Line x testers analysis of tropical maize inbred lines under heat stress for grain yield and secondary traits

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Abstract

The combining ability and mode of gene action in tropical maize germplasm is not extensively studied. In the present study, a line x tester analysis involving 290 test-cross hybrids developed by crossing 145 tropical maize inbred lines with two testers and four standard checks was conducted for grain yield and other agronomic traits under heat stress during summer 2013 at B gudi agriculture research station. The main objective of the investigation was to study mode of gene action governing the traits under heat stress along with identification of superior inbred lines based on combining ability to develop heat tolerant hybrids. Analysis of variance showed that mean squares for genotypes was highly significant for grain yield, days to anthesis and silking, anthesis silk interval, plant height and ear height under heat stress. The combining analysis for lines (GCA), tester (GCA) and line x tester (SCA) showed significant difference ($P < 0.01$) for all the traits under study except ASI for LXT interaction. This indicates that both additive and non additive gene action control the expression of these traits under heat stress. The low GCA variance to SCA variance ratio for all the traits showed preponderance of non-additive gene action in the inheritance of the traits. Among 145 inbred lines used for study, the inbreds L78, L73, and L37 showed good general combining ability for grain yield. The crosses L118 x L2 and L143 x L1 were having good specific combiners ability for grain yield under heat stress. These inbreds can be used in breeding program for development of heat tolerant hybrids through exploitation of dominant gene action.

Keywords: tropical maize, line x tester, heat stress, gene action

Introduction

Maize is queen of cereal crops due to high yielding potential and enormous genetic diversity (Prasanna, 2012). In India, maize production stands at third position, next to rice and wheat with annual production of 23 m t cultivated in an area of 9.4 m h with productivity of 2.5 t h^{-1} (India maize summit, 2014). Maize cultivation in India was severely affected by both biotic and abiotic stresses. One of the major abiotic stresses affecting maize yields in recent times is high temperatures. In general, heat stress is defined as a transient elevation in temperature, usually 10°C to 15°C above ambient temperature (Wahid et al, 2007). The optimal temperatures for growth of tropical maize is between 25°C to 33°C, while night temperatures range between 17 °C to 23°C (Ellis et al, 1992). The temperature above 35°C for a long period is considered to be unfavorable for maize cultivation and over 40°C cause irreversible damage to yield levels. According to the report of intergovernmental panel on climatic change (IPCC, 2007), the global mean temperature would rise 0.3°C per decade reaching to approximately 1°C and 3°C above the present value by years 2025 and 2100, respectively. Under high temperature above 35°C during pollination and grain filling stage, an estimated yield loss of 101 kg ha^{-1} day^{-1} was observed (Smith, 1996). Heat stress showed record drop maize production due to heat waves (Ciais et al, 2005; Van der Velde et al, 2010). If current trends persist by 2050, Maize yields may decrease by 17%, wheat by 12%, and rice by 10% in irrigated areas in South Asia because of climate change induced heat stress (IFPRI, 2009). Despite many challenges faced by maize, there is a demand of 45 million tons by 2030 for maintaining self sufficiency (DMR, 2011). To accomplish is task there is a need to develop climate resilient hybrids that can with stand extreme stresses viz., heat stress. Very little improvement was done regarding heat tolerant hybrids for tropical and sub tropical maize (Cairns et al, 2012). To withstand the extreme temperature and maintain the maize production there is a need to develop high yielding maize hybrids resilient to climatic conditions. The identification of best combiners is of foremost important step in developing hybrids. Hence, combining ability is a useful biometric tool to the plant breeders for formulating efficient breeding programs (Hallaurer and Miranda, 1981). Line x tester analysis (Kempthome, 1957) has widely been used for evaluation of inbred lines by crossing them with testers. The value of any inbred line in hybrid breeding ultimately

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Table 1 - Mean squares from line x tester analysis under heat stress for grain yield, anthesis date, silking date, anthesis silk interval, plant height and ear height of 145 inbred lines crossed to two testers.

Source of variation	Degrees of freedom	GY	AD	SD	ASI	PH	EH
Replication	1	0.41ns	43.53	35.26	1.96	7558.68**	3866.43**
Genotype	293	1.67**	18.81**	15.73**	3.90**	218.17**	125.08**
Cross	289	1.66**	18.94**	15.47**	3.77**	219.12**	125.92**
LINE	144	1.67**	29.39**	24.24**	4.80**	333.98**	176.91**
TESTER	1	28.75**	397.24**	151.06**	70.37**	384.43*	1236.99**
LXT	144	1.47**	5.85**	5.76**	2.27	103.12*	67.22**
Checks	3	2.28*	2.83ns	28.83**	16.33**	117.91ns	60.22ns
Chk vs cros	1	0.11ns	30.86**	51.59**	2.93ns	243.06ns	57.92ns
Error	293	0.70	2.77	2.73	2.64	76.98	45.52
σ^2gca		0.04	0.03	0.02	0.03	0.26	0.13
σ^2sca		0.38	1.53	1.53	-0.188	14.46	10.94
σ^2gca / σ^2sca		0.11	0.02	0.04	-0.16	0.02	0.01
CV %		24.46	2.70	2.53	45.18	7.78	11.69

depends on its ability to combine very well with other lines to produce superior hybrids. Hence, combining ability is a useful biometric tool to the plant breeders for formulating efficient breeding programs. The present study was designed to study breeding value of inbred lines and mode of gene action involved in the expression of traits under heat stress with emphasis on identification of best combiners, in development of heat tolerant hybrids for India.

Materials and Methods

The experiment was carried out at Raichur during 2013 in summer. The experimental material consist 290 hybrids developed from 145 tropical maize inbred lines test crossed to two testers CML451 and CL02450 along with four checks sown in alpha lattice design with two replications and randomized. Each plot consists of two rows with spacing of 0.75 cm x 0.25 cm, with net plot size of 4 m. The recommended cultural practices were followed during crop growth period. The following traits were recorded under heat stress condition, plant height (PH), ear height (EH), anthesis silk interval (ASI), day to 50% anthesis (AD), days to 50% silking (SD), and grain yield (GY). The estimates of general combining ability (GCA) for lines, testers and specific combining ability (SCA) for crosses were also estimated following function of Kempthorne (1957). The L x T analysis was performed using TNAUSTAT using LXTCMLTH program with checks. The weather data during crop period was presented in S1.

Results and Discussion

Analysis of variance showed that mean squares for genotypes was highly significant for traits such as grain yield, days to anthesis and silking, anthesis silk interval, plant height and ear height under heat stress. Similar reports were found by Khodarahmpour et al (2012) in maize under normal and heat stress. The mean sum of square for crosses also showed significant difference for all the traits under study, indicating that the genotypes had wide genetic diversity among themselves for all traits providing opportunity for selection. The cross vs. check found to be non significant for most studied traits except anthesis date and silking date. Among checks, significant differences were found for grain yield, silking date and ASI and non significant for EH, PH, and AD. The combining analysis for lines (GCA), tester (GCA) and line x tester (SCA) showed significant difference ($P < 0.01$) for all the traits under study except ASI for LXT interaction (Table 1). Our results were in accordance with previous results for most of the traits (Hussain et al, 2006). This indicates that both additive and non additive gene action control the expression of these traits under heat stress (Kaur et al, 2012). The variance of SCA was higher than the GCA variances for all the traits indicating preponderance of non-additive gene action in the inheritance of the traits. This fact is supported by low GCA variance to SCA variance ratio. The results were in accordance with previous results (Akbar et al, 2008). This suggests that greater importance of non-additive gene action in expression of traits and provided the opportunity for exploitation of traits in of hybrid tolerant heat stress. The proportional contribution of lines, testers and their interaction to the total variance showed that lines played an important role towards the trait indicating predominant lines influence for traits. The greater contributions of lines x testers interaction than testers for all the characters indicates higher estimates of variance due to specific combining ability (Table 2).

General combining ability (GCA) effects

The GCA effect for grain yield showed that out of 145 inbred lines used for line x tester analysis 15 inbred showed positive and significant effects, while 12 inbred lines showed negatively significant gca effect. The highly positive gca effect was shown by inbred L78 (1.64 t h^{-1}), L73 (1.31 t h^{-1}) and L37 (1.36 t h^{-1}) were best combiners for high hybrid development under heat stress. The significant negative GCA effect was observed for inbred L126 (-1.76 t h^{-1}), L12 (-1.47 t h^{-1}) and L131 (-1.43 t h^{-1}) were poor combiners (Supplementary Table 1). This indicates presences of best and poor general combiners in present investigation. Similar results were reported for grain yield (Hussain et al, 2006). The identified best inbred lines can be used in development of heat tolerant hybrids with high yielding ability. These lines show high potential to transfer desirable traits to their progenies.

Table 2 - Contribution of lines, testers, and lines x testers to the total variance for six characters under heat stress.

character	Contribution (%)		
	Line	Tester	Line x tester
GY	49.92	5.95	44.13
AD	77.34	7.26	15.43
SD	78.06	3.38	18.56
ASI	63.47	6.45	30.08
PH	75.94	0.61	23.45
EH	70.00	3.40	26.60

As expected both positive and negative GCA effects were found for anthesis and silking dates (Kaur et al, 2012). For anthesis date, 80 inbred lines showed significant positive and negative GCA effects. The lines L91, L98, and L106 showed GCA effect of -5.48 days and the inbred line L1 (-5.23 days) were considered has good general combiners for antheis date. Similarly, the lines L66, L117, and L126 were poor combiners, showing GCA effect of 5.77, 8.27, and 9.02 days respectively were poor combiner. For silking date, the lines L126 and L117 were bad combiners showing 6.94 and 7.44 days of significant positive effects. Use of these inbred lines promotes development of hybrids with long crop growth period which is not preferable under heat stress. On contrary, the L1 (-5.56 days) and L98 (-5.23 days) were good combiner showing highly significant negative values. The exploitation of this inbreds promotes early maturing hybrids with short duration. The significant GCA effects for anthesis and silking date showed 80% common inbred lines. The lines L1 and L98 were best combiners for anthesis and silking date.

The estimates of GCA effects for ASI showed 23 significant positive and negative effects, among them 11 lines showed significant positive effects with L93 (3.14 days), L36 (3.39 days) and L80 (3.39 days) were observed as poor combiners. The best combiners for reduced anthesis silk interval were L30 and L126 lines with gca effect of -2.11 days. The inbred line L48 and L141 were good combiner for grain yield and anthesis silk interval. Reduced anthesis-silking interval along with high yielding hybrids proved effective in selection for tolerant hybrids (Mhike et al, 2012). For plant height, 23 inbreds showed significant positive gca effect in L x T analysis. The inbred lines L135 (22.38 cm), L144 (24.70 cm), L67 (26.02 cm) and L94 (27.68 cm) were good combiners because under heat stress grain yield is significantly positively correlated with plant height (Khodarahmpour, 2012). Use of this trait can promote increased grain yields under heat stress. Twenty-one inbred lines showed significant and negative effects for plant height viz., L116 (-21.88 cm), L131 (-21.48 cm) and L133 (-24.48 cm) were regarded as poor combiners for plant height under heat stress. The later inbreds can be used for developing lodging resistant hybrids. Under heat stress for ear height, a total of 48 inbreds showed significant positive and negative effects, showing the presence poor and best combiners for hybrid development. The line L94 (23.13 cm), L114 (16.43 cm), L144 (15.63 cm), and L4 (13.96 cm) were good general combiners and contrarily the lines L42 (-16.04 cm), L133 (-13.94 cm), and L100 (-13.12 cm) were poor combiners.

Estimates of specific combining ability (SCA) effect

For grain yield, both negative and positive significant SCA effects were observed among the crosses. The crosses L118 x L2 and L143 x L1 were good specific combiners for yield, whereas, L118 x L1 and L143 x L2 were poor combiners under heat stress (Supplementary Table 2). Highly significant SCA effects of the crosses indicate that significant deviation from what would have been predicted based on their parental performances. The crosses with highly positive and significant estimates of SCA effect could be selected for their specific combining ability to use in maize improvement program (Abrha et al, 2013). For anthesis date, 11 significant specific crosses were identified, L117 x L2 (3.67 days) and L126 x L2 (5.92 days) were poor combiners and the cross L117 x L1 and L126 X L1 were best specific combiners for anthesis date. Days to silking an important trait showed the 8 significant SCA effects in L x T analysis. Among the significant effects, the crosses L126 x L2, L118 x L2, and L117 x L2 were poor specific combining cross and in contrary, L126 x L1, L118 x L1, and L117 x L1 good specific cross. Only one specific cross L36 x L2 for ASI was found to be best cross and poor combiner was L36 X L1. The specific combining ability for plant height showed 3 best cross L108 x L2 (12.51 cm), L105 x L2 (12.61 cm), and L7 x L1 (12.91 cm) which can be used for developing high yielding hybrids with tall stature. With respect to ear height, the crosses L117 x L1 and L71 x L2 showed positive SCA effect.

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