Performance of Heat Tolerant Maize Genotypes (RCRMH 2, RCRMH 3 and RCRMH 4) under Moisture Stress during Rainy Season

ABSTRACT

This research was aimed at studying the response of heat tolerant genotypes to prolonged period of water stress prevalent under rain fed situation with irrigation commands in northern Karnataka. The design was the completely randomized block, conducted at the Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India, during rainy season (kharif) 2019**; t**he present study comprised of three stress tolerant CIMMYT genotypes (RCRMH 2, RCRMH 3 and RCRMH 4) with four moisture stress stages (imposed between 20-40, 40-60, 60-80 and 80-100 DAS) which were sown during mid-June, July and August**.** The results revealed superior performance of RCRMH 3 (5321 kg ha^{-1}) over other genotypes whether stressed or not, but all the genotypes were on par with each other in terms of physiological parameters *viz.*, proline accumulation, relative water content, canopy temperature, NDVI, relative chlorophyll content and ASI, and these parameters exhibited good correlation with yield and hence found ideal for stress studies. Of the cultivars, RCRMH 3 and RCRMH 2 withstood moisture stress better than RCRMH 4 and sustained kernel yield, and therefore, are suitable to semiarid region characterized by inclement weather.

Keywords: Heat tolerant genotypes, Moisture stress, Proline, Relative water content, Canopy temperature, Grain yield.

1. INTRODUCTION

Many different abiotic stresses affect and reduce the yield of the main cereal crops produced in the world and maize grown in the semiarid tropics is no exception. The factor with the greatest impact on stable production, especially in tropical countries, is water stress [1]. In India, maize is predominantly grown as rain fed crop, approximately 80% of wet-season maize areas are rain fed, where crops are adversely affected by the erratic behavior of rains [2] wherein, monsoon is characterized by unpredictable rainfall which results into moisture stress at different growth stages of maize [3]. The rainfall mostly occurs in the early growth stages facilitating better stand establishment and early growth, and the crop faces water deficit stress (WDS) from the pre-flowering to late grain-filling stages.

Such problems considerably affect the phenotype, reproductive system and seed set [4]. Maize is more susceptible to water stress (drought) than other crops because of its unusual floral structure with separate male and female floral organs and the near-synchronous development of florets on a (usually) single ear borne on each stem. The reduction of maize productivity under drought stress conditions depends on different factors such as plant development stage, drought intensity and duration of water deficit, and varietal sensitivity to drought stress [5]. Moisture stress at critical stages decreases yield up to 40 per cent [6]. The annual estimated yield loss due to drought may be around 24 million tonnes which is equivalent to 17 % of a normal year's production in a developing world.

Increased frequency and intensity of droughts under changing climate necessitates adaption of agro-techniques to combat water stress situation during crop growth period. One such adaptation strategy is use of drought-tolerant maize hybrids which have potential to stabilize the grain yield [7]. Heat tolerant maize genotype RCRMH-2 released by University of Agricultural Sciences, Raichur, for cultivation in Zone-II of Karnataka state during summer as it withstands higher summer temperature. Crop breeders claim that the heat tolerant maize genotypes are able to withstand drought condition also. This necessitated to study the response of CIMMYT heat tolerant genotypes to prolonged period of water stress prevalent under rainfed situation in northern Karnataka irrigation commands as response of these genotypes likely to differ to stage of water stress.

2. MATERIAL AND METHODS

The experiment was conducted during rainy season (*kharif*) 2019 at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India, situated between 15° 46' N latitude and 76° 45' E longitude with an altitude of 358 meters above the mean sea level. The soil of the experimental site was medium black, near neutral in reaction (pH 7.53), normal in soluble salts (EC 0.86), low in organic carbon (0.47 %), medium in available nitrogen (282 kg ha^{-1}) and phosphorus (47 kg ha^{-1}), and high with regard to potassium (356 kg ha^{-1}). The experiment consisted of 13 treatments with three genotypes RCRMH 2 (recommended for summer), RCRMH 3 and RCRMH 4 exposed to moisture stress at 20-40 DAS (V2 – V6, knee height stage), 40-60 DAS (V_{12} – V_{15}, c), 60-80 DAS (VT, R_1 & R_2, reproductive stage) and 80-100 DAS (R_4, R_5 & R_6, ripening stage) by withholding of irrigation at 20 days interval, besides control with no stress (RCRMH 2). Among these 20-40 DAS, 60-80 DAS and 80-100 DAS were not successfully imposed because of receipt of rainfall in between but at 40-60 DAS moisture stress treatment was successful because of dry spell occurred during the period and was found useful for varietal assessment. Two meters buffer zone was maintained between plots and between replication to avoid effect of horizontal water movement. All the three genotype used in the present study were heat stress tolerant single cross maize hybrids developed by UAS Raichur, Karnataka in collaboration with CIMMYT-Asia, Hyderabad under 'Heat Stress Tolerant Maize for South Asia through public private partnership' (HTMA) project funded by USAID.

The crop was sown on 18th June 2019 and was raised as per the specific package of practices recommended for the region. The Sunscan canopy analyzer (Delta-T Device, Cambridge, UK) probe was used for recording LAI [8], SPAD-502 (Soil and plant analysis development) chlorophyll meter was used for recording leaf chlorophyll, Normalized Difference Vegetative Index (NDVI) was measured by Green seeker and the canopy temperature was measured by using a hand held Infrared thermometer, between 11.30 am and 01:30 pm (local time) during clear sunny days. RWC (Relative water content) was estimated as per the method of Barrs and Weatherly, 1962 [9]. Proline content was measured by methods given by Bates *et al*., 1973 [10]. Data were subjected to statistical analysis as described by Gomez and Gomez 1984 [11]. Means were compared using Duncan's Multiple Range Test. Correlation analysis was carried out to study the nature and degree of relationship between various growth parameters, physiological parameters, yield parameters and yield. Regression analysis was worked out as per the procedure outlined by Panse and Sukhatme 1967 [12].

3. RESULTS AND DISCUSSION

The experimental site falls in North eastern dry zone of Karnataka which experiences tropical semi arid climate throughout the year. During the year of experimentation the annual rainfall received (525.3mm) was 10 per cent lesser than the annual average rainfall of the region (584.54mm). Moisture stress occurred during vegetative stage (when the sink size was fixed) because of dry spell during the period which significantly affected the physiological parameters and kernel yield of maize (Table 1.) *viz.*, leaf area index, relative chlorophyll content (SPAD values) and normalized vegetation index.

Among the different treatments, proline contents (123,125 and 118 µmoles g^{-1} respectively) were significantly higher in all the genotypes *viz.*, RCRMH 2, RCRMH 3 and RCRMH 4 (and RCRMH 3 faring better), exposed to moisture stress at 40-60 DAS. Also, they were significantly superior with no moisture stress, indicating that under moisture stress conditions all the three genotypes were capable of accumulating higher amounts of proline, and the leaf proline content plays important role in osmotic regulation. This condition helps in drought tolerance as reflected in relative water content and canopy temperature in the present study. These results corroborate with the findings of Zhang *et al*., 2010 [13] who reported higher proline in drought tolerant mutant. In their study under drought, drought-tolerant maize mutant C7–2t accumulated more proline and soluble sugars in the leaves than those in C7–2, a drought sensitive genotype.

Relative water content (RWC) is another key physiological factor helping to assess the effect of moisture stress. In the present investigation, RCRMH 3 recorded higher RWC under all situations and RWC was significantly lower with RCRMH 4 under moisture stress condition (S_2G_3 - 68.17%), but was on par with rest of the treatments except S_1G_2 (RCRMH 3 under moisture stress at 20-40 DAS – 75.45%). It was due to increased accumulation of proline in moisture stressed condition in all the genotypes which helped in maintaining the leaf water content comparable to that of non moisture stressed treatments and thereby, helped to maintain photosynthesis under stress condition while having normal transpiration. Similarly, Moussa and Abdel-Aziz, 2008 [14] reported that high relative water content could help the tolerant genotype to perform physio-biochemical processes more efficiently under water stress conditions than the susceptible genotype.

Lower canopy temperature is another good physiological indicator of stress tolerant genotype. Canopy temperature was slightly higher in moisture stressed treatments (T_6, T_4 and T_5 31.9, 31.37 and 32.04^o C respectively) but not to a significant level over rest of the non moisture stressed treatments. This was due to maintenance of leaf water content in these genotypes under stressed condition as evidenced from correlation (Table 3), wherein canopy temperature and relative water content have significant negative association. The quantum of canopy temperature per unit increased in relative water content, and was at the rate of 1.35 (Fig.1). Higher leaf water in these genotypes helped in moderating the canopy temperature under stress condition. Consequently, it helped to avoid the disruption of cellular activities and photosynthesis as reflected in total dry matter production (TDM). These results are in conformity with the findings of Effendi *et al*. 2019 [15] who reported high leaf relative water content and low leaf temperatures in drought stress condition in drought tolerant genotypes.

Relative chlorophyll content (SPAD values) was higher with genotypes RCRMH 3 under non-stressed treatment combinations (T_8, T_2 and T_{11} 51.25, 50.90 and 50.63) and was superior to RCRMH 4 under moisture stressed condition. However, the latter was also in turn on par with RCRMH 3 and RCRMH 2 under non-stressed condition. This indicates that, because of better performance of these genotypes even under stressed condition in terms of physiological parameters *viz.*, leaf proline content, RWC and canopy temperature helped in avoiding damage to chlorophyll content under moisture stressed condition, and maintaining higher relative chlorophyll content to a comparable level to that under non-moisture stressed conditions.

Similar trend was also observed with NDVI values. This might also be due to significant positive association of NDVI with RWC (0.959**) and SPAD (0.859**), and significant negative association with canopy temperature (-0.871**). Hence, better performance in these physiological parameters helped in maintaining good NDVI value under moisture stress condition in tolerant genotypes, particularly RCRMH 3 and RCRMH 2.

Table 1: LAI, proline, RWC, canopy temperature, NDVI and SPAD in maize genotypes as influenced by stress during rainy season

Stress stage/Genotype			LAI	**Proline** (µmoles g^{-1})	**RWC (%)**	**Canopy Temperature (^{o}C)**	**NDVI values**	**SPAD values**
T_1	20-40 DAS (S_1)	RCRMH 2 (G_1)	103^{bc}	74.25^{ab}	31.30^{a}	0.70^{ac}	49.32^{ac}	3.18^{ab}
T_2		RCRMH 3 (G_2)	108^{b}	75.45^{a}	31.21^{a}	0.73^{a}	50.11^{ab}	3.21^{ab}
T_3		RCRMH 4 (G_3)	99^{bc}	73.42^{ab}	31.37^{a}	0.70^{ac}	46.80^{ac}	3.10^{ab}
T_4	40-60 DAS (S_2)	RCRMH 2 (G_1)	123^{a}	69.52^{ab}	32.04^{a}	0.66^{bc}	45.56^{bc}	2.98^{ac}
T_5		RCRMH 3 (G_2)	125^{a}	71.84^{ab}	31.90^{a}	0.69^{ac}	46.42^{ac}	3.05^{ac}
T_6		RCRMH 4 (G_3)	118^{a}	68.17^{b}	32.12^{a}	0.64^{c}	44.51^{c}	2.80^{c}
T_7	60-80 DAS (S_3)	RCRMH 2 (G_1)	103^{bc}	74.63^{ab}	31.36^{a}	0.72^{ab}	50.46^{ab}	3.20^{ab}
T_8		RCRMH 3 (G_2)	107^{bc}	75.34^{ab}	31.28^{a}	0.75^{a}	51.25^{a}	3.26^{a}
T_9		RCRMH 4 (G_3)	98^{c}	73.10^{ab}	31.42^{a}	0.70^{ac}	49.58^{ab}	2.95^{bc}
T_{10}	80-100 DAS (S_4)	RCRMH 2 (G_1)	104^{bc}	73.49^{ab}	31.32^{a}	0.71^{ab}	50.01^{ab}	3.19^{ab}
T_{11}		RCRMH 3 (G_2)	108^{b}	74.52^{ab}	31.23^{a}	0.73^{a}	50.90^{a}	3.28^{a}
T_{12}		RCRMH 4 (G_3)	98^{c}	72.45^{ab}	31.42^{a}	0.69^{ac}	50.63^{a}	3.00^{ac}

T_{13}	No stress	RCRMH 2	102^{bc}	74.58^{ab}	31.31^{a}	0.72^{ab}	50.25^{ab}	3.19^{ab}
S.Em$\pm$			2.9	2.108	0.779	0.018	1.493	0.089

Days to 50 % anthesis and 50% silking were significantly influenced by moisture stress and little higher number of days were taken for 50% anthesis and silking due to moisture stress by all the genotypes (T_4, T_5 and T_6 2.95, 2.89 and 2.81 days respectively), nevertheless not to a significant level. As a consequence of non-significant increase in number of days to 50% anthesis and 50% silking, the tolerant genotypes could maintain anthesis-silking interval besides accumulation of photoynthates during this extended period. On the other hand, significantly higher interval between anthesis to silking interval was observed with RCRMH 4 under moisture stressed treatment (T_6 2.95 days) but was on par with the rest of treatments except T_2 (2.71 days), and though T_2 recorded significantly lower ASI, it was in turn on par with the rest of the treatments except for the former treatment (T_6). These variations indicate that the genotypes used were able to have lower ASI even under moisture stressed condition as lower ASI is beneficial in the maize productivity. Otherwise, each day of delay between pollen shed and silk emergence would have reduced the rate of sexual fertilization and increased barrenness [3].

Consequently, the total dry matter production followed the similar trend. Significantly higher TDM was observed with RCRMH 3 under non-stresses condition (T_2, T_8 and T_{11} - 331.4, 331.2 and 332.5 g pl^{-1}, respectively) over RCRMH 4 under stressed condition which recorded lower TDM under moisture stress (T_6 -300.8 g pl^{-1}) and it was on par with rest of the genotypes under moisture stress (T_4-310.5 and T_5-318.2 g pl^{-1}) and also with treatments having RCRMH 2 and RCRMH 4 under non-stressed treatments. This might be due to the ability of these genotypes under moisture stress condition to have higher relative water content, relative chlorophyll content and temperature moderation comparable to that of non-moisture stressed treatments which helped in accumulating higher total dry matter even under moisture stressed condition, as evidenced from significant correlation association of these attributes with total dry matter production.

Finally, higher kernel yield was observed with RCRMH 3 under non-moisture stress treatments (T_8 T_{11} and T_2, 5707, 5670 and 5559 kg ha^{-1} respectively) and also under moisture stress condition. Significantly lower kernel yield was recorded with RCRMH 4 under moisture stress condition (T_6 4826 kg ha^{-1}), but in turn it was statistically comparable to the rest of the genotypes under moisture stress condition (T_4 5027 and T_5 5321 kg ha^{-1}). The sustaining yield even under moisture stress condition can be traced back to their physiological performance, particularly the cumulative effect of all these growth and physiological parameters (Tables 1 and 2) and their association with kernel yield (Table 3). The association of these can be quantified by regression equations in which it was observed that every unit of LAI and TDM increased the yield to the tune of 1694.80 and 25.930 respectively. However, per unit increase in ASI and canopy temperature decreased yield at the rate of 3222.61 and 654.25 units, while proline accumulation had low association with yield in the present study (Fig.1).

Table 2: Days to 50% anthesis and silking, ASI, TDM and yield of maize genotypes as influenced by stress during rainy season

Stress stage/Genotype			Days to 50% anthesis	Days to 50% silking	ASI (days)	TDM (g m^{-2})	Yield (Kg ha^{-1})
T_1	20-40 DAS (S_1)	RCRMH 2 (G_1)	54.61^{a}	57.38^{a}	2.77^{ab}	323.5^{ab}	5451^{ab}
T_2		RCRMH 3 (G_2)	53.77^{a}	56.49^{a}	2.71^{b}	331.4^{a}	5558^{ab}
T_3		RCRMH 4 (G_3)	55.64^{a}	58.52^{a}	2.88^{ab}	315.5^{ab}	5315^{ac}
T_4	40-60	RCRMH 2 (G_1)	56.38^{a}	59.27^{a}	2.89^{ab}	310.5^{ab}	5027^{bc}

T_5	DAS	RCRMH 3 (G_2)	55.49[a]	58.30[a]	2.81[ab]	318.2[ab]	5321[ac]
T_6		RCRMH 4 (G_3)	57.52[a]	60.47[a]	2.95[a]	300.8[b]	4826[c]
T_7	60-80 DAS	RCRMH 2 (G_1)	54.23[a]	57.05[a]	2.82[ab]	321.8[ab]	5559[ab]
T_8		RCRMH 3 (G_2)	53.17[a]	55.92[a]	2.75[ab]	331.2[a]	5707[a]
T_9		RCRMH 4 (G_3)	55.70[a]	58.59[a]	2.89[ab]	311.1[ab]	5220[ac]
T_{10}	80-100 DAS	RCRMH 2 (G_1)	54.50[a]	57.29[a]	2.80[ab]	324.1[ab]	5399[ac]
T_{11}		RCRMH 3 (G_2)	53.64[a]	56.37[a]	2.73[ab]	332.5[a]	5670[a]
T_{12}		RCRMH 4 (G_3)	55.69[a]	58.54[a]	2.85[ab]	314.1[ab]	5172[ac]
T_{13}	No stress RCRMH 2 (Control)		54.21[a]	57.02[a]	2.81[ab]	322.7[ab]	5450[ab]
S.Em±			1.577	1.578	0.066	7.826	176

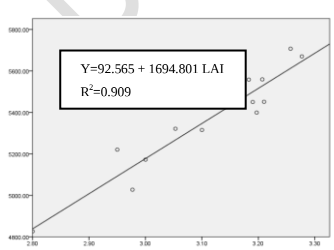
Note: The means followed by the same letter are not significantly different.

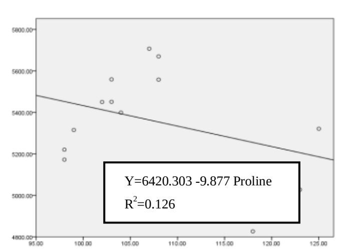
Table 3: Correlation between growth components, yield and physiological traits of maize as influenced by response of maize genotypes to moisture stress during rainy season

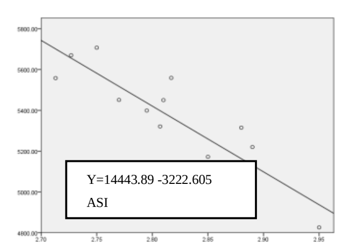
	Yield	LAI	TDM	PROLINE	RWC	CanTemp	NDVI	SPAD	Anthesis	Silking	ASI
Yield	1										
LAI	.953**	1									
TDM	.957**	.946**	1								
PROLINE	-.355	-.338	-.245	1							
RWC	.934**	.881**	.876**	-.612*	1						
Canopy Temp	-.816**	-.793**	-.774**	.799**	-.942**	1					
NDVI values	.963**	.885**	.914**	-.482	.959**	-.871**	1				
SPAD values	.791**	.736**	.757**	-.674*	.861**	-.890**	.859**	1			
Days to 50% Anthesis	-.980**	-.949**	-.972**	.363	-.929**	.827**	-.967**	-.842**	1		
Days to 50% Silking	-.979**	-.949**	-.976**	.352	-.927**	.823**	-.964**	-.838**	1.000**	1	
ASI	-.895**	-.880**	-.973**	.134	-.807**	.691**	-.828**	-.702**	.915**	.924**	1

** Correlation is significant at the 0.01 level

Correlation is significant at the 0.05 level







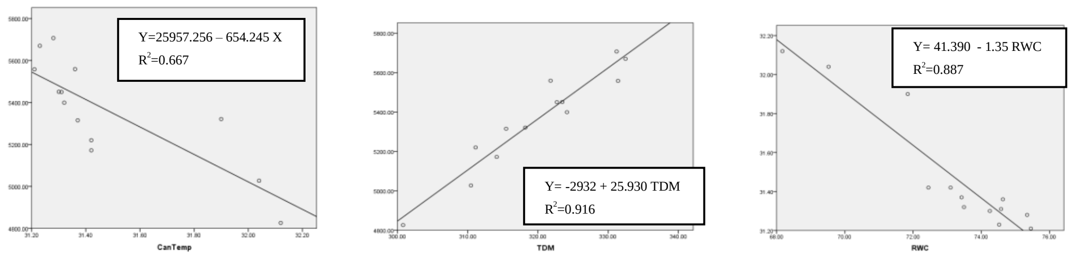


Fig.1. Relationship of LAI, proline, ASI, canopy temperature and TDM with grain yield and RWC and canopy temperature of maize genotypes during rainy season under moisture stress condition

4. CONCLUSION

The study brought forth that mid-season droughts be the major constraints in maize production under rain conditions especially with rising trend of climate change, stress tolerant genotypes particularly RCRMH 3 and RCRMH which were recommended for sowing in summer to overc the heat stress for semi-arid tropics of Karnataka could as w be recommended during rainy season under varied moist conditions.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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