International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(2): 812-818

Received: 11-01-2021
Accepted: 24-02-2021

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Evaluation of chickpea genotypes for heat stress under elevated temperature

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DOI: https://doi.org/10.22271/chemi.2021.v9.i2l.11921

Abstract
An experiment was conducted to study the short time exposure of high temperature during flowering period to six chickpea genotypes. Chickpea plants were exposed to high temperature (34.37/15.10 ºC) and control (30.90/13.50 ºC) for 10 days at flowering stage. High temperature stress significantly decreased pollen fertility percentage (21.12%) and pollen germination percentage (45.77%) compared to optimum temperature or control (53.45% and 66.04%) respectively. High temperature also significantly reduces the plant height (24.97cm), total dry matter (8.277 g plant^{-1}) compared to control (28.05 cm and 14.55 g plant^{-1}) respectively whereas, high temperature stress significantly increased the antioxidant enzymes such as peroxidase (0.788 µmoles min^{-1}mg^{-1} of protein) and superoxidase dismutase (67.28 U/mg protein) enzyme activity compared to control (0.442 µmoles min^{-1}mg^{-1} of protein and 34.85 U/mg protein), respectively.

Keywords: Chickpea genotypes, elevated temperature, antioxidative enzymes, pollen studies

Introduction
The chickpea being most popular pulse crop grown across tropical, sub-tropical and temperate regions of the world. Though India is the largest producer of chickpea, the major growing regions often experience high temperature episodes that are detrimental to production and productivity. The extreme high temperature events are likely to occur with greater frequency under climate change conditions. Hence, sustaining chickpea productivity under such situations is of paramount importance. The suitable adaptation strategies are required to be identified to cope up with the high temperature conditions. Though, cultivation practices like shifting the sowing dates come handy to alleviate such stresses in the short term but in the long term we need cultivars those are tolerant to high temperature. The identification of high temperature tolerant genotypes is the first step in such crop improvement programmes. Hence, an attempt made in this study to examine the effect of different temperature regimes on chickpea productivity is of high practical utility. With an objective to quantify the effects of short episode of HT stress (10 days) on morpho-physiological changes in chickpea genotypes.

Methodology
The experiment was conducted during 2019-20 at University of Agricultural Sciences (UAS), Dharwad, to study the effect of short high temperature stress at reproductive phases *i.e.,* pollen fertility and pollen germination percentage, antioxidative enzymes such as peroxidase enzyme activity and super oxide dismutase enzyme activity and morphology parameters such as plant height and total dry matter in chickpea genotypes.

Treatment details
The heat stress treatment was imposed at 30 DAS by constructing polythene chamber of size 10×3 feet using polythene sheet. There are two sets of plants for studying the heat stress in chickpea plants. One set is imposing heat stress by polythene sheet chamber and other one is control plants, which were present in outside. At the time of flower initiation this polythene chamber were transferred to the already grown chickpea plants. Temperature was recorded daily with the help of thermometer. The temperature details of polythene chamber and ambient temperature was recorded and general view of experimental set up was depicted in table 1 and Plate 1, respectively. The methodology for recording observations was as follows.

The morphological parameters such as plant height and total dry matter was recorded at final stage (after 10th day), like that biochemical components such as super oxide dismutase and peroxidase enzyme activity was recorded at alternative days (30, 32, 34, 36, 38 and 40 DAS), whereas, reproductive components such as pollen fertility and pollen germination was recorded at daily basis. The details of observation taken and standard procedures adopted are described in detail as follows.

Plant height (cm): Plant height at harvest was measured by taking the vertical distance from the base of the plant to the tip of the terminal bud of five different plants, average will be calculated and expressed in centimeter.

Table 1: Dailey temperature data at experimental plot during 2019-20 at UAS, Dharwad.

Date	Control (Outside polythene chamber)		High temperature stress (Inside polythene chamber)	
	Maximum temperature (Cº)	Minimum temperature(Cº)	Maximum temperature (Cº)	Minimum temperature(Cº)
10-02-2020	29.9	13.5	34.4	15.1
11-02-2020	29.2	17.8	32.5	18.2
12-02-2020	30.0	17.0	31.7	18.9
13-02-2020	29.5	16.0	32.6	19.1
14-02-2020	27.5	14.6	34.1	18.6
15-02-2020	29.0	16.0	34.0	19.5
16-02-2020	29.9	15.0	34.1	19.1
17-02-2020	28.6	14.3	34.3	18.9
18-02-2020	30.9	17.4	33.3	19.2
19-02-2020	30.7	15.2	34.1	19.5
20-02-2020	30.8	13.9	34.3	18.4
Mean	29.64	15.52	33.58	18.59
Mean Maximum temperature	30.90	17.80	34.37	19.50
Mean Minimum temperature	27.50	13.50	31.70	15.10

Total dry weight at harvest (g plant^{-1}): From each plot at harvest, five plants were selected randomly, cut at the base and the samples were dried at 72 ºC till a constant weight was achieved and expressed as g plant^{-1}.

Pollen fertility percentage: Flowers were collected regularly from the initiation of flowering, pollen grains were collected and fertility per cent will be observed under microscope using 2.0 per cent aceto carmine stain. Stained pollen grains which are fertile and unstained grains are sterile will be counted and per cent fertility was assessed (Alexander, 1969) [1].

Plate 1: General view of experimental plot

$$\text{Pollen fertility (\%)} = \frac{\text{Number of fertile pollen grains}}{\text{Total number of pollen grains}} \times 100$$

Pollen germination (%)

The collected pollen grains were incubated for 15 minutes in a prepared Kwacks media given by Brewbaker and Kwack (1963) composed of sucrose, boric acid, calcium nitrate and magnesium sulphate. 2.0 µl droplets of media and pollen suspension was put on the slide and it was observed under compound microscope for the germinated pollens and the per cent germination will be assessed using below formula.

$$\text{Pollen germination (\%)} = \frac{\text{Number of germinated pollen grains}}{\text{Total number of pollen grains}} \times 100$$

Antioxidant enzymes

Enzyme extract for superoxide dismutase (SOD) and peroxidase enzyme activity was prepared by homogenizing 0.2 g of fresh leaves in extraction buffer (0.1 M phosphate buffer, pH 7.0, and 1 mM ascorbic acid) at 4 °C and centrifuged.

Superoxide dismutase enzyme activity

Superoxide dismutase [EC 1.15.1.1] enzyme activity was estimated by recording the formazone complex made by nitro-blue tetrazolium with superoxide radicals (Dhindsa *et al.*, 1981). The 3.0 ml reaction mixture contained 13 mM methionine, 25 mM nitro-blue tetrazolium chloride (NBT), 3.0 mM EDTA, 50 mM phosphate buffer (pH 7.8), 50 mM sodium carbonate, 2 mM riboflavin and 0.1 ml enzyme. A non-irradiated complete reaction mixture served as a blank and absorbance was recorded at 560nm.

Peroxidase enzyme activity

Peroxidase [EC 1.11.1.1] enzyme activity was estimated by (Nakano *et al.*, 1980) [7]. The 3.0 ml reaction mixture contained 50 mM potassium phosphate buffer (pH 7.0), 0.5 mM ascorbic acid, and 1.0 mM EDTA, 0.1 mM H_2O_2, and 0.1 ml enzyme. Peroxidase enzyme activity content determined at 290 nm by monitoring the H_2O_2 decomposition rate and calculated by extinction coefficient.

Results and Discussion

The present study in both control (Outside polythene chamber) and stress environments (Inside polythene chamber) for all important traits was conducted to compare the variation between two environments (Non-stress and stress).

Data on plant height and total dry matter (Table 2) differed significantly with respect to partial elevated temperature condition, genotypes and their interaction. The stress condition (24.97cm) recorded significantly least plant height compared to control condition (28.05 cm). Among the genotypes, KAK-2 (29.13 cm) genotype recorded maximum plant height followed by JG-14(28.41 cm), BGD-128(26.90 cm), JAKI-9218 (26.48 cm) and the least plant height was recoded in Annigeri-1(23.13 cm). In interaction effects, maximum plant height was noticed in JG-14 (30.66 cm) under control condition, which was on par with KAK-2(30.40 cm) under control condition, followed by JAKI-9218 (29.56 cm) under control condition and KAK-2(27.86 cm) under stress condition. In the present investigation, the plant height reduced with delayed or late sowing due to change in climatic variables especially rise in temperature. The decrease in the overall growth of chickpea plants at delayed sowing (49th SMW) is due to changes in physical characteristics of the structural systems of cells and alteration in the metabolic reactions that affect physiological processes. The reduction in plant height subjected to stress under delayed sowing is in conformity with earlier studies Zaman *et al.* (2011) [11], Kiran (2014) [5] and Kiran (2018) [6].

There was a significant differences was observed with respect to genotypes, partial elevated temperature conditions and their interaction effects. Maximum total dry matter was observed in control condition (14.55 g plant^{-1}) compared to stress condition (8.277 g plant^{-1}). Among the genotypes JG-14 (15.98 g plant^{-1}) recorded maximum total dry matter followed by JAKI-9218 (11.83 g plant^{-1}), JG-11(11.27 g plant^{-1}), KAK-2 (10.45 g plant^{-1}) and the least total dry matter content was observed in Annigeri-1(7.863 g plant^{-1}) genotype. In interaction effect, maximum total dry matter was observed in JG-14 (22.13 g plant^{-1}) genotype under control condition followed by JAKI-9218 (17.55 g plant^{-1}), JG-11 (14.97 g plant^{-1}) under control condition and the least total dry matter was observed in Annigeri-1 (5.847 g plant^{-1}) genotype under stress condition. High temperature induces increase in rate of respiration, resulting in loss of stored food material, which results in decline in shoot length and dry weight (Tripathi *et al.*, 2009) [10]. The reduction in total shoot biomass mainly resulted from grain yield decrease by 77 per cent and 58 per cent respectively in heat stress conditions compared to controlled conditions.

The data on peroxidase enzyme activity was presented in table 4 was differed significantly with respect to partial elevated temperature, genotypes and their interaction. Peroxidase enzyme activity increased with increasing days after sowing. Under partial elevated temperature condition (Polythene chamber) peroxidase enzyme activity vary from 0.324 to 0.788 µmoles min^{-1}mg^{-1} of protein under different stages of crop growth whereas, under control (Outside polythene chamber) condition peroxidase enzyme activity vary from 0.244 to 0.442 µmoles min^{-1}mg^{-1} of protein. At 30 DAS, among the genotypes JAKI-9218 (0.419 µmoles min^{-1}mg^{-1} of protein) genotypes recorded maximum peroxidase enzyme activity followed by BGD-128 (0.361 µmoles min^{-1}mg^{-1} of protein), JG-14(0.300 µmoles min^{-1}mg^{-1} of protein), JG-11(0.243 µmoles min^{-1}mg^{-1} of protein) and Annigeri-1(0.209 µmoles min^{-1}mg^{-1} of protein) and the lowest was recorded in KAK-2 (0.172 µmoles min^{-1}mg^{-1} of protein) genotype similar trend was observed under different stages of crop like 32, 34, 36, 38 and 40 DAS. At 40 DAS, peroxidase enzyme activity varies from 0.810 (JAKI-9218) to 0.452 µmoles min^{-1}mg^{-1} of protein (KAK-2). In interaction effect, Maximum peroxidase enzyme activity was observed in JAKI-9218(0.444 µmoles min^{-1}mg^{-1} of protein), followed by BGD-128(0.394 µmoles min^{-1}mg^{-1} of protein), JG-14(0.331 µmoles min^{-1}mg^{-1} of protein) and JG-11(0.293 µmoles min^{-1}mg^{-1} of protein) under stress condition and the least was observed in KAK-2 (0.125 µmoles min^{-1}mg^{-1} of protein) under control condition. Similar results were observed in all stages of crop like 32, 34, 36, 38 and 40 DAS. At 40 DAS, peroxidase enzyme activity varies from 0.318 to 0.985 µmoles min^{-1}mg^{-1} of protein. At 40 DAS, maximum peroxidase enzyme activity was observed in partial elevated temperature stress condition (0.788 µmoles min^{-1}mg^{-1} of protein), genotypes (0.810 µmoles min^{-1}mg^{-1} of protein) and their interaction effect (0.985 µmoles min^{-1}mg^{-1} of protein) compared to other stages of crop.

Superoxide dismutase (SOD) differed significantly with respect to partial elevated temperature stress condition,

genotypes and their interaction effect. Initially at 30 DAS, maximum SOD activity was observed in stress condition (31.49 U/mg protein) compared to control (25.68 U/mg protein). SOD enzyme activity increased with increasing in days after exposure of crop to elevated temperature from 30 days to 40 days. At 40 DAS, maximum SOD was noticed in stress condition (67.28 U/mg protein) compared to control (34.85 U/mg protein). With respect to genotypes at 40 days after sowing maximum SOD was noticed in JAKI-9218 (68.23 U/mg protein) genotype followed by BGD-128 (58.60 U/mg protein), JG-14(51.90 U/mg protein), JG-11(45.96 U/mg protein) and Annigeri-1(42.42 U/mg protein) and the lowest was recorded in KAK-2 (39.27 U/mg protein) genotype. Similar trend was observed in all stages of crop like 30, 32, 34, 36, 38 and 40 DAS. With respect to interaction level, at 40 days after sowing maximum SOD was noticed in JAKI-9218(86.24 U/mg protein), followed by BGD-128(75.66 U/mg protein), JG-14(71.36 U/mg protein) and JG-11(60.91 U/mg protein) under stress condition and the least was observed in KAK-2 (25.21 U/mg protein) under control condition. Similar results were observed in all stages of crop like 30, 32, 34, 36, 38 and 40 DAS.

In the present study both the antioxidant enzymes *i.e.,* SOD and POX showed increased activity under high temperature as compared to normal temperature under different growth stages. Increase in enzyme activity may be induced by the presence of different reactive oxygen species (ROS), thus providing indirect evidence for the extent of generation of reactive oxygen species (Sairam *et al.,* 2000) [9]. This shows that the tolerant genotypes combated the ROS by maintaining efficient antioxidant mechanism. It shows the increase in antioxidant enzyme activities in plants and decrease in ROS content was greater in high temperature than optimum temperature. The tolerant genotypes combated the ROS by maintaining efficient antioxidant mechanism. Tolerance to high temperature stress in crop plants has been reported to be associated with an increase in antioxidant enzymes activity.

Pollen fertility differed significantly with respect to genotypes and maximum and minimum temperature (fig. 1a). Compare to stress maximum mean pollen fertility was observed in control condition. Among the genotypes JAKI-9218(79.72%) recorded maximum mean pollen fertility percentage followed by BGD-128 (72.05%) and JG-11(68.24%) whereas, the least mean pollen fertility was observed in KAK-2(53.45%) genotype under control condition. Under stress condition (Polythene chamber) maximum mean pollen fertility was observed in JAKI-9218(51.48%) followed by BGD-128 (44.63%), JG-11(36.23%) and JG-14(31.62%) and the least was observed in KAK-2(21.12%) genotype. Maximum genotypic variability was observed among the genotypes with respect to mean pollen fertility percentage. Like that, with respect to pollen germination significant variation was observed among the genotypes (fig. 1b). Among the genotypes, JAKI-9218(78.09%) recorded maximum mean pollen germination percentage followed by BGD-128 (73.39%) and JG-11(66.75%) whereas, the least mean pollen germination was observed in Annigeri-1(65.01%) genotype under control condition. Under stress condition (Polythene chamber) maximum mean pollen germination was observed in JAKI-9218(64.16%) followed by BGD-128 (60.12%), JG-11(53.38%) and JG-14(51.47%) and the least were observed in KAK-2(45.77%) genotype. This research showed evidence that high temperature (34.37/15.10 ºC) (a) decreased pollen viability (b) decreased pollen germination due to anatomical changes in pollen grains compared to optimum temperature or control (30.90/13.50 ºC) Pacini (1996) [8] showed that pollen cytoplasmic carbohydrates, reducing sugars, and sucrose are involved in protecting and maintaining pollen viability and pollen germination. Decreased sucrose utilization by impairment of cell wall invertase mediated sucrose hydrolysis and subsequent lack of sucrose biosynthesis by pollen grains under high temperature stress also may lead to pollen sterility in grain sorghum (Jain *et al.,* 2007) [4].

There was a much genotypic differences was observed with respect to pollen fertility and pollen germination between control (outside polythene chamber) and stress condition(Polythene chamber). Under control condition maximum temperature was observed 30.90/13.50 ºC, whereas, under stress condition (Polythene chamber) the maximum temperature is 34.37/15.10 ºC. So there was a 1.87 ºC temperature differences were observed between control and stress condition environment.

Table 2: Effect of temperature regimes on plant height (cm) and total dry matter (g plant^{-1}) of chickpea genotypes at harvest.

Treatments	Plant height	Total dry matter
Stress conditions		
Control (C_1)	28.05^{a}	14.55^{a}
Stress (C_2)	24.97^{b}	8.277^{b}
S.Em.	0.117	0.043
C. D @ 5%	0.344	0.127
Genotypes (G)		
G_1- Annegeri-1	23.13^{e}	7.863^{e}
G_2- JAKI-9218	26.48^{c}	11.83^{b}
G_3-JG-11	25.03^{d}	11.27^{c}
G_4-JG-14	28.41^{b}	15.98^{a}
G_5-BGD-128	26.90^{c}	11.07^{c}
G_6-KAK-2	29.13^{a}	10.45^{d}
S.Em.	0.203	0.075
C. D @ 5%	0.595	0.221
Interaction		
C_1G_1	24.36^{f}	9.880^{g}
C_1G_2	29.56^{b}	17.55^{b}
C_1G_3	26.73^{de}	14.97^{c}
C_1G_4	30.66^{a}	22.13^{a}
C_1G_5	26.60^{de}	11.72^{d}
C_1G_6	30.40^{ab}	11.05^{e}
C_2G_1	21.90^{h}	5.847^{i}
C_2G_2	23.40^{g}	6.120^{i}
C_2G_3	23.33^{g}	7.58^{h}
C_2G_4	26.16^{e}	9.83^{g}
C_2G_5	27.20^{cd}	10.42^{f}
C_2G_6	27.86^{c}	9.853^{g}
S.Em.	0.291	0.106
C. D @ 5%	0.845	0.312

Alphabets in the column followed by the same letter do not differ significantly as per the DMRT.

Table 3: Effect of temperature regimes on peroxidase enzyme activity (µ mol per min mg protein) at different growth stages in chickpea genotypes.

Treatments	Peroxidase enzyme activity					
	30 DAS	32 DAS	34 DAS	36 DAS	38 DAS	40 DAS
Stress conditions						
Control (C_1)	0.244^{b}	0.279^{b}	0.324^{b}	0.360^{b}	0.404^{b}	0.442^{b}
Stress (C_2)	0.324^{a}	0.386^{a}	0.461^{a}	0.545^{a}	0.682^{a}	0.788^{a}
S.Em.	0.002	0.002	0.001	0.002	0.002	0.002
C. D @ 5%	0.004	0.005	0.004	0.006	0.007	0.007
Genotypes						
G_1- Annegeri-1	0.209^{e}	0.250^{e}	0.299^{e}	0.355^{e}	0.427^{e}	0.512^{e}
G_2- JAKI-9218	0.419^{a}	0.501^{a}	0.587^{a}	0.656^{a}	0.754^{a}	0.810^{a}
G_3-JG-11	0.243^{d}	0.289^{d}	0.354^{d}	0.413^{d}	0.502^{d}	0.574^{d}
G_4-JG-14	0.300^{c}	0.339^{c}	0.399^{c}	0.471^{c}	0.571^{c}	0.637^{c}
G_5-BGD-128	0.361^{b}	0.402^{b}	0.459^{b}	0.512^{b}	0.640^{b}	0.708^{b}
G_6-KAK-2	0.172^{f}	0.216^{f}	0.260^{f}	0.306^{f}	0.362^{f}	0.452^{f}
S.Em.	0.003	0.003	0.003	0.004	0.004	0.004
C. D @ 5%	0.008	0.008	0.008	0.011	0.013	0.012
Interaction						
C_1G_1	0.155^{h}	0.186^{j}	0.224^{j}	0.256^{j}	0.289^{k}	0.339^{k}
C_1G_2	0.394^{b}	0.430^{c}	0.491^{c}	0.527^{d}	0.596^{e}	0.634^{f}
C_1G_3	0.192^{g}	0.254^{i}	0.304^{i}	0.336^{i}	0.369^{j}	0.394^{j}
C_1G_4	0.268^{e}	0.293^{g}	0.348^{g}	0.386^{h}	0.424^{i}	0.453^{i}
C_1G_5	0.327^{c}	0.354^{e}	0.385^{f}	0.417^{g}	0.476^{g}	0.513^{h}
C_1G_6	0.125^{i}	0.156^{k}	0.195^{k}	0.236^{k}	0.268^{l}	0.318^{l}
C_2G_1	0.263^{e}	0.314^{f}	0.374^{f}	0.454^{f}	0.566^{f}	0.685^{e}
C_2G_2	0.444^{a}	0.571^{a}	0.682^{a}	0.785^{a}	0.912^{a}	0.985^{a}
C_2G_3	0.293^{d}	0.323^{f}	0.403^{e}	0.489^{e}	0.636^{d}	0.753^{d}
C_2G_4	0.331^{c}	0.384^{d}	0.450^{d}	0.556^{c}	0.717^{c}	0.820^{c}
C_2G_5	0.394^{b}	0.450^{b}	0.533^{b}	0.607^{b}	0.805^{b}	0.903^{b}
C_2G_6	0.218^{f}	0.276^{h}	0.326^{h}	0.376^{h}	0.456^{h}	0.585^{g}
S.Em.	0.004	0.004	0.004	0.005	0.006	0.006
C. D @ 5%	0.011	0.011	0.011	0.015	0.018	0.017

Alphabets in the column followed by the same letter do not differ significantly as per the DMRT

Table 4: Effect of temperature regimes on superoxide dismutase enzyme activity (U/mg protein) at different growth stages in chickpea genotypes.

Treatments	Superoxide dismutase enzyme activity					
	30 DAS	32 DAS	34 DAS	36 DAS	38 DAS	40 DAS
Stress conditions						
Control (C_1)	25.68^{b}	28.44^{b}	29.65^{b}	31.15^{b}	32.91^{b}	34.85^{b}
Stress (C_2)	31.49^{a}	40.14^{a}	48.28^{a}	56.73^{a}	61.68^{a}	67.28^{a}
S.Em.	0.424	0.392	0.398	0.328	0.371	0.379
C. D @ 5%	1.245	1.15	1.168	0.962	1.088	1.111
Genotypes						
G_1- Annegeri-1	21.19^{e}	26.30^{e}	31.37^{e}	35.34^{e}	38.96^{e}	42.42^{e}
G_2- JAKI-9218	39.31^{a}	48.25^{a}	53.21^{a}	60.82^{a}	65.06^{a}	68.23^{a}
G_3-JG-11	27.43^{d}	32.55^{d}	36.97^{d}	40.51^{d}	42.35^{d}	45.96^{d}
G_4-JG-14	30.25^{c}	34.60^{c}	39.21^{c}	44.12^{c}	48.07^{c}	51.90^{c}
G_5-BGD-128	35.91^{b}	41.05^{b}	45.81^{b}	51.51^{b}	54.64^{b}	58.60^{b}
G_6-KAK-2	17.43^{f}	22.99^{f}	27.23^{f}	31.34^{f}	34.71^{f}	39.27^{f}
S.Em.	0.735	0.679	0.690	0.568	0.643	0.656
C. D @ 5%	2.156	1.992	2.023	1.666	1.885	1.925
Interaction						
C_1G_1	17.59^{ef}	21.64^{h}	22.84^{i}	24.18^{i}	26.03^{h}	28.66^{j}
C_1G_2	36.69^{b}	42.51^{c}	43.22^{e}	45.51^{e}	48.11^{e}	50.22^{g}
C_1G_3	23.59^{d}	25.59^{g}	26.97^{h}	28.66^{h}	30.32^{g}	31.01^{ij}
C_1G_4	26.24^{d}	27.00^{g}	28.08^{h}	30.32^{h}	31.61^{g}	32.45^{i}
C_1G_5	34.66^{b}	35.45^{e}	36.83^{g}	37.57^{g}	39.01^{f}	41.55^{h}
C_1G_6	15.30^{f}	18.44^{i}	19.95^{j}	20.66^{j}	22.40^{i}	25.21^{k}
C_2G_1	24.79^{d}	30.95^{f}	39.89^{f}	46.51^{e}	51.89^{d}	56.19^{e}
C_2G_2	41.94^{a}	53.99^{a}	63.19^{a}	76.14^{a}	82.01^{a}	86.24^{a}
C_2G_3	31.27^{c}	39.52^{d}	46.96^{d}	52.36^{d}	54.37^{d}	60.91^{d}
C_2G_4	34.25^{bc}	42.20^{cd}	50.34^{c}	57.91^{c}	64.52^{c}	71.36^{c}
C_2G_5	37.16^{b}	46.66^{b}	54.80^{b}	65.45^{b}	70.27^{b}	75.66^{b}
C_2G_6	19.56^{e}	27.55^{g}	34.51^{g}	42.02^{f}	47.03^{e}	53.34^{f}
S.Em.	1.040	0.960	0.975	0.803	0.909	0.928
C. D @ 5%	3.049	2.817	2.861	2.357	2.666	2.722

Alphabets in the column followed by the same letter do not differ significantly as per the DMRT

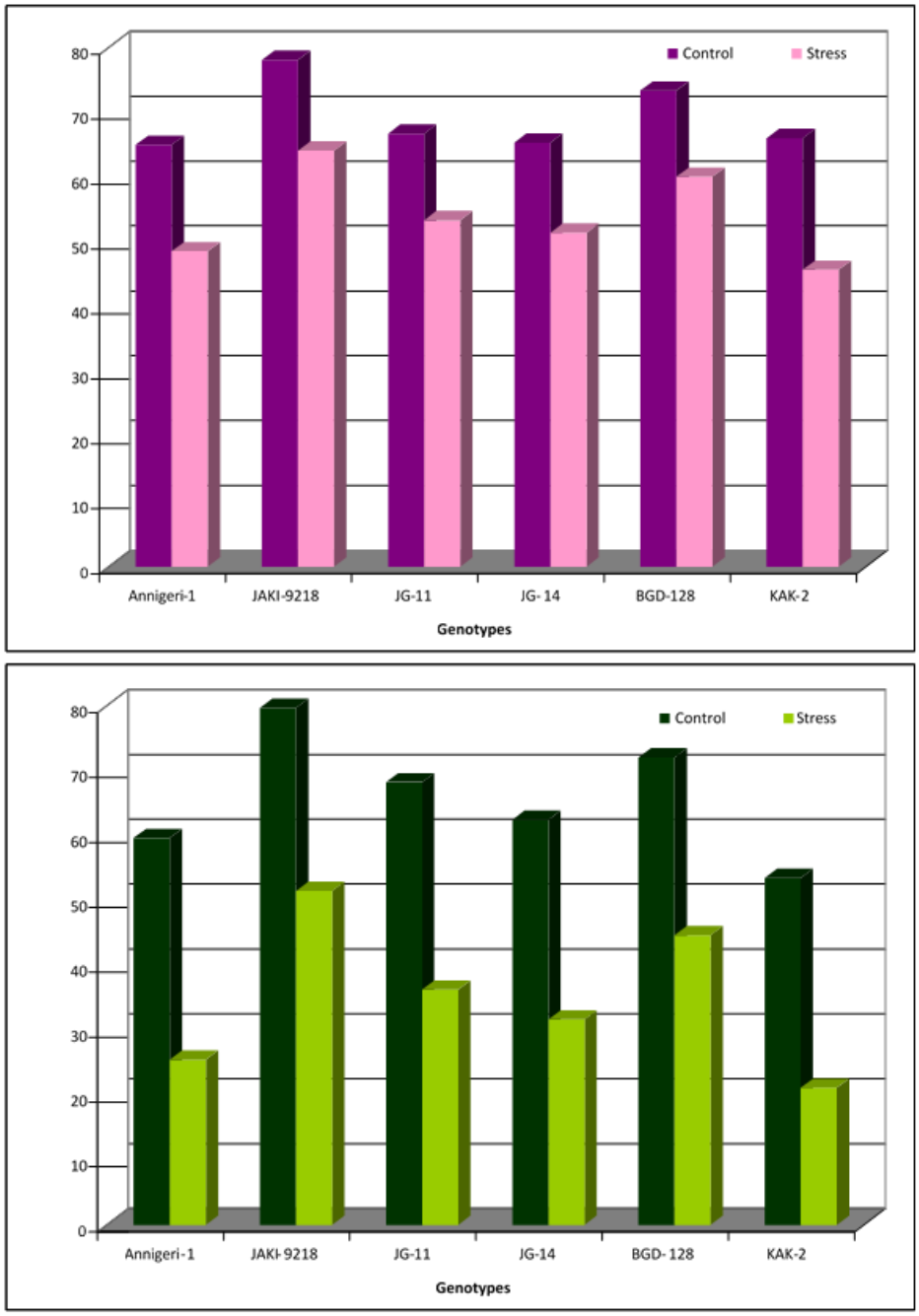

Fig 1: Effect of temperature regimes on pollen germination and pollen fertility of chickpea genotypes

Conclusion

From the foregoing experiment it was clear that high temperature stress (Polythene chamber) significantly decreased pollen fertility and pollen germination percentage compared to optimum temperature (Outside polythene chamber or control). High temperature also significantly reduces the plant height, total dry matter and antioxidant enzymes such as peroxidase and super oxidase dismutase enzyme activity compared to control. Among the genotypes JAKI-9218, BGD-128 and JG-14 genotypes shows better tolerance to high temperature stress condition with respect to morphological, pollen morphology and antioxidant defense system compared to Annigeri-1, JG-11 and KAK-2 genotypes.

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