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Effect of high temperature and low moisture stress on morpho-physiological and biochemical characters and yield of maize hybrids

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ABSTRACT

Forty six maize hydrids were sown on two dates of sowing for two years (2010 and 2011) to identify tolerant and susceptible genotype(s) on the basis of morpho-physiological and biochemical characteristics with respect to stress caused due to high temperature and low moisture. Different morphological characters i.e. leaf number, leaf area and physiological characters i.e. chlorophyll reading by SPAD chlorophyll meter, relative water content (RWC), membrane injury index etc. were studied. HTS and LMS affected the crops growth rate as and when the stress was induced. The most tolerant lines were LM-17, HKI-209 and HKI-325-AN under control condition whereas LM-17 performed quite well under stress condition as well. HKI-586-3 performed extremely poor under stress condition whereas HKI-488 performed extremely poor under control condition. It was also seen that inbreds performed better in 2011 as compared to 2010 as the climatic condition was more favorable with respect to rainfall and humidity. The tolerant lines performed better photosynthesis and had better osmotic adjustment and protection as compared to the susceptible lines.

Keywords: High temperature, moisture stress, biochemical, characters, yield, maize hybrids

INTRODUCTION

Maize is one of the most important cereal crop across the world whereas in countries like India it is mainly used as fodder crop. It's a versatile crop that is grown across all the three seasons i.e. rabi, kharif and spring / summer. High temperature is a major environmental factor that determines the crop growth and yield. These variations are leading to a lot of ups and downs in the carbon and oxygen level in the environment, thus, affecting the agriculture production. Due to scanty rainfall people are shifting from rice to maize or other crops. The importance of stresses, whether biotic or abiotic, affecting the food security stand as a major problem for researchers to identify tolerant genotype to various types of stress. Among the abiotic stress, drought and high temperature with low moisture is one of the important stresses to study. These two stress have been identified as the limiting factor affecting major crops and cropping system. When high temperature is accompanied by low moisture stress together, it leads to huge reduction in yield. (Ashraf and Hafeez, 2004). The maize crop that is sown in February or March generally termed as spring maize faces high temperature at the time of flowering. If the high temperature accompanied by low moisture in the environment is a severe situation for the crop. Plants are very sensitive at flowering phase and maize specially is very susceptible to stress at its flowering and grain filling.It has been identified that high temperature stress leads to a reduction in number of kernels, pollen viability, silk receptivity, leads to kernel abortion, decreased cell division reduction in yield (Stone, 2001). Ortiz *et al.* (2008) reported that if temperature increases by 3-4 degree C the yield reduces by 15-35%. However, extreme variations during hot summers can damage the intermolecular interactions needed for proper growth, thus impairing plant development and fruit set (Bita *et al.* 2013). Transitory or constantly high temperatures cause an array of morpho-physiological, anatomical and biochemical changes in plants, which eventually affects plant growth and development, and lead to a drastic reduction in biological and economic yield (Commuri and Jones, 2001).High temperature and drought stress result in a negative impact on the overall development of a plant. The basic requirement is to understand the physiology and identify and develop tolerant lines against the stress. The study was, therefore, carried out to evaluate and identify

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different genotypes as tolerant and sensitive on the basis of morpho-physiological characters and yield.

MATERIAL AND METHODS

The field trials was conducted for 2 years (2010 & 2011) in the "Net House" of the research farm of the Directorate of Maize Research, Pusa, New Delhi, India. The rainfall received during the growing period from June to March) was 297 mm in 2010 and 318.5 mm in 2011. Maize seeds were sown on February 26 and March 15 in both the year of study i.e. 2010 and 2011. The experiment was laid out in randomized block design with three replications. Irrigation was restricted at flowering and grain filling stages of the crio. Number of leaves was counted from base till fully open third leaf stage at flowering stage. For dry matter partitioning single plant/plot were selected and uprooted from sampled row at flowering stage. These plants that were separated in leaf, shoot, root, lamina, tassel and cob were air-dried followed by oven dried at 65^{o}C for 24 hours and weighed. Leaf area was measured at flowering stage with the help of leaf area meter. Tassel blasting score was observed visually in the whole plot and was rated accordingly between1-5 (lowest 1). Leaf Firing score was observed visually in three plants selected randomly and was rated accordingly 1-5 (lowest 1). Leaf Senescence score was observed visually in three plants selected randomly and was rated accordingly from 1-10 (lowest 1). For calculating ASI i.e. anthesis silking interval days to 50% of anthesis was calculated from days to sowing and similarly days to 50% silking was calculated. From days to 50% of silking days to 50% anthesis was substracted to find out the anthesis silking interval. The chlorophyll content was measured using a chlorophyll meter (Minolta SPAD). It was done in third fully opened leaf at flowering stage. Relative Water Content was calculated as RWC= (Fresh Weight-Dry Weight)/ Turgid Weight-Dry Weight. The membrane injury index (MII) was calculated as per formula, MII=(C1/C2*100) where C1 is electrical conductivity before autoclaving and C2 is electrical conductivity after autoclaving. Final yield was recorded and computed as grain yield g/plant.The data were expressed as the mean± standard error and were analyzed statistically using Statistical Analysis System (SAS 9.2). Significance level of $p< 0.05$ was used.

RESULTS AND DISCUSSION

High temperature stress reduced the growth of maize plants during flowering and post flowering the stress was induced at flowering and grain filling, two of the most critical growth stages for maize crop under stress. The meteorological data during the experimental periods showed that the weather conditions varied a lot in both the years of study. However, the weather condition were more favorable in 2011 i.e. the second year of study as compared to 2010. The average minimum temperature was comparatively lower as well as the rainfall distribution was also better in the second year of study. The evaporation rate was comparatively higher in the first year that might have resulted in better yield of grain and better yield and growth attributes in the second year.

The performance of the genotype for leaf area, leaf number and chlorophyll content was better in control condition as compared to stress condition. Leaf area was maximum in February sowing for the year 2011 and minimum for March 2010. Similar results were noticed for leaf number, chlorophyll content as measured by SPAD chlorophyll meter (Table 1) and dry matter partitioning (Table 2)

Table1: Interaction table for Genotypes and Date of Sowing for leaf area, leaf number and chlorophyll content

Year	Leaf area	Leaf Number	Chlorophyll Content
G x D1	328.23±28.469	12.39±0.711	55.38±3.226
G x D2	200.22±13.055	10.60±0.772	46.45±4.159
G x D3	330.44±26.211	12.56±1.059	58.42±5.183
G x D4	203.39±14.639	10.88±0.726	51.68±5.08

Where G-Genotypes, D1-Feb planting, 2010, D2-Mar planting, 2010, D3-Feb planting 2011 and D4- Mar planting, 2011

Table 2: Interaction table for Genotypes (Dry Matter Partitioning) and Date of Sowing

Year	DW Sheath	DW Root	DW Lamina	DW Shoot	DW Cob	DW Tassel
G x D1	47.20±1.396	25.61±0.793	42.65±1.344	25.61±0.793	58.73±1.980	10.49±0.397
G x D2	43.58±2.144	22.57±1.312	40.07±2.156	22.57±1.312	54.30±2.936	10.27±0.706
G x D3	48.05±1.668	26.30±1.054	43.49±1.699	26.30±1.054	59.06±2.318	10.48±1.295
G x D4	44.08±2.284	24.03±1.356	40.53±2.240	24.03±1.356	56.61±3.229	10.46±0.705

Where G-Genotypes, D1-Feb planting, 2010, D2-Mar planting, 2010, D3-Feb planting 2011, D4- Mar planting, 2011 and DW- Dry Weight

The most tolerant lines for membrane injury index (M II) were by HKI 170(1+2) under normal condition whereas LM-16 performed best under stress condition. For RWC, LM-17 performed best under normal condition whereas LM-16 performed best under stress condition (Table 3).

Table 3: Interaction table for genotypes and date of Sowing for membrane injury index, anthesis silking interval and grain yield

Year	MII	RWC	ASI	Grain Yield
G x D1	12.98±.699	60.47±2.827	1.41±0.218	17.44±1.057
G x D2	12.2±.822	50.14±2.805	4.32±0.220	0.78±0.081
G x D3	13.12±.551	60.81±1.936	1.37±0.209	18.18±0.942
G x D4	12.67±.749	51.06±3.309	3.28±0.250	1.01±0.106

Where G-Genotypes, D1-Feb planting, 2010, D2-Mar planting, 2010, D3-Feb planting 2011 and D4- Mar planting, 2011

The anthesis silking interval (ASI) was maximum for HKI-288-2 under stress condition whereas HKI 325-AN showed maximum ASI under control condition (Table 3). The inbred LM-7, HKI-209 and HKI-325-AN were superior under control condition whereas LM-17 performed quite well under stress condition as well. HKI-193-1 performed extremely poor under stress condition whereas HKI-488 performed extremely poor under normal condition. In second year (2011) the genotypes performed better than the first year (2010) of sowing whereas February sowing performed better as compared to March sowing (Table 3) for grain yield. The temperature and precipitation plays a very important role for genotype to resist against stress. It has been reported by Brisson *et al.*, (2010) that number of hot days affect the yield of the plant. It was also noticed that the value for February planting in 2010 for 46 inbred lines ranged from 10.3g/plant to 32.8g/plant whereas March sowing fell in range of 0-16.92g/plant. Similarly, for 2011 the value for February planting fell in the range of 11.1-36.6 and that for March fell in between 0 and 18.8. Under both stress and control condition LM-17 performed best followed by HKI-209 under control condition and HKI-325-17AN under stress condition.

High temperature and low moisture stress together can lead to have huge loss in yield. From our study it was concluded that LM-17, LM-16, HKI-209 and HKI-193-1 AN performed better than the other maize inbreds and can be selected as promising inbred to develop hybrids that are tolerant to stress.

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