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Evaluation of chickpea genotypes for heat stress under partially controlled condition (Elevated temperature) in polybags

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Abstract
The polybag experiment was set up during 2017 at Main Agriculture Research Station, UAS, Dharwad to screen heat stress tolerant chickpea genotypes *viz.*, Annigeri-1 (G_1), JG-11 (G_2), JG-14 (G_3), Jaki-9218 (G_4) and KAK-2 (G_5) were evaluated for heat stress. The genotypes were subjected to two different conditions like partial elevated temperature (C_2 - stress) and were ambient condition (C_1 - control) by creating polythene structure. The genotypes were screened for root length, shoot length, root dry weight, shoot dry weight and root to shoot ratio. The shoot length, shoot dry weight and root dry weight were affected under partial elevated temperature condition than ambient condition but root length and root to shoot ratio was found higher in the partial elevated temperature condition as compared to ambient. The genotype which found tolerant to the heat stress under partial elevated condition was JG-14 than JG-11, Jaki-9218, Annigeri-1 and KAK-2 which were found as moderately tolerant genotypes.

Keywords: ambient temperature, elevated temperature, heat stress

Introduction

Legumes play an important role in Agriculture and they sustain productivity in cropping system. They are good source of protein and having ability to use atmospheric nitrogen through biological nitrogen fixation is environmentally acceptable. In India pulses are cultivated on marginal lands under rain fed conditions, as they are perceived to be low yielding and less remunerative crops. As a result, the growth rate of production of pulses in India, the major pulse growing country in the world is low compared to cereals (Anonymous, 2016) [3]. Only around 15 per cent of the area under pulses has assured irrigation, because of the high level of fluctuations in pulse production (biotic and abiotic stress) and prices (no minimum support price) therefore, the farmers are not very keen on taking up pulse cultivation despite high wholesale pulse prices in recent years.

High temperature stress is one of the most important detriments among several abiotic constraints in chickpea growth and yield over a range of environments (Basu *et al*., 2009) [5]. This threat is mainly associated with global warming and significant changes in cropping system that have driven chickpea production to relatively warmer growing conditions. India, is a major chickpea production in the world, there has been a major shift in chickpea production areas from cooler long season environment of northern India (Indo-Gangetic plains) to warm, short season environment of central and southern India (Gowda *et al*., 2009) [8]. The area under late sown conditions has significantly increased due to inclusion of chickpea in new cropping systems and intense cropping practices such as soybean, chickpea in central India, resulting in a prolonged exposure of crop to high temperature conditions (Bhatia *et al*., 2008 and Krishnamurthy *et al*., 2011) [6, 10]. Despite severe threat from increasing temperatures, very few studies elucidating the high temperature effects on vegetative and reproductive stages using agronomic, phenological, morphological and physiological assessment have been reported in chickpea (Wang *et al*., 2006) [11]. Therefore this study was carried out in order to evaluate chickpea genotypes to heat stress and determine the best heat stress measures for increase and improvement of yield in stress and non-stress condition. Also, this study was undertaken to assess the selection criteria for identifying heat stress tolerance in chickpea genotypes, so that suitable varieties can be recommended for cultivation.

Materials and Methods

The experiment was conducted during 2016 to check the performance of five chickpea genotypes for heat tolerance through morphological and root traits. The experiment was carried out in polythene bag with 3 kg soil mixture. The heat stress treatment was imposed by constructing polythene chamber of size 3×3×3 feet using polythene sheet. The seedlings were transferred to the polythene chamber after 14 days of emergence of seedlings which were raised in a normal condition. The temperature details of polythene chamber and ambient temperature was recorded and presented in table 1 and general view of experimental set up was depicted in Plate 1 and 2. The observations on root length, shoot length, root to shoot ratio, root weight and shoot weight were recorded. The methodology for recording observations was as follows.

Table 1. The temperature details of polythene chamber and ambient temperature

Temperatures	Out side the chamber	Inside the chamber	Average
$T_{max.}$ °C	30.6	38.5	34.5
$T_{min.}$ °C	34.0	42.9	38.5
$T_{avg.}$ °C	28.0	31.7	29.9

Plate 1: General view of partial elevated temperature condition

Plate 2: Performance of genotypes under ambient (control) and elevated temperature condition

Shoot length: Shoot length was measured from collar region to the growing tip and expressed in centimetre (cm).

Root traits: Polybags were watered and roots were separated from the soil and washed in running water and the following observations were recorded at 30 DAS.

Root length: Root length was measured from collar region to the tip of the root and expressed in centimetre (cm).

Root dry weight: The root of each plant after separation was oven dried at 72°C for 72 hours and recorded in grams (g).

Root to shoot ratio: The ratio of root length to shoot length and root dry weight to shoot dry weight of each seedling was calculated and the experimental data was subjected to statistical analysis as described by Gomez and Gomez (1984). The levels of significance used in 'F' and 't' tests was P=0.05 and P=0.01.

Results and Discussion

There were systematic and consistent differences between the plants under partial elevated temperature and ambient condition. The results of the present study indicated that on root length, shoot length, root to shoot ratio, root weight and shoot weight were differed significantly differed under partial elevated temperature (C_2) and ambient condition (Control, C_1). The results of the present investigation are presented as following.

Root Length

Data on root length (Table 2) differed significantly with respect to partial elevated temperature condition, genotypes and their interactions. Plant height was generally reduced when subjected to elevated temperature compared to that ambient condition. At both temperature regimes, there were significant differences were observed among the genotypes. The stress condition (29.40 cm) recorded significantly higher root length than control (23.76 cm). Among the genotypes Annigeri-1 has shown significantly higher root length which was followed by JG-14 (26.25 cm), JG-11 (25.96 cm), KAK-2 (24.90 cm) and Jaki-9218 (24.42). The genotype Annigeri-1 under ambient condition (32.72 cm) was recorded significantly higher root length which was on par with JG-11 (30.17 cm), Annigeri-1 (30.00) and Jaki-9218 (30.33) which was followed by JG-14 (29.00 cm) under partial elevated condition whereas, lower root length was recorded in JG-11 (21.75) which was on par with KAK-2 (22.31) and JG-14 (23.50) under ambient condition.

Shoot Length

The high temperature stress had significantly reduced the mean plant height in all the genotypes under the partial elevated condition over to their ambient condition. The data on shoot length was recorded and presented in table 2. Significantly lower shoot length was recorded in stress (13.84 cm) compared to control (15.75). Among the genotypes lowest shoot length was recorded in Annigeri-1 (13.69) which was on par with Jaki-9218 (14.76) and JG-11 (14.54). Significantly higher shoot length was recorded in KAK-2 (15.49) and JG-14 (15.49). Similar results was observed by Adil *et al*. (2003) reported that plant height of tomato was generally reduced for the plants that subjected to heat shock treatment compared to that not subjected to heat shock treatment.

Table 2. Effect of different stress condition (Drought and temperature) on chickpea genotypes in polybags

Treatments	Root length	Shoot length	R:S ratio	Root weight	Shoot weight	R:S ratio
Stress conditions						
Control (C_1)	23.76^{b}	15.75^{a}	1.54^{b}	0.26^{a}	0.36^{a}	0.73^{b}
Stress (C_2)	29.40^{a}	13.84^{b}	2.13^{a}	0.15^{b}	0.19^{b}	0.78^{a}
S.Em.±	0.33	0.17	0.06	0.00	0.00	0.00
CD at 5 %	1.32	0.69	0.24	0.01	0.01	0.02
Genotypes						
Annigeri-1 (G_1)	31.36^{a}	13.69^{b}	2.29^{a}	0.17^{d}	0.24^{d}	0.72^{c}
JG-11 (G_2)	25.96^{b}	14.76^{ab}	1.82^{b}	0.19^{c}	0.27^{c}	0.73^{b}
JG-14 (G_3)	26.25^{b}	15.49^{a}	1.73^{b}	0.30^{a}	0.36^{a}	0.83^{a}
Jaki-9218 (G_4)	24.42^{b}	14.54^{ab}	1.71^{b}	0.17^{b}	0.23^{c}	0.74^{b}
KAK-2 (G_5)	24.90^{b}	15.49^{a}	1.63^{b}	0.22^{b}	0.30^{b}	0.74^{b}
S.Em.±	0.52	0.27	0.09	0.00	0.00	0.01
CD at 5 %	2.08	1.09	0.37	0.01	0.02	0.03
Interactions						
$C_1 G_1$	32.72^{a}	14.38^{b}	2.28^{a}	0.21^{d}	0.31^{d}	0.68^{f}
C_1G_2	21.75^{c}	16.33^{a}	1.34^{c}	0.25^{c}	0.36^{c}	0.69^{d-f}
C_1G_3	23.50^{c}	16.75^{a}	1.42^{bc}	0.38^{a}	0.46^{a}	0.83^{a}
C_1G_4	18.50^{d}	14.58^{b}	1.33^{c}	0.21^{d}	0.27^{e}	0.74^{bc}
C_1G_5	22.31^{c}	16.69^{a}	1.34^{c}	0.28^{b}	0.40^{b}	0.70^{ef}
C_2G_1	30.00^{ab}	13.00^{b}	2.31^{a}	0.13^{g}	0.17^{f}	0.76^{b-d}
C_2G_2	30.17^{ab}	13.19^{b}	2.30^{a}	0.13^{g}	0.17^{f}	0.76^{b}
C_2G_3	29.00^{b}	14.22^{b}	2.04^{a}	0.21^{f}	0.25^{f}	0.84^{a}
C_2G_4	30.33^{ab}	14.50^{b}	2.10^{a}	0.14^{d}	0.19^{e}	0.74^{bc}
C_2G_5	27.50^{b}	14.29^{b}	1.93^{ab}	0.15^{e}	0.19^{f}	0.74^{bc}
S.Em.±	0.73	0.38	0.13	0.001	0.01	0.01
C.D. at 5 %	2.94	1.54	0.53	0.005	0.02	NS

Note C_1: Control C_2: Stress R: Root S: Shoot

Root to shoot ratio (length basis)

Significantly higher root to shoot ratio under stress condition was recorded in stress condition (2.13) than control (1.54). Among the genotypes significantly higher root to shoot ratio was recorded in Annigeri-1 (2.29) which was followed by JG-11 (1.82), JG-14 (1.73), Jaki-9218 (1.71) and KAK-2 (1.63) these were on par with each other. Among the interactions significantly higher root to shoot ratio was recorded in Annigeri-1 (2.31) which was on par with JG-11 (2.30), C1G1 (2.28) and Jaki-9218 (2.10) under partial elevated temperature condition. Lowest root shoot ratio was recorded in Jaki-9218 (1.33) which was on par with JG-11 (1.34), KAK-2 (1.93) and JG-14 (1.42) under ambient condition.

Root dry weight

The mean root dry weight under ambient condition (0.26 g plant^{-1}) recorded significantly higher root dry weight as compared to partial elevated temperature condition (0.15 g plant^{-1}). The genotype JG-14 (0.23 g plant^{-1}) was significantly differed with Jaki-9218 (0.21 g plant^{-1}) and KAK-2 (0.21 g plant^{-1}) whereas, lowest was recorded in Annigeri-1 (0.17 g plant^{-1}) and JG-11 (0.19 g plant^{-1}). Genotypic interactions with the different environmental condition i.e., significantly higher root dry weight was recorded in JG-14, which was followed by KAK-2 (0.28), JG-11 (0.25), Annigeri-1 (0.21) and Jaki-9218 (0.21) under ambient condition while, lowest was recorded in Annigeri-1 (0.13), JG-11 (0.13), JG-14 (0.14) and KAK-2 (0.15) under partial elevated condition.

Shoot dry weight

Temperature affects significantly the shoot dry weight (leaf + stem) in chickpea cultivars (Jumrani and Singh Bhatia, 2014). Reduction in shoot biomass under heat stress and genotypic variation in root trait has been reported in chickpea (Krishnamurthy *et al*., 2011) [10] similar results was also recorded in the present study with respect to shoot dry weight where different temperature stress condition, genotypes and their interactions differed significantly. Temperature stress condition (0.19) recorded significantly lesser shoot weight as compared to control (0.36). The genotype JG-14 (0.32) recorded significantly higher shoot weight which was on par with KAK-2 (0.30) and these genotypes were followed by JG-11 (0.26) and Jaki-9218 (0.26). Significantly lower was recorded in Annigeri-1 (0.24). In interaction effect, lower shoot dry weight was recorded in Annigeri-1 (0.17), JG-11 (0.17), JG-14 (0.19) and KAK-2 (0.19) where as in contrary to this higher shoot dry weight was recorded in JG-14 (0.46 g plant^{-1}) which was differed significantly with KAK-2 (0.47 g plant^{-1}), Annigeri-1 (0.31 g plant^{-1}) in ambient condition and Jaki-9218 (0.25) under partial elevated condition.

Root to shoot ratio

The root to shoot ratio was generally increases with the stress treatment. The partial elevated condition (0.78) recorded significantly higher root to shoot ratio than control (0.71). The genotypes Jaki-9218 (0.80) recorded significantly higher root to shoot ratio which was significantly differed with JG-11 (0.75), JG-14 (0.75), KAK-2 (0.72) and Annigeri-1 (0.71). the root shoot ratio in Jaki-9218 (0.84) which was significantly differed with JG-11 (0.78), JG-14 (0.77) under partial elevated condition in contrary to this significantly lower root to shoot ratio was recorded in Annigeri-1 (0.68), KAK-2 (0.69), JG-11 (0.71), JG-14 (0.73) under ambient condition, Annigeri-1 (0.74) under partial elevated temperature condition and these were on par to each other.

Conclusion

It is concluded that the experiment was studied with the five chickpea genotypes were evaluated to identify tolerant genotypes under partial elevated temperature stress and ambient condition. Among the genotypes, JG-14 showed higher root and shoot weight gave higher root to shoot ratio and also root and shoot length in different stress conditions hence this was considered as tolerant genotypes and this was on par with JG-11, Jaki-9218, Annigeri-1 and KAK-2 in most of the parameters recorded hence these genotypes were considered as semi tolerant but Annigeri-1 was considered as least tolerance by considering the less performance of Annigeri-1 in two situations in most of the parameters.

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