerance efficiency was observed in

BGD-128 (213.6) genotype followed by JAKI-9218 (145.5) but the least was observed in KAK-2 (109.8) genotype (Fig 2). In $D_2$ temperature regime, tolerance efficiency ranged from 155.5 to 261.7, the maximum tolerance efficiency was observed in BGD-128 (261.7) genotype followed by JG-11 (187.1) the lowest was observed in JG-14 (155.5) genotype. In $D_1$ temperature regime, stress tolerance index varied from 0.422 to 0.988. The highest stress tolerance index was observed in JAKI-9218(0.988) genotype (Fig 3) followed by JG-14 (0.880), JG-11(0.782) and Annigeri-1(0.714). The lowest stress tolerance index was observed in KAK-2 (0.422) genotype. In $D_2$ temperature regime, the lowest stress tolerance index was observed in BGD-128 (0.351) genotype whereas, the highest stress tolerance index was observed in JAKI-9218 (0.703) genotype followed by JG-11(0.656), JG-14 (0.648) and Annigeri-1(0.567). The stress tolerance index ranged from 0.351 to 0.703. Among two dates of sowing $D_1$ temperature regime recorded mean highest stress tolerance index (0.707) and the least stress tolerance index was observed in $D_2$ temperature regime (0.558). This study confirmed that, in chickpea genotypes showed lower the value of stress susceptibility index, tolerance efficiency and tolerance index means higher the stress tolerant, higher the value of stress susceptibility index, tolerance efficiency and tolerance index means susceptible to high temperature stress found the suitable parameter for screening for stress tolerant. Heat susceptibility is responsible for yield loss in chickpea [12-13].

Heat tolerance index was vary from 105.7 (KAK-2) to 914.4 (BGD-128) and mean value was 530.7 in $D_1$ temperature regime. In $D_2$ temperature regime, heat tolerance index was vary from 787.7 (JG-14) to 1301.4 (BGD-128) and mean value was 982.3 (Fig 4).

Likewise, considering mean productivity as an important selection parameter for heat tolerance. In $D_1$ temperature regime JAKI-9218 recorded the highest mean productivity followed by JG-14 (1655), JG-11(1566) and Annigeri-1(1496) the lowest mean productivity was noticed in KAK-2 (1135) genotype (Fig 5). In $D_2$ temperature regime KAK-2 (1504) genotype recorded the least mean productivity whereas, JAKI-9218(2062) genotype recorded maximum mean productivity followed by JG-11 (2001), JG-14 (1930) and Annigeri-1(1849). Mean productivity was recorded from 1135 (KAK-2) to 1766 (JAKI-9218) and mean value was 1480 in $D_1$ temperature regime. In $D_2$ temperature regime, Mean productivity was vary from 1504 (KAK-2) to 2062 (JAKI-9218) and mean value was 1838 [14].

Considering yield index as an important heat tolerance index. Among the genotypes, in $D_1$ temperature regime JAKI-9218 (1.199) genotype recorded maximum yield index followed by JG-14 (1.084), JG-11 (1.049), and Annigeri-1 (1.002). The lowest yield index was observed in KAK-2(0.680) genotype (Fig. 6). Like that, in $D_2$ temperature regime, JG-11 (1.108) genotype recorded maximum yield index followed by JAKI-9218 (1.074), JG-14 (1.004) and Annigeri-1 (1.002) the lowest was observed in KAK-2 (0.853) genotype. Importantly, yield index as an important selection parameter for drought tolerance in chickpea [15].

Geometric mean productivity was recorded from 1133 (KAK-2) to 1735 (JAKI-9218) and mean value was 1450 in $D_1$ temperature regime. In $D_2$ temperature regime, geometric mean productivity was recorded from 1302 (BGD-128) to 1842 (JAKI-9218) and mean value was 1628. JAKI-9218 (1735) genotype recorded maximum geometric mean productivity followed by JG-14 (1638), JG-11 (1544) and Annigeri-1 (1475) in $D_1$ temperature regime (Fig 7). The lowest geometric mean productivity was observed in KAK-2 (1133) genotype. In $D_2$ temperature regime, the maximum geometric mean productivity was observed in JAKI-9218 (1842) genotype followed by JG-11 (1780), JG-14 (1769) and Annigeri-1 (1654). The lowest geometric mean productivity was observed in BGD-128 (1302) genotype [16].

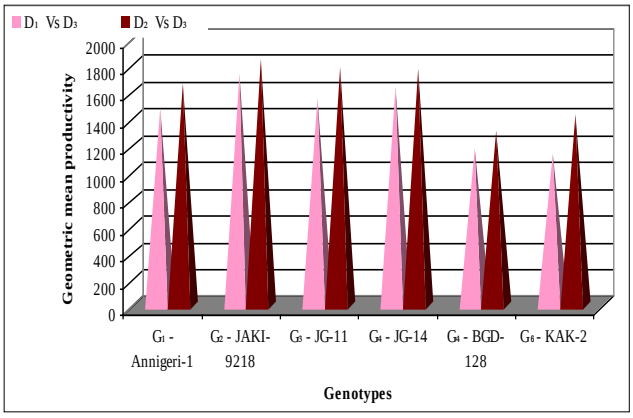


Fig 7 Effect of temperature regimes on geometric mean productivity of chickpea genotypes

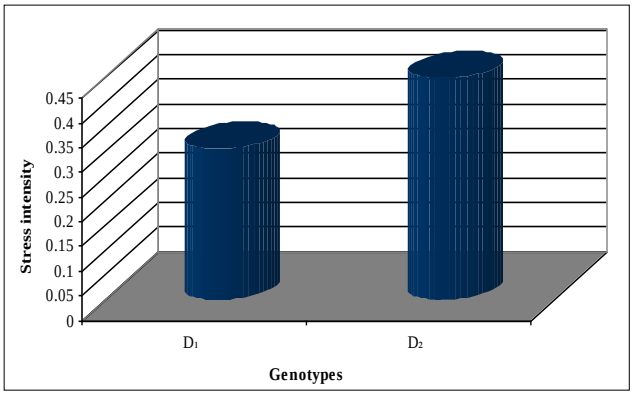


Fig 8 Effect of temperature regimes on stress intensity of chickpea genotypes

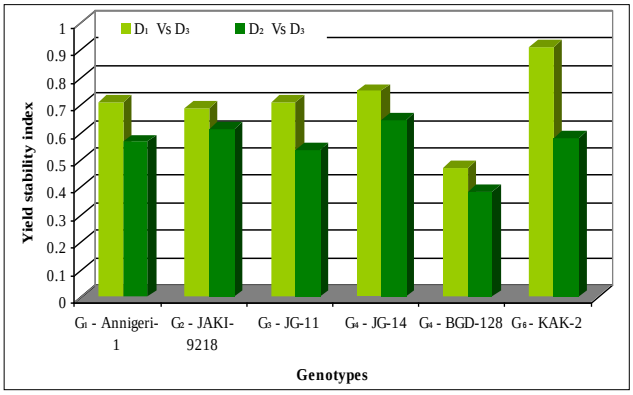


Fig 9 Effect of temperature regimes on yield stability index

Among two dates of sowing the mean of highest heat stress intensity was observed in $D_2$ temperature regime (0.447). The lowest mean heat stress intensity was observed in $D_1$ temperature regime (0.304). The mean of stress intensity was in two dates of sowing ($D_1$ and $D_2$) is 0.376 (Fig 8).

In $D_1$ temperature regime, yield stability index varied from 0.468 to 0.911. The highest yield stability index was observed in KAK-2 (0.911) genotype followed by JG-14 (0.750), JG-11 (0.711) and Annigeri-1 (0.710). The lowest yield stability index was observed in BGD-128 (0.468)

genotype. In $D_2$ temperature regime, the lowest yield stability index was observed in BGD-128 (0.382) genotype. The highest yield stability index was observed in JG-14 (0.643) genotype followed by JAKI-9218 (0.610), KAK-2 (0.577) and Annigeri-1 (0.710). The yield stability index ranged from 0.643 to 0.382 (Fig 9). This study confirmed that, in chickpea genotypes showed higher value of mean productivity, geometric mean productivity, yield index, yield stability index, stress tolerance index and stress intensity means higher the stress tolerant genotype, lower the value of mean productivity, geometric mean productivity, yield index, yield stability index, stress tolerance index and stress intensity means susceptible to high temperature stress genotypes found the suitable parameters for screening or selecting for stress tolerant genotype [17-18].

Significant genotypic variation was recorded in heat susceptibility index (HSI), heat tolerance index (HTI) and heat yield stability index (HYSI) under late sown condition. Among two dates of sowing the mean of highest heat stress intensity was observed in $D_2$ temperature regime (0.447). The lowest mean heat stress intensity was observed in $D_1$ temperature regime (0.304). Thus, genotypes exhibiting higher MP, GMP and YI could be efficiently used in selecting superior genotypes under high temperature stress. While, emphasizing stress susceptible index as selection parameter for heat tolerance genotypes showing stress susceptible index less than 1 were considered as higher heat tolerance [19-20].

## CONCLUSIONS

In conclusion, there were highly significant differences observed among the tested chickpea genotypes response to heat stresses. Significantly higher values of MP, YI, YSI, and GMP with an associated decrease in TE and SSI values suggested that, JAKI-9218, JG-14 and JG-11 were the most heat tolerant genotypes. 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 heat tolerance indicators of plants can be used for to select stress-resistant economically productive chickpea genotypes suitable to grow under different climatic conditions.

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