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Research Paper

Chlorophyll and Canopy Temperature Depression as a Tool to Monitor Physiological Status of *Cicer Arietinum* L. Genotypes under Normal and Heat Stress Environment

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A B S T R A C T

Environmental mortification and mounting temperature are investigated to be the prime cause of the catastrophe of agriculture. Chickpea is a cool-season crop that is badly damaged by heat stress. In the present research, *IR* and *SPAD-502 plus* meters are used to evaluation of chickpea germplasm in a heat stress environment before the stress and strain symptoms were visible. Experiments performed November (normal-sown) and December (heat-sown) month of the year 2019 at the Department of Botany, Campus C. C. S. University, Meerut Uttar Pradesh. Tolerant genotypes (*JG 11, JAKI 9218*) which is *Desi* shows higher canopy temperature depression and chlorophyll content while the susceptible genotype i.e., *JGK 2* which is *Kabuli* shown lower canopy temperature depression and chlorophyll values. Tolerant genotypes showed lower % decline values of grain yield plant^{-1} (5.0 and 7.0% decline) as compared to susceptible genotype which has the higher % decline value i.e., 41%. Results have concluded that chlorophyll content and leaf canopy temperature depression are sophisticated tools for the early selection of heat-tolerant chickpea genotypes.

Key words: *SPAD-502 plus, IR*, Canopy temperature depression, Chlorophyll, High temperature, Chickpea

Environmental mortification and mounting temperature are considered to be the prime cause of the catastrophe of agriculture. Therefore, to gratify the demands of food for an ever-growing population, there is an immediate requirement for an intensive and in-depth agriculture practice for the selection of high yielding crops without wasting time. The present agricultural and research practices need sophisticated technologies for achieving high-yielding agricultural varieties for future dietary demands without damaging the crop and environment. Moreover, to manage indelible food security, the production of agriculture should grow faster for alarming population growth by endorsing resource-intensive agricultural practices because today's world is already facing twin challenges of food security and environmental degradation. Chickpea is a cool-season food crop, which is highly affected by heat stress than the warm season legume crops. According to global simulation models prediction, atmospheric temperatures will raise 4–5°C by the year 2100 [1]. Effects of climate change are expected to be more severe in the tropics where the temperature is already quite high, hampering crop production. The development of heat-tolerant genotypes is the adaptation strategy to cope up with a heat stress environment. Chickpea has a relatively narrow genetic base and the development of heat-tolerant chickpea cultivars is a big challenge [2]. *SPAD-502 plus* and *IR* are better tools that are non-invasive, non-destructive, less laborious, and rapid, for screening high-temperature stress-tolerant genotypes on a large scale [3]. Present work objectives are to check the *SPAD-502 plus* and *IR* is to use tools to select tolerant genotypes under heat stress environment. Also, to find out the degree of high-temperature effects on 5 contrast chickpea genotypes based on chlorophyll, canopy temperature depression, and yield attributes.

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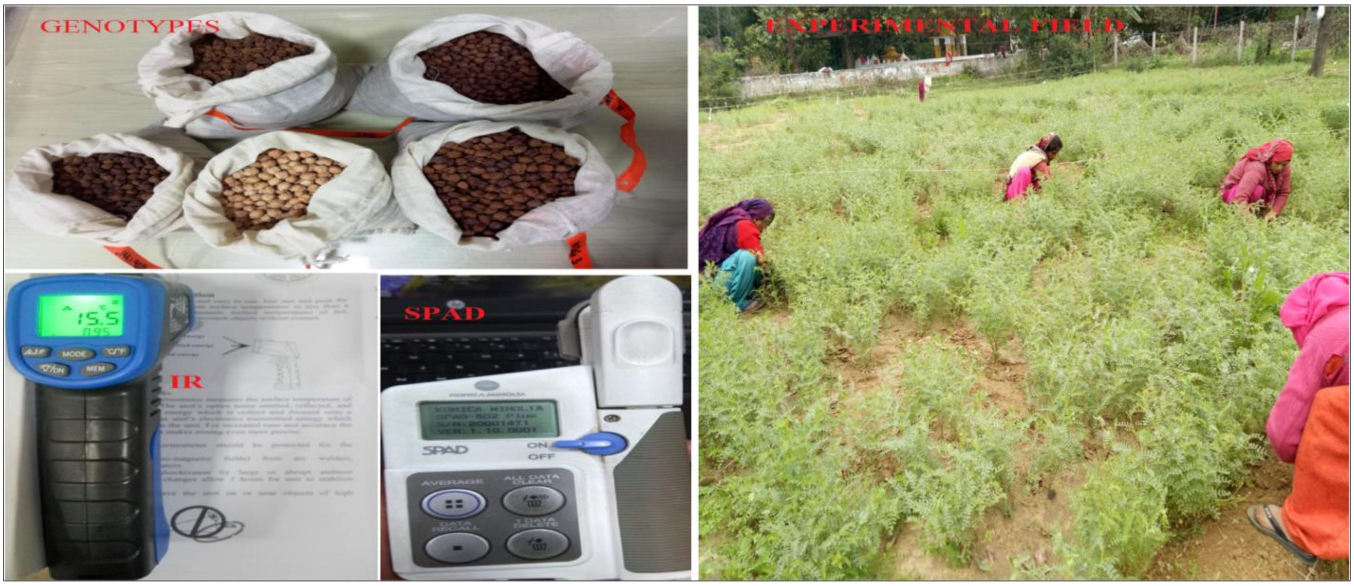
MATERIALS AND METHODS

Experimental material consisted of 5 (4 *Desi* and 1 *Kabuli*) diverse chickpea genotypes i.e., *JG 14 (Desi), NBeG 3(Desi), JG 11(Desi),* and *JAKI 1921(Desi), JGK 2 (Kabuli)* procured from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). These genotypes were evaluated in randomized block design with 3 replications under normal (planting date, 2/11/2019) and heat stress (planting date, 2/12/2019) environments at the Department of Botany, C. C. S. University, Meerut Uttar Pradesh. Each genotype was raised in a plot of 2 rows of 2m with row-to-row distance was 0.30m and seed to seed distance was 0.10m. Canopy Temperature Depression (CTD) was measured using a handheld infrared (*IR*) thermometer (Model ANMOL 8811). An infrared thermometer measured a temperature range -20 to 60°C, repeatability 1°C (1% of reading), ambient operating range 0 to 60°C, with an accuracy of ± 0.25°C. An infrared thermometer was held about 0.3m above the canopy surface for about six seconds with about 20°C fields of view so that a wider canopy could be accounted, avoiding pointing at the ground, gaps in the canopy of the sky. During the reproductive stage (at the time of 50% flowering) three observations were recorded of each genotype in each replication and environment on bright sunny days between 1.00 pm to 3.00 pm and the average of the three observations was used for further data analysis. Ambient temperature (°C) was also measured just before recording data of the canopy temperature of each genotype. Canopy temperature depression was calculated using the following formula:

Canopy Temperature Depression = (Ambient Temperature – Canopy Temperature).

Using a *SPAD-502* Plus chlorophyll meter (Konica Minolta Sensing Americas Inc., USA) measured chlorophyll. A *SPAD 502 plus* the reading of < *45* indicated a yellow-green color and a reading < *50* indicated a dark green color. The *SPAD 502 plus* readings were taken 4-5 times from fully expanded leaves, using the second or third node counting down from the tip of the main stem in each replication (at the time of 50% flowering) in a normal and heat sown environment. *SPAD 502 plus* mean reading was calculated by the instrument itself. The grains obtained after harvesting and threshing of a plot were weighed in gm using Digital Analytical Balance CP124S and the measured weight was recorded as grain yield/plant (100 seed weight). Using Microsoft excel 2012 mean graphs were prepared.



Photograph 1 Experimental material, Location, and used Instruments

RESULTS AND DISCUSSION

The present research has carried out to examine the genetic variability available for grain yield and other traits associated with tolerance to heat stress in chickpea germplasm. The chlorophyll content is intended to be an index of the plant supplements and health stature, which is firmly associated with the quantity and ratio of chlorophyll content in plant leaves. It contributes indispensable information for the examination of a plant's physiological status including water and nitrogen status [4]. Measurement of chlorophyll by the *SPAD 502 plus* has been used successfully as a quantitative assessment of inhibition or damage to the e- transport system in several crops. This technique is sophisticated and non-destructive and it can also show damage before the visible symptoms appear. We, however, opted to use the *SPAD 502 plus* meter in this study because in a previous experiment, [5] also used it in the legume crop for chlorophyll measurement. It was observed that the chlorophyll content in the normal environment measured maximum then the heat stress environment while the genetic variability in both the environment found to differ.

Present research results revealed that maximum chlorophyll content was observed in *JG 11, JAKI 9218* genotypes (heat-tolerant), and minimum chlorophyll content was observed in the *JGK 2* genotype (heat susceptible-26.0%)) under heat stress environment but in the normal environment, all the genotypes have been higher chlorophyll values as compared to heat stress environment genotypes while *NBeG3, JG 14* is intermediate between tolerant to susceptible genotypes (fig 1). Heat stress alters photo pigments and damage thylakoid membranes, usually leading to either reduced chlorophyll biosynthesis or increased chlorophyll degradation or combined effects of both processes [6]. The damage due to these concurrent stresses affects light reactions occurring in the thylakoid lumen and light-dependent chemical reactions taking place in the stroma. Photosystem II is very sensitive to concurrent stresses, and its activity is significantly altered or even reduced to zero under severe heat stress environment [7].

Canopy temperature depression defined as the deviation of temperature in plant canopies from the ambient temperature has been recognized as another key trait after chlorophyll content for assessing genotypes response to heat and other environmental stresses. Canopy temperature depression directly or indirectly suffering from wind, cloudiness, temperature, relative humidity, radiation, soil water status, plant capacity to water extraction, evapotranspiration etc. Canopy temperature depression increased as the weather became hot and dry with high air temperature in heat stress conditions; whereas in normal conditions were associated with low canopy temperature and CTD [8]. Genotypes *JG 11* and *JAKI 9218* show minimum canopy cooler which means higher CTD values which indicate the tolerant level of these genotypes in a heat stress environment (Fig 2). Contrarily, the *Kabuli-JGK 2* genotype shows lower CTD and higher canopy value which shows susceptibility of this genotype (Fig 2). Based on observed results it concludes that the tolerant genotype with a low canopy temperature and high CTD under a heat stress environment has been the capacity to avoid transpiration and use more available soil moisture to enhance their deeper root system [9]. According to [10], Low canopy temperature and high CTD associated with the ability to extract water from the deeper soil profiles under heat stress environments provide tolerance to high temperature. *JG 11* and *JAKI 9218* are the most heat tolerant genotypes due to their high chlorophyll and CTD values in a normal environment and minimum %decline in a heat stress environment. *SPAD 502 plus* (Chlorophyll) and *IR* (CTD) tools can be used as a good indicator of a genotype's fitness under high temperatures stress [11].

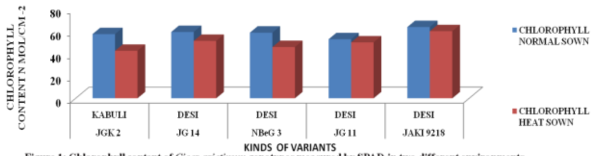


Figure 1: Chlorophyll content of *Cicer arietinum* genotypes measured by SPAD in two different environments.

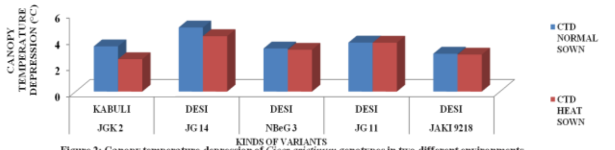


Figure 2: Canopy temperature depression of *Cicer arietinum* genotypes in two different environments.

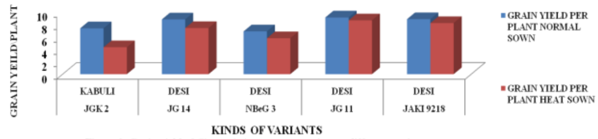


Figure 3: Grain yield of *Cicer arietinum* genotypes in two different environments.

However, it would be difficult to make conclusions regarding tolerant and susceptible genotypes. Grain yield parameters also studied to validate the results. Genotypes *JG 11*, *JAKI 19218* show maximum grain yield/plant (Fig 3) and minimum %decline value under heat stress environment which is significantly correlated with the chlorophyll content and CTD. Contrarily, susceptible genotypes show minimum grain yield/plant and maximum % decline value under heat stress environment. So, it can conclude that based on chlorophyll, CTD, we can screen heat-tolerant chickpea cultivars under heat stress environment.

CONCLUSIONS

Literature has very few records regarding *SPAD 502 plus* meter on chickpea. The present research focuses on the potential use of *SPAD 502 plus* and *IR* tools for heat-tolerant chickpea cultivar screening under heat stress environment. Overall, results show that chlorophyll and CTD and grain yield found maximum in *JG 11* and *JAKI 19218* under heat stress environment. However, heat-tolerant genotypes maintained unaltered physiological response at a flowering stage as well as their grain yields after exposure to heat stress environment. These two genotypes have the ability to reduce cooler canopy and high chlorophyll content to maintain their productivity. The observed relationship between measured chlorophyll *SPAD 502 plus* meter and *IR* is a relatively rapid and non-destructive method. It could use as a phenotyping tool during the early selection of heat-tolerant germplasm screening under field conditions.

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