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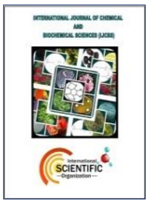

Modification in Physiological Characteristics by Genotype in Maize during High Temperature Stress

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Abstract

The output and productivity of maize, a significant grain crop in India and across the globe, are significantly impacted by high-temperature anxiety. The differences in several physiological variables over high-temperature stress were assessed in 21 maize genotypes that were staggered seeded. Several measurements were made, including those of the net photosynthetic rate, leaf temperatures, canopy temperatures, highest quantum yield PSII photochemistry (Fv/Fm), SPAD, ASI, Stover yield, and grain harvest. According to meteorological records from the cropping season for the 1st and 2nd dates of sowing. In contrast to the late-planted crop, these temperature changes were undesirable for reproduction and grain-rich during the recent-planted crop's photosynthesis, fertilization, and grain development processes. Except for leaf temperature, all parameters were found to be significant when compared to genotypes (G), dates of sowings (T), and their interplay (G*T). Due to enhanced photosynthesis and the highest quantum yield PSII photochemistry under high-temperature stress, plants gained weight in their Stover, which may have improved overall plant development. The findings showed that although high temperatures had an impact on yield-related indicators, they also encouraged the development of vegetative plant components. The increased net photosynthetic rate during vegetative development led to an increase in average Stover yield of twenty eight percent at maturity. It affected photosynthate availability and pollen viability, resulting in a 13% drop in grain yield across all genotypes.

Keywords:physiological characteristics, genotype, Maize, High-temperature stress, Maize, fertilization

Full length article *Corresponding Author, e-mail:d.p.singhg@gmail.com

1. Introduction

The most widely cultivated cereal in the world is maize, which many developing nations use as their main source of food. Maize is cultivated in India throughout the year and is the country's third-highest grain crop, after rice and wheat [1]. The crop is primarily grown in Kharif, though. Just 9% of the nation's entire output of food grains comes from it. India is especially at risk from climate disruption due to its economy's reliance on climate-sensitive industries like agriculture. In general, global agriculture will be negatively impacted by temperature increases above 2.5 °C .Crop output throughout the globe is seriously threatened by heat stress brought on by high ambient temperatures [2]. Temperatures are recognized to develop by 1.8–4.0 °C by 2100 as a result of the globe air temperature rise of 0.2 °C per ten years. Under ideal climatic and crop management circumstances, maize is very prolific. On average, fifteen to twenty percent of the globe's potential maize output is failed each year as a result of these pressures since maize plants are also particularly vulnerable to heat and drought. The tendency towards increasing temperatures will be one of the major abiotic issues that influence plant output, particularly for summer-sown crops such as maize and rice grown in subtropical and tropical areas [3].

The effects of high temperatures on plants may be felt at several levels of an organization, resulting in alterations in morphology, physiology, biochemistry, and gene expression. Therefore, development is inhibited; leaves lose chlorophyll, display burning, and endure tip necrosis, senescence, and abscission during the vegetative level. The buds and flowers shrink throughout the reproductive stage, and the pod set decreases, resulting in a lesser seed output. High-temperature stress might have an impact on cellular functions such as heat shock protein synthesis, protein breakdown, chloroplast and mitochondrial enzyme deactivation, protein denaturation, and protein degradation [4]. Higher temperature causes oxidative damage by producing reactive oxygen species “such as lipid peroxides, singlet oxygen and superoxide radicals, hydrogen peroxide (H_2O_2), and hydroxyl radicals”. This concept, which states that maximum temperature causes the abortion of kernel development, has indeed been supported by the observation of a decrease in the amount of starch in maize endosperm. It is principally brought by changes to the inverts' activity that repeatedly fails to discharge sucrose from the pedicel and hinder the endosperm from synthesizing starch [5]. As an outcome, the pedicel has higher sucrose quantities and lower fructose and glucose levels. Hence, among the main goals for maize genetic development to increase stress endurance.

The paper [6] described a number of these physiological and molecular methods that could help to reduce the negative impacts of heat stress on maize production. The research [7] discovered the variance gene expression in various maize genotypes below temperature stress. The appearance of genes in leaves taken at various time points was then assessed. The research [8] evaluated maize, sorghum, and pearl-millet, major C4 cereals, for the evaporation rate (TR) in response to rising atmospheric and soil water pressure. The research was to measure the impacts of atmosphere, genotype, and control on ideal plant density and yield to lodging [9]. The research [10] emphasizes that the degree of heterosis changes depending on the attribute examined and the setting in which that trait is tested rather than being an intrinsic characteristic of a particular hybrid. The study [11] examined the agro-climatic parameter variability that affects maize output in South Africa during several seasons. The research [12] examined the effect of adopting DT maize varieties on smallholder farmers' overall maize production, including unique information and empirical evidence on the effects of adopting better agriculture technology. The paper was giving a general overview of Indonesia's maize demands and how the country achieved maize self-sufficiency to replace imports. It also gives a general account of Indonesia's maize breeding development [13]. The research [14] examined the precipitation under recent climate change that affected the output of maize for both grain and silage across the entire Czech Republic from 2002 to 2019. The study [15] investigated whether bZIP60 mRNA splicing, which causes the UPR, occurs as a result of diurnal temperature variations that mimic field circumstances as opposed to heat shock.

2. Materials and methods

During the 2013 summer season, the research was carried out at institute A, India Santoshnagar, and Hyderabad. The A-National Institute of Genetic Materials from Plants, the A-Directorate of Maize investigate, and CIMMYT, both in New Delhi, provided the seed material, among other sources. An investigational material of maize genotypes 21 utilized in the current research, namely “HKI 161, HKI 3-4-8-6- ER, Z 40-183, HKI 324-17 AN, Z 162-12, RJR 068, PSRJ 13099, NSJ 155, RJR 270, NSJ 189, SNJ 2011-15, Harsha, NSJ 176, Varun, PSRJ 13086, RJR 163, NSJ 221, Z 59-11, Z 59-9, PSRJ 13038 and PSR 13247,” was inbred lines garnered from the source mentioned above.

Three replicates with a net plot size of 18 * 10 m^2 were set up in a method of randomizing whole blocks. In the off-season, at the ending of Jan and the beginning of Feb of 2013, seeds were planted at 30-day intervals. The aim was to expose the phase of plants' reproduction planted on the 2nd sowing date to hot weather in April and May. After the seeds were planted, the field was immediately watered. The suggested application of NPK was made. Sowing was followed by applications of 1/8 of the total N, all of the P, and 1/5 N at the four leaf level, 1/3 at the massive growth level, and 1/3 N right before blossoming.

All the genotypes were grown using the same suggested cultural techniques. The information was gathered using the same criteria as the widely used maize evaluation system. Making use of an intensity of light of 1500 mol m^{-2} s^{-1} PAR and a consistent 390 bar partial pressure of CO2 in the sample cell, an LI-COR (LI-6400) movable photosynthesis lab recordings information on vegetation and leaf temperature, canopy temperature and net photosynthetic rate,; a Fluorpen (FluorPen FP 100) measured Highest Entanglement produce PSII photochemistry (Fv/Fm). Each genotype's data was recorded three times for accuracy. One and two-factor Analysis of Variance (ANOVA) was conducted using the factorial analysis module of the MSTAT software, and genotype CD values were calculated. Results for 9 treatments were arguably important at the $P<0.05$ and $P<0.01$ levels.

The growth cycle was additionally utilized to collect meteorological data. The highest and average daytime temperatures were 37.6 and 38.3 °C for the early sown crop during the reproductive stage, while they were 41.4 and 37.5 °C for the later sown crop. The delayed crop had intense grain filling duration heat shocks with average monthly temperatures well over the threshold value for crop maize at the blooming and grain filling levels (Figure 1).

3. Results and Discussions

The High-temperature stress in field-grown plants crop typically results in permanent tissue damage. Molecular and cellular impacts up to the growth of the entire plant are influenced by temperature. Screening potato genotypes for abiotic stress resistance was reported by Arvin and Donnthy, who used electrical conductivity measurements. Significant variations between genotypes were found using an investigation of differences for all values tested in the high-temperature setting. Several measurements were made, including those of the net photosynthetic rate, leaf temperatures and canopy temperatures, maximum quantum yield PSII photochemistry (Fv/Fm), SPAD, ASI, Stover yield, and grain yield. Here we analyse some of the major genotypes with the measurements that are leaf temperature, canopy temperature, and net photosynthetic rate. Comparing the 2nd date of sowing (T2) to the 1st date of sowing, all genotypes had induced Pn (T1). The range of Pn's increase in percentage was 0.24 to 183%. Overall mean data showed that HKI-161 had the greatest Pn (71.08), followed by HKI-324-17AN (71.00), and Z-40-183 (68.51). Because of the standard leaf temperature and canopy temperature, which were measured in the phase of reproduction on two separate date of sowing, are correspondingly shown in Figure 2 and 3. At 35–36 and 38–40 C and 35–36 and 38–40 C. At leaf temperatures above 38(°C), corn's net photosynthetic rate was reserved, but as growth temperature increase, the optimal variable for photosynthesis also increases. Relative humidity drops when the air temperature rises, increasing evaporative need and transpiration rate. Stomata closure caused a decrease in transpiration rate, which raised leaf temperature in areas with limited water availability.

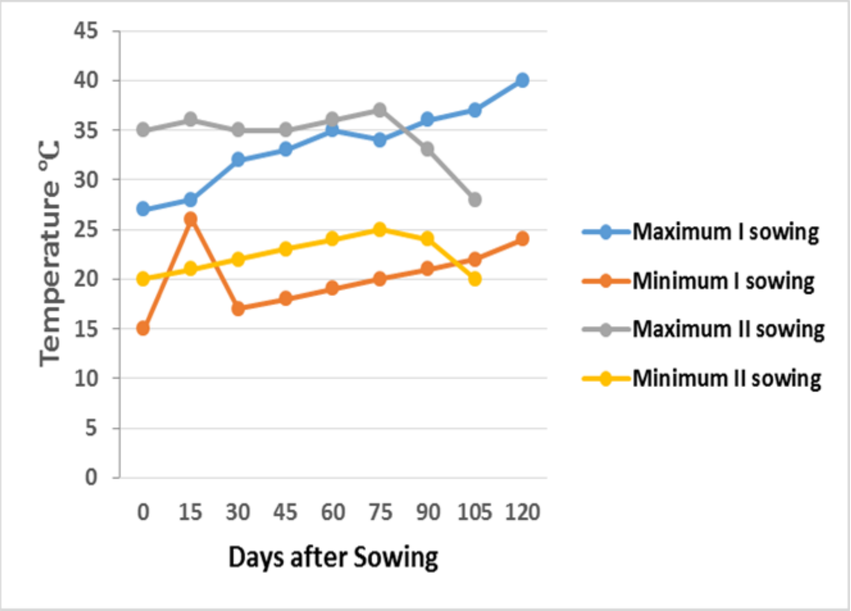

Figure 1: Minimum and maximum temperatures for the maize genotypes

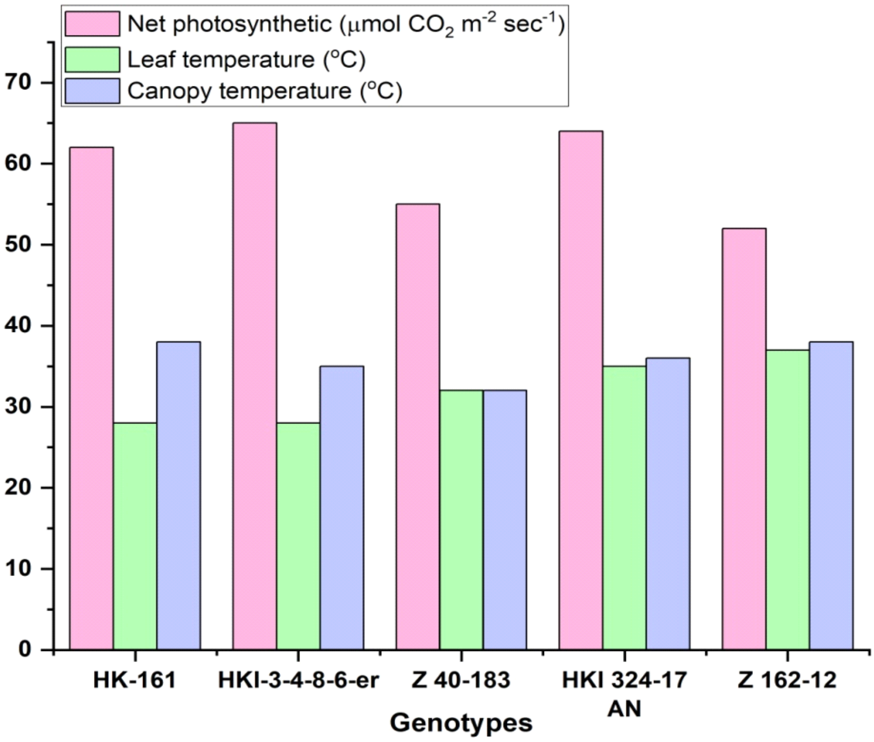

Figure 2: first dates of sowing are affected by high temperatures

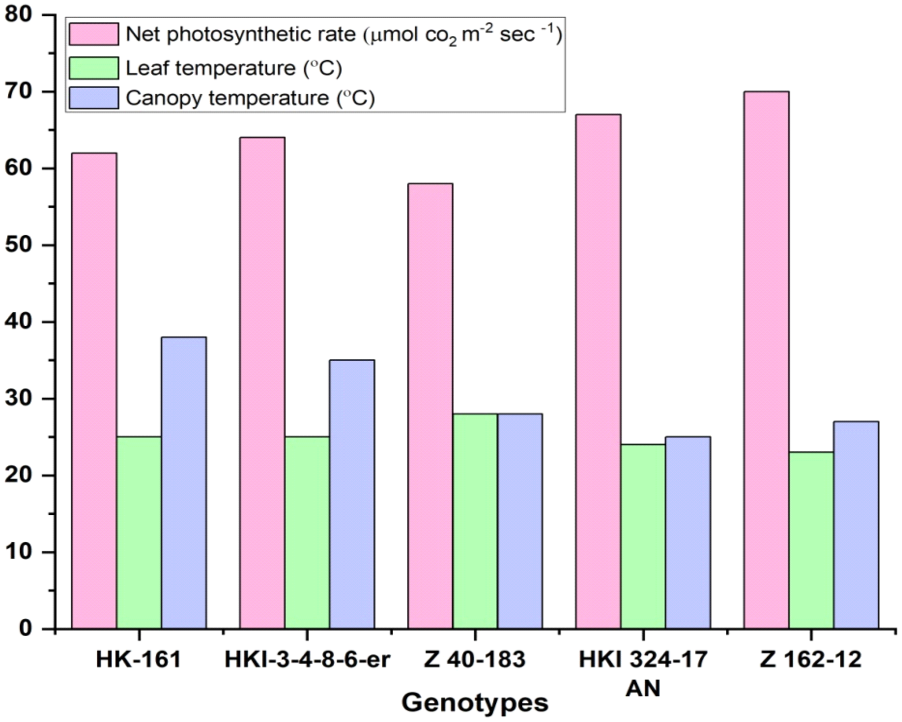

Figure 3: second dates of sowing are affected by high temperatures

Table 1: the study of how different traits change in corn genotypes that have been exposed to high temperatures.

Source	df	Net photosynthetic rate	Stomatal conductance	Transpiration rate	Leaf temperature	Maximum quantum yield PSII photochemistry	Canopy temperature	Soil–plant analysis development	Anthesis silking interval	Stover	Yield
Error	83	4.41	0.01	0.14**	5.50	0.0007	0.44	1.20	0.18	37.79	7.20
Treatments	42	666.92*	0.07**	31.91**	3.37NS	0.0221**	17.67**	121.28**	14.41**	2987.29**	1773.90**
Replications	3	2.70	0.01	0.02	0.22	0.0026	0.50	2.39	0.20	142.10	9.36
Genotypes x DOS	21	314.89**	0.03**	11.85**	0.27 NS	0.00775**	5.43**	83.22**	5.87**	609.96**	589.68**
DOS	2	13.697.93**	0.94**	742.73**	55.96**	0.0493**	380.16**	1102.43**	7.63**	13,271.49**	721.45**
Total	126	221.68	0.022	10.56	4.72	0.00773	6.09	40.61	4.85	1006.90	586.71
Genotypes	21	367.39**	0.06**	16.44**	3.85 NS	0.0351**	11.79**	110.29**	23.29**	4850.47**	3010.75**

Table 2: The finest, highest, and fatal temperatures for several crucial physiological processes in maize

	Maximum (°C)	Celsius (°C)	Optimal (°C)
Fertilization (pollen viability)	<35	35	28
Germination	40	-	30
Seedling growth	40	52	25
Net photosynthetic rate	40	-	30–40
Grain filling (kernel mass)	40	-	20–35

ANOVA was performed on transpiration rate, leaf temperature, and stomatal conductance, under 1st and 2nd date of sowing and the combined investigation ($P<0.01$) was significant. By hindering evaporative cooling, defects in transpiration were found to enhance the vulnerability of healthy vegetation to high-temperature stress. The reproductive stage of maize is much more susceptible to high temperatures than the tassel blast and the vegetative stage is the most obvious pollination efficiency, viability, and trait with decreased pollen shedding which impacts the weight of the kernel, development of the kernel, size of the kernel and lowers seed quantity. The thermal environment during the post-anthesis stage of maize is extremely important because temperatures over 30(°C) throughout this time significantly lowered subsequent kernel development rate and final kernel size. The shanks, leaves, stalk, tassels, silks, cobs, and husks make up maize Stover. Stalks and leaves make up 70% of the total biomass of corn Stover, and the remaining 30% is made up of silks shanks, husks, and cobs. The data of Stover shown in (Figure. 3) indicated higher Stover because of greater Pn with Fv/Fm, which can enhance plant growth. Due to marginally highest temperatures that were ideal for net photosynthetic rate but potentially fatal to the source to sink supply of photosynthates, high total Stover at development and lower yield were produced on the second planting date. While high temperatures boosted the development of the plant's vegetative components, they inhibited the synthesis of hemicelluloses and cellulose by reducing photosynthates availability, hence limiting ear development and, in particular, cob extensibility. Thus, the high-temperature treatment increased plant biomass production through impacts on sink action rather than source action, while decreasing grain yield. Table 1 shows the study of how different traits change in corn genotypes that have been exposed to high temperatures.

High-temperature stress has a less well-understood but important effect on leaf area growth and dynamics. When reproductive development was halted due to heat stress, the number of leaves increased dramatically without any reduction in leaf photosynthetic rates. The volume of solar radiant that may be captured and utilized to accumulate biomass crop is directly proportional to the development of leaf and period of crop growth. A variety of maize processes, including their optimum, maximal, and fatal temperatures, are listed in Table 2. High temperatures during seed filling for only short periods might hasten senescence, reduce seed set and seed weight, and lower yield. When maize kernels were exposed to temperatures exceeding 30 degrees Celsius, cell division and amyloplast replication were severely hampered, resulting in diminished grain sink strength and yield. Reduced antioxidant enzyme activity caused by high-temperature stress led to increased H_2O_2 levels, which in turn promoted lipid peroxidation and ethylene production. Starch accumulation and proper protein synthesis were both negatively affected, leading to slower development and lighter grains when exposed to high-temperature stress.

4. Conclusions

This study's results add new information about the physiology of temperature acclimatization in plants by using a systems-level approach to analyse that the source and sink organs interact with their disturbed environment. There was a slight increase in stover quality from the higher temperatures, but the cob development was stunted. The reproductive stage of maize seemed especially vulnerable to these kinds of influences. Although neither of the genotypes used in the study showed any inhibition of leaf photosynthesis under high temperatures, it was concluded that the variation in stress tolerance couldn't be attributed to a difference in source movement. We can conclude that full comprehension of thermal cycling processes continues to remain indefinable and demands a more strategic approach to future research. To increase crop endurance to high temperatures, sensory, signaling, or regulatory elements must be altered without interfering with other vital functions, such as yield. The primary result of this research was a sharp decline in grain yield and related SPAD parameters in the I date of sowing (T2) compared to the II date of sowing. At the phases of anthesis, and grain rich, Unlike the maize grown in January, the crop planted in February was exposed to abnormally high air temperatures for a few days. The outcomes generated that high temperatures performed a significant part in the lower grain yields and the number of grains given by maize sown on the 2nd date of sowing. The actual high degree of emotions and their cumulative influence on crop output over numerous agro-weather environments must be clarified through the extending of field research, physiological, biochemical, and molecular methods, as well as agronomic control strategies. Understanding the mechanisms causing yield loss over high-temperature stress is essential.

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