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Evaluation of tropical maize hybrids for seed yield and its related traits under heat stress environment (*Zea mays* L.)

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Abstract

Aims: The aim of the present investigation was to evaluate the magnitude of variability that exists among the various genotypes when grown under heat stress environments. The study emphasized on screening maize hybrids under high temperature environments and to know the adaptability of the hybrids to tropical agro-climatic conditions.
Study design: Alpha lattice design
Place and Duration of Study: Agriculture College Farm, Bheemarayanagudi, Karnataka during the cropping season 2016.
Methodology: Forty nine maize hybrids developed and further evaluated under high temperature conditions in alpha lattice design along with three checks. Data was recorded on days to 50% tasseling, days to 50% silking, anthesis silking interval, plant height (cm), ear eight (cm), cob length (cm), cob diameter (cm), number of kernel rows, kernels per row and yield per plant (g).
Results: The results from ANOVA revealed there existed significant differences among the various maize hybrids that were evaluated. The hybrids *viz.,* ZH16848 91 (g/plant), ZH16866 92(g/plant) and ZH16880 91(g/plant) exhibited higher grain yield as compared to other hybrids and also showed reasonable tolerance against high temperature.
Conclusion: The present study revealed considerable amount of variation among the tested hybrids that may be exploited in future breeding programs for developing heat tolerant maize hybrids accompanied with other desirable attributes.

Keywords: Maize, heat stress, climate change, hybrid evaluation

Introduction

Maize (*Zea mays* L.; 2n = 20) is one among the three major cereal crops which contributes to food security after Rice and Wheat. Its importance is uncontestable in the world agricultural economy as food for humans (Morris *et al.*, 1999) [20], feed for animals and as a crop of industrial value (White and Johnson, 2003) [37]. It is a miracle C_4 crop. There is no other cereal, which has such an immense genetic potential and thus is rightly called as ‘Queen of Cereals’. It is one of the most versatile emerging crops possessing wider adaptability under varied agro-climatic conditions. It is reported that by 2050 demand for maize will double in the developing world and maize is predicted to become the crop with the greatest production globally and in the developing world by 2025 (Rosegrant *et al.*, 2009) [30]. The demand for maize is increasing significantly. On the contrary, maize production and productivity are severely constrained by global climate change which is imposing severe negative effects on agriculture and resulting in severe rise in temperature, frequent heat waves, drought, floods, desertification and weather extremes (IPCC, 2009) [13].

Projections of climate change will further exacerbate the ability to ensure food security and foster economic growth within many maize producing areas. The development of improved germplasm to meet the needs of future generations in the light of climate change and population growth is of the utmost importance. According to the report of Intergovernmental Panel on Climatic Change (IPCC, 2007) [12], global mean temperature will rise 0.3 °C per decade reaching to approximately 1 ^{0}C and 3 ^{0}C above the present value by the year 2025 and 2100 respectively, and which will result in global warming. The impact of climate change on agricultural production will be greatest in the tropics and sub tropics, with South Asia projected to be particularly vulnerable from multiple stresses and low adaptive capacity (IPCC, 2007; Rodell *et al.*, 2009; Niyogi *et al.*, 2010) [12, 29, 25]. These reports highlight the need to develop heat stress tolerant crop varieties in general and maize in particular, as it is being grown throughout the year (Battisti and Naylor, 2009) [5].

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Heat stress has severe, multiple, negative impacts on crop yields, including reduced leaf photosynthesis and enhancing leaf senescence rates. More critically for yield determination, however, there are reported effects of decreasing grain number when heat stress occurs before or around anthesis and reduced grain weight when it occurs during grain filling (Wilhem *et al.,* 1999) [38]. Heat stress can occur very abruptly and even short episodes of high temperatures can cause a severe decline in grain yields (Noor, 2012) [26]. Maize is particularly vulnerable to heat stress during reproductive stage (Cairns *et al*., 2012) [8]. A recent study showed that each degree day spent above 30 ^{0}C reduced the final yield of maize by 1% under favourable growing conditions and 1.7% under drought stressed environments (Lobell *et al*., 2011) [16]. More recent studies suggest a 2 to 5 % decrease in yield potential of maize for a temperature rise of 0.5 ^{0}C to 1.5 ^{0}C in India (Aggarwal, 2003) [2]. If current trends persist by 2050, maize yields may drop by 17%, wheat by 12%, and rice by 10% in irrigated areas in South Asia because of climate change induced heat and water stress (IFPRI, 2009) [11]. Therefore, the major challenge is to keep pace with unprecedented increase in maize demand by enhancing the overall productivity and production and at the same time to adapt and mitigate the climate change effects such as global warming. However, relatively little research has been conducted on heat stress compared to other abiotic stresses in maize. Identification of traits related to high yield under heat stress and the elucidation of their inheritance have important ramifications in maize breeding programs attempting to develop more heat tolerant genotypes. Thus, genetic improvement under these environments can be achieved by incorporating heat stress-adaptive traits containing sufficient genetic variability and high heritability into good agronomic backgrounds or using these traits in selection of the heat tolerant genotypes. Breeding for heat tolerance is in its infancy stage and warrants more attention than it has been given in the past. In his regard the present investigation was conducted to identify high yielding hybrids with narrow ASI under heat stress environment.

Material and methods

In order to assess the impact of heat stress on grain yield for the various hybrids generated by CIMMYT, the experiment was conducted under natural heat stress conditions. The experiments were conducted during summer (Mid-March – July 2016) at Agriculture College Farm, Bheemarayanagudi. It lies at latitude 16°44' N and 76 °47' E longitude with an altitude of 458 m above mean sea level. Meteorological data for the cropping period is in Table 1. The parental lines developed at CIMMYT-Asia, ICRISAT campus, Hyderabad which were either tolerant or moderately tolerant to heat stress were utilized for generating hybrids. The hybrids (Table 2) were evaluated in alpha lattice design during summer (mid-March to a June), 2016. Each plot consisted of two rows of 3m length with spacing of 60 cm × 20 cm. Recommended agronomic practices were adopted to raise a healthy crop under drip irrigation till physiological maturity. In the experiment, the leading commercial hybrids *viz.*, P1844, DKC9108 Plus and BIO9544 were used as checks. The climate data was collected from automatic weather stations situated at ARS, Bheemarayanagudi. The temperature during the crop growth period ranged from 21.4 to 43.5 °C at Bheemarayanagudi. The vapour pressure deficit was also calculated for the cropping period and was more than 3 kPa indicating high heat stress (data not shown). Thus, the hybrids were appropriately screened for heat stress. During the course of investigation the following plant characters were recorded *viz.*, days to 50% anthesis, days to 50% silking, anthesis to silking interval (days), plant height (cm), ear height (cm), ear length (cm), ear girth (cm), number of kernels per row, number of kernel rows and grain yield per plant (g). The data was subjected to Xlstat and Indostat version 9.3 for statistical analysis.

Table 1: Monthly meteorological data for the cropping period (2016) recorded at the meteorological observatory of the Agricultural Research Station, Bheemarayanagudi (Karnataka)

Month	Week	Rainfall (mm)	Temperature (ºC)	
			Maximum	Minimum
March	1st week	0	36.90	21.70
	2nd week	0	39.40	21.40
	3rd week	0	40.90	22.90
	4th week	0	40.70	24.10
April	5th week	0	40.50	24.90
	6th week	0	39.00	23.70
	7th week	0	42.90	28.80
	8th week	0	43.50	25.90
	9th week	0	42.00	26.80
May	10th week	0.18	40.50	22.90
	11th week	0.36	40.70	26.30
	12th week	0.29	40.70	24.40
	13th week	0	40.10	26.90
June	14th week	1.07	39.7	23.4
	15th week	1.50	35.1	24.7
	16th week	2.25	37.2	23
	17th week	1.17	33	23.2

Results and discussion

Descriptive statistics and various genetic parameters were determined for the tested hybrids (Table 3). The results of the analysis of variance (ANOVA) for various quantitative traits of the tested genotypes are presented in (Table 4). The analysis of variance results showed that there was considerable amount of variation between the tested hybrids.

Phenotypic and genotypic variation

The phenotypic variance can be partitioned into genotypic and environmental variance which in turn helps to estimate the contribution of each of the variance components to the total variation. The minimum (4.01) and maximum (50.81) percentages of phenotypic coefficient of variation (PCV) were observed for days to silking and anthesis silking interval (ASI), respectively (Table 3). The PCV values for ASI were high indicating the phenotypic differences between the tested genotypes is considerably high (Table 3). Phenotypic coefficient of variation values for ear height, yield per plant and kernels per row were moderate (Bello *et al.,* 2012; Golam *et al.,* 2014) [6, 9]. Whereas, low values of PCV were observed for days to tasselling, days to silking, cob diameter, number of kernel rows, the results were in accordance with Reddy *et al.,* 2012 [28]. Genotypic coefficient of variation measures the genetic variability with in a character. The extent of the environmental influence on any character is indicated by the magnitude of the differences between the genotypic and phenotypic coefficients of variation. Large differences reflect high environmental influence, while small differences reveal that the influence of environment on the genetic variance is low (Manjunatha *et al.,* 2018) [19]. The very little difference between PCV and GCV of a trait indicates the possibility of genetic improvement of the respective trait. Genotypic coefficients of variability (GCV) values were low for days to tasselling, days to silking, cob length, cob diameter, number of kernel rows, kernels per row and yield per plant. The results obtained by Golam *et al.,* 2014 [9], were in accordance with that of the results in our study. Comparatively moderate to high was observed for ASI (Table 3). It reflects that the selection can be effective for these traits and also indicates the existence of substantial amount of variability, ensuring ample scope for their improvement through selection. The difference between PCV with the corresponding GCV values was relatively higher for ASI and yield per plant, indicating the higher influence of the environment on the expression of these traits. If there are small differences between the values of PCV and GCV, it indicates that there is a minimal influence of environment on the expression of these traits. In addition, it also indicates the presence of sufficient genetic variability for observed traits may facilitate the selection process. Therefore, selection based on phenotypic performance of the traits would be effective to bring considerable improvement in these traits.

Heritability and genetic advance: Heritability is the proportion of genetic variance and phenotypic variance. Knowledge about heritability of quantitative traits of a crop plant is of extreme interest to plant breeders. The heritability (%) estimates detected for the characters studied ranged between 0.18 to 0.85. High levels of heritability were estimated for days to 50% tasselling, plant height, ear height, days to 50% silking (Table 3). Similar results were obtained by Beyene (2005) and Muhammad (2009) [7, 23]. High heritability of the above traits indicates that influence of environment on these characters is negligible or low. Therefore, selection can be effective on the basis of phenotypic expression of these traits in the individual plant by implementing simple selection methods. Medium heritability was recorded for ASI, and kernels per row, which indicates that these traits were moderately influenced by environmental factors, the results were in accordance with that of Lorenzana and Bernardo, 2008 [18].

Genetic advance under selection (GA) refers to the improvement of traits in terms of its genotypic value. The genetic advance as percent of mean was high for ASI (Table 3). Genetic advance as percent of mean was moderate for plant height and ear height. In view of the fact that, high heritability does not always indicate a high genetic gain, heritability should be used together with genetic advance in predicting the ultimate effect for selecting superior varieties. In this study, high heritability and high genetic advance were recorded for ASI which could be considered as an essential trait for maize improvement by selection (Bello *et al.,* 2012) [6].

Days to 50% tasseling: The results of ANOVA showed significant differences among hybrids for days to tasseling. The critical difference was 1.66% (Table 4). Data for days to 50%tasseling ranged from 49 days to 59 days. Minimum days to 50% tasseling (49) were observed for the hybrids ZH16850 and ZH16847, while on the other hand maximum days to 50% tasseling (59) was observed for ZH16845. High broad sense heritability value of 71% was observed for this trait under heat stress environments (Table 3). Days to 50% tasseling determines the maturity duration of the crop and is an important character in maize breeding. The results obtained in this study are in correspondance to the results of Muchie and Fentie (2016) [21] who observed highly significant ($P \leq 0.01$) differences for days to tasseling in maize hybrids. Vashistha *et al.* (2013) [36] also reported highly significant ($P \leq 0.01$) differences among different maize genotypes along with high broad sense heritability value for days to 50% tasseling.

Days to 50% silking: ANOVA revealed that there are no significant differences among the various hybrids tested under heat stress for days to 50% taselling. The critical difference was 1.98% (Table 4). Days to 50% silking ranged from 52 days after owing upto 60.5 days after sowing. Different maize hybrids had great variation for this trait. Minimum days to 50% silking were observed for the hybrids ZH16847, ZH15278, ZH16870 and DKC9108 Plus. Maximum days to 50% silking were observed for ZH16845. Broad sense heritability value of 60 % was observed for this trait under heat stress environments (Table 3). Akbar *et al.* (2008) [3] observed highly significant differences among different maize hybrids along with high broad sense heritability value.

ASI (days): The results from the anova revealed no significant differences among the hybrids for this trait. The critical difference was 1.04% (Table 4). The days to 50% anthesis ranged from 0 days to 5.5 days. Minimum days to 50% anthesis were observed for ZH16841. Maximum days to 50% anthesis were observed for the hybrid ZH16846. Broad sense heritability value of 48% was observed for this trait (Table 3). Pollen grains are more sensitive to environmental stresses and they may lose their viability quickly under high temperatures coupled with drought conditions. For successful pollination there must be synchronization between pollen shedding and receptivity of silk, as it leads to increased seed set leading to higher yields. Similar results were obtained by Rahman *et al*., 2010 [27] who also reported non-significant differences for anthesis- silking interval among different maize hybrids while evaluating different maize hybrids for stability. Similar results were obtained by Ullah *et al*., 2017 [34].

Plant height (cm): The height of a plant reflects its growth behavior, besides genetic characteristics, availability of essential nutrients, space, water and environmental conditions under which it is grown determine its development. Increase in temperature affects the plant growth which ultimately influences the plant height. Plant height is an important agronomic character that plays significant role in plant lodging. Therefore, maize breeders give special attention to this character in maize breeding. Semi-dwarf plants are desired, because such plants are more resistant to lodging and are fertilizer responsive as well. Analysis of variance revealed highly significant ($P \leq 0.01$) differences for plant height among the hybrids tested. The critical difference was 10.22% (Table 4). The height of the hybrids ranged from plant height 112.5 (cm) to 180 (cm). Due to the genetic difference among different maize hybrids and varying capacities to grow in higher temperatures, there is variation in the plant height (Bakker and Van Uffelen, 1998) [4]. The hybrid that showed the least height (112.5) was ZH16855. Conversely, the tallest plants (180) were observed for the hybrid ZH15416. High broad sense heritability value (85%) was observed for this trait. Similar results were obtained by Hussain *et al*., 2016 [10] as well, indicating highly significant differences among maize hybrids and high broad sense heritability value for plant height. Muchie and Fentie (2016) [22] also obtained highly significant differences among maize hybrids and high broad sense heritability value for plant height which are in conformity to our results. Similar results were obtained by Ullah *et al*., 2017 [34] and (Saleem *et al*., 2013) [33].

Ear height (cm): Ear height is considered as one of the important character in maize hybrids. Normally as the ear height increased, it is considered to receive more photo synthates from the leaves which ultimately affects the individual grain weight and final yield of the crop. Ear height indirectly increases yield through reduction in lodging, hence an optimum ear height is always desirable. Reducing the ear height below the optimum level will decrease the yield as it gets exposed to rodent attacks in open field condition. Highly significant ($P \leq 0.01$) differences were observed among hybrids tested for ear height. The critical difference observed was 9.4%. The range for ear height was from 40 cm to 102.5 cm. The local check-2 (DKC9108 Plus) exhibited minimum ear height (40 cm), while the hybrid ZH16876 showed maximum ear height (102.5 cm). High broad sense heritability value of 73% was observed for ear height. Our results are in accordance to those of Nayaka *et al*. (2015) [24] and Ullah *et al*., 2017 [34], who also obtained highly significant differences among the different genotypes for ear height along with high broad sense heritability value.

Cob length (cm): The results from ANOVA revealed no significant differences among the hybrids for this trait. The critical difference was 1.86% (Table 4). The range for cob length was 12 (cm) to 17.5 (cm). The hybrid ZH16845 exhibited minimum cob length while the hybrid ZH16872 showed maximum cob length. A low broad sense heritability value of 29% was observed for cob length (Table 3).

Cob diameter (cm): The results from ANOVA revealed no significant differences among hybrids for this trait. The critical difference was 0.97% (Table 4). The cob diameter ranged from 10.2 (cm) to 13.3 (cm). The hybrid ZH16862 exhibited minimum cob length while ZH16851 showed maximum cob length. Very high broad sense heritability value 97% was observed for Cob diameter.

Number of kernel rows: The results from ANOVA revealed no significant differences among hybrids for this trait. The critical difference was 1.42% (Table 4). The number of kernel rows ranged from 12 to 16. The hybrids *viz*., ZH16849, ZH1685, ZH16869 exhibited least rows of kernels while, the hybrids *viz.*, ZH16844, ZH15278 showed maximum of kernels. A pretty moderate broad sense heritability value of 31% was observed for this trait.

Kernels per row: The results of ANOVA revealed no significant differences among hybrids for this trait. The critical difference was 4.2% (Table 4). The range for number of kernels per row was from 22 to 37. The hybrids *viz.*, ZH16840, ZH1688, ZH16862 exhibited minimum kernel number per row while, the hybrid ZH16865 showed maximum kernels per row. Moderate broad sense heritability value of 41% was observed for this trait.

Yield per plant (g/plant): Grain yield of a crop is the expression of combined effects of various yield related components. High temperatures may affect the pollen viability and fertilization efficiency which results in higher yield reduction in maize (Jones and Thornton, 2003; Lobell *et al.*, 2008; Rowhani *et al*., 2011) [15, 17, 31]. Highly significant ($P \leq 0.01$) differences were observed among hybrids tested for yield per plant. The range for this trait was from 51 to 92 (g/plant). The hybrid ZH16840 exhibited minimum yield per plant, while the hybrid ZH16866 showed maximum yield per plant. The value for broad sense heritability was 18%. This difference in grain yield among different hybrids might be due to their genetic variation and difference in adaptation to high temperature, which reduced the yield drastically due to its detrimental effects on metabolism and duration of phonological phases (Saini and Dadhwal, 1986; Acevedo *et al*., 1990; Jenner, 1991) [32, 1, 14].

Table 2: List of hybrids evaluated under heat stress environment

Sl. No.	Hybrid	Parentage	Sl. No.	Hybrid	Percentage
1	ZH16839	VL108844/ZL126643	27	ZH16863	VL1018794/VL1010877
2	ZH16840	VL108848/ZL126643	28	ZH16864	VL1238/VL1010877
3	ZH16841	ZL132088/ZL126643	29	ZH16865	VL1051/VL1010877
4	ZH16842	VL109126/ZL126644	30	ZH16866	ZL126643/VL1010877
5	ZH16843	VL145313/ZL126644	31	ZH16867	ZL134971/VL1010877
6	ZH16844	VL1018673/ZL126644	32	ZH16868	VL107578/VL1253
7	ZH16845	VL1051/ZL126644	33	ZH16869	VL109126/VL1253
8	ZH16846	ZL134971/ZL126644	34	ZH16870	VL1110232/VL1253
9	ZH16847	ZL134937/VL1018816	35	ZH16869	VL109126/VL1253
10	ZH16848	VL107578/VL1018816	36	ZH15416	VL145313/VL1253
11	ZH16849	VL109126/VL1018816	37	ZH16871	VL1018673/VL1253
12	ZH16850	VL1110232/VL1018816	38	ZH16872	VL1051/VL1253
13	ZH16851	VL145313/VL1018816	39	ZH16873	ZL126643/VL1253

14	ZH16852	VL1018673/VL1018816	40	ZH16874	ZL134937/VL0556
15	ZH16853	VL1018794/VL1018816	41	ZH16875	VL107578/VL0556
16	ZH16854	VL1238/VL1018816	42	ZH16876	VL109126/VL0556
17	ZH16855	VL1051/VL1018816	43	ZH16877	VL1110232/VL0556
18	ZH16856	ZL126643/VL1018816	44	ZH16878	VL145313/VL0556
19	ZH16857	ZL134971/VL1018816	45	ZH137413	VL1018673/VL0556
20	ZH1688	ZL134937/VL1010877	46	ZH137118	VL1018794/VL0556
21	ZH15279	VL107578/VL1010877	47	ZH16879	VL1051/VL0556
22	ZH15278	VL1244/VL1010877	48	ZH16880	ZL126643/VL0556
23	ZH16859	VL109126/VL1010877	49	ZH16881	ZL134971/VL0556
24	ZH16860	VL1110232/VL1010877	50	LocalCheck-1 (P1844)	
25	ZH16861	VL145313/VL1010877	51	LocalCheck-2(DKC9108 Plus)	
26	ZH16862	VL1018673/VL1010877	52	Local_Check3 (BIO9544)	

Table 3: Estimates of descriptive statistics and genetic parameters on the tested hybrids

	DT	DS	ASI	PH	EH	CL	CD	NR	KR	YPP
Mean	53.74	55.79	2.07	145.76	72.24	14.52	11.95	12.9	28.28	71.61
Min	49	52	0	112.5	40	12	10.2	12	22	51
Max	59	60.5	5.5	180	102.5	17.45	13.3	16	37	92
Range	10	8.5	5.5	67.5	62.5	5.45	3.1	4	15	41
Variance (n)	4.34	4.24	0.74	339.54	147.16	1.61	0.5	0.89	12.66	96.58
Standard deviation	2.08	2.06	0.86	18.42	12.13	1.26	0.71	0.94	3.55	9.82
Variation coefficient	0.03	0.03	0.41	0.12	0.16	0.08	0.05	0.07	0.12	0.13
Skewness	0	0.16	1.14	0.17	0.12	0.38	-0.34	0	0.25	0.08
Kurtosis	0.29	-0.25	3.99	-0.98	0.54	-0.29	-0.12	-0.13	-0.44	-0.15
SE of the mean	0.29	0.28	0.12	2.58	1.69	0.17	0.1	0.13	0.49	1.37
Broad sense heritability	0.71	0.6	0.48	0.85	0.73	0.29	0.34	0.31	0.41	0.18
Genetic advance (%)	6.14	4.97	50.86	23.13	27.30	6.56	5.15	6.22	11.99	6.94
Environment variance	2.2	2.53	36.43	4.98	9.26	9.14	5.8	4.78	10.59	16.2
Genotypic variance	3.52	3.11	35.42	12.14	15.450	5.880	4.240	5.360	8.990	7.780
Phenotypic variance	4.15	4.01	50.81	13.120	18.010	10.870	7.190	9.520	13.890	17.970

DT: Days to 50% tasseling; DS: Days to 50% silking; ASI: Anthesis silking interval; PH: Plant height; EH: Ear height; CL: Cob legth; CD: Cob diameter: NR: Number of kernel rows; KR: Kernels per row; YPP: Yiled per plant (g).

Table 4: Genotypic and Error mean square values and critical difference for various traits of the tested hybrids

	GMS	EMS	CD(5%)
DT	8.58**	1.41	1.66
DS	2.05	2	1.98
ASI	1.59	0.55	1.04
PH	680.87**	52.91	10.22
EH	294.43*	44.82	9.4
CL	3.22	1.76	1.86
CD	0.99	0.48	0.97
NR	1.98	1.03	1.42
KR	21.82	8.93	4.2
YPP	196.35*	134.37	16.29

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