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Research Article

Genetic variability in heat tolerant maize (*Zea mays* L.) hybrids and their parents for yield and grain quality traits

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ABSTRACT
The present investigation was carried out to estimate genetic variability, heritability and GAM in inbred lines and hybrids. ANOVA indicated the availability of considerable variation for all the characters among inbred lines and hybrids except for ASI. PCV was higher than the GCV for all the characters. In inbred lines, important traits like plant height, number of grains per row, number of grains per cob, 1000-grain weight, grain yield per plant, dietary fibre, and β-carotene exhibited high PCV and GCV along with high heritability and GAM. Whereas, hybrids showed high values of PCV and GCV for ASI, phytic acid and high heritability coupled with high GAM were observed for traits like ASI, plant height, number of grains per row, number of grains per cob, shelling percentage, grain yield per plant, protein, dietary fibre, and β-carotene indicating the presence of variability in inbred lines and hybrids for these traits. Hence, simple selection for these traits in early generations for developing heat-tolerant maize lines can be practised.
Keywords: Heat tolerance, GCV, PCV, heritability and GAM.

INTRODUCTION
Maize (*Zea mays* L.) is an important cereal and staple food crop of the world. Maize is an important source of carbohydrates, protein, vitamins and minerals for humans and animals. The rapidly increasing human population is an alarming issue and would need more food production under changing climate. Abiotic stresses like heat stress and temperature fluctuation are becoming key issues to be addressed for boosting crop production. Grain yield losses in maize from heat stress are expected to increase owing to a higher temperature during the growing season. This situation demands the development of maize hybrids tolerant to heat stress without compromising grain yield and quality under stress conditions (Sabagh *et al*., 2020). Under the Heat Stress Tolerant Maize for Asia (HTMA) project, UAS, Raichur in collaboration with CIMMYT has identified several heat stress tolerant maize hybrids and released a heat tolerant hybrid, RCRMH 2 for cultivation in Karnataka, recently. Department of Biotechnology, UAS, Bangalore in collaboration with UAS, Raichur has also identified a few heat stress tolerant maize inbred lines. Therefore, there is a need to evaluate all these inbred lines and hybrids for grain yield and quality traits and to identify the superior inbred lines and hybrids for grain yield and quality traits and their specific utilization.

Genetic variability is a pre-requisite and important tool of any breeding programme. It provides not only the basis of selection but also some valuable information regarding the selection of diverse parents for use in the hybridization programme. Heritability is the most important among the parameters as this will provide information on whether the trait is genetically inherited or influenced by the environment and how this can be improved. Burton (1952) suggested that the genetic components of variation together with heritability estimates would give the best picture of the amount of genetic advance to be expected from the selection. Many reports on estimates of genetic variability are available in maize information on released genotypes is limited. Hence the present study was planned to determine the estimates of variability, heritability and genetic advance as a per cent of the mean for yield and grain quality traits.

MATERIALS AND METHODS

The experiment was carried out during *Kharif* 2019 at Main Agricultural Research Station, Raichur. Experimental material for the present investigation comprised 14 hybrids and three commercial checks and 21 inbred lines and two testers which were obtained from the College of Agriculture, Bheemarayanagudi. The inbred lines used in this study are parental lines of hybrids allocated to UAS, Raichur by CIMMYT. Two separate experiments were laid out in RBD with two replications. Each entry was grown in two rows of 4.0 m in length at a spacing of 60 cm between rows and 20 cm within rows. From each row two plants which are of equal height were selected for manual selfing to develop pure parental seed for assessing quality traits. The selfing process includes bagging of silk, tassel and hand pollination.

The data on morphological traits like Days to 50 % anthesis, Days to 50 % silking, Anthesis to Silking Interval (ASI), Plant height (cm), Ear height (cm), Number of grains per row, Number of grains per cob, Shelling percentage, 1000-grain weight (g) and Grain yield kg/ha were recorded on five randomly selected plants per entry per replication except days to 50 % tasselling and days to 50 % silking which were recorded on plot basis and quality traits like Protein (%), Carbohydrate (%), Dietary fibre (g), β-carotene (mg), Phytic acid (mg) were estimated from seeds obtained from self-pollinated plants and characters were analyzed to estimate genetic variability parameters. Genetic variability was measured and subjected to statistical analysis as suggested by Robinson *et al.* (1949). Heritability (broad sense) and Genetic Advance as a per cent of Mean (GAM) were worked by following the method suggested by Robinson *et al.* (1949) and Johnson *et al.* (1955), respectively.

RESULTS AND DISCUSSION

In the present investigation, analysis of variance indicated that the mean sum of square due to inbred lines and hybrids exhibited significant variation among inbred lines and hybrids for all the characters except ASI indicating the existence of a high level of variability for these traits among inbred lines and hybrids and the possibility of selection of traits of interest. The results of the analysis of variance for 15 characters in maize inbred lines and hybrids are presented in Table 1 and Table 2, respectively.

The mean performance, range, variability, heritability and GAM for yield, yield attributing and grain quality traits across inbred lines and hybrids are presented in Table 3 and Table 4, respectively. It is evident from both tables that the magnitude of PCV was higher than that of the GCV for yield, yield attributing and grain quality traits indicating the larger influence of environment for the expression of these characters which is similar to the study made by Sharma *et al*. (2014). In inbred lines, the values for PCV obtained for different characters ranged from 3.10 % for carbohydrates to 45.90 % for β-carotene and the values for GCV ranged from 2.87 % for carbohydrates to 40.16 % for β-carotene. The PCV and GCV values were high for ASI, plant height, ear height, number of grains per row, number of grains per cob, 1000-grain weight, grain yield per plant, dietary fibre, β-carotene and phytic acid. It indicates the presence of a considerable level of observable variation among the inbred lines for a trait and suggests that the selection based on this trait would facilitate the successful isolation of desirable types with high grain yield. Similar results were observed by Gazala *et al.* (2017). Low PCV and GCV were recorded for days to 50 % anthesis, days to 50 % silking, shelling percentage, protein and carbohydrate indicating the presence of less variability among inbred lines for these traits. Similar results were observed by Sharma *et al*. (2016).

In hybrids, the values for PCV obtained for different characters ranged from 3.58 % for carbohydrates to 26.72 % for ASI and the values for GCV ranged from 3.26 % for carbohydrates to 22.54 % for phytic acid. The PCV and GCV values were high for ASI and phytic acid. Low PCV and GCV were observed for traits like days to 50% anthesis, days to 50% silking, ear height, shelling percentage and carbohydrate. This indicates that there is a need to create variability for these traits among hybrids. Similar results were observed by Prakash *et al*. (2016) and Ogunniyan and Olakojo (2014).

In inbred lines, estimates of heritability ranged from 50.1 % for days to 50 % anthesis to 98.6 % for plant height and estimates of GAM ranged from 5.48 % for carbohydrate to 77.86 % for grain yield per plant. High heritability along with high GAM was observed for traits like ASI, plant height, ear height, number of grains per row, number of grains per cob, 1000-grain weight, grain yield per plant, dietary fibre and β-carotene which indicated that these traits were governed by additive gene action and least influenced by environmental factors and more valuable in predicting the effect of selection. Similar kind of observations was made by Bharathiveeramani *et al.* (2012) and Sandeep *et al.* (2013). High heritability and moderate GAM were observed for protein while, high heritability and low GAM were observed for days to 50 % silking, shelling percentage and carbohydrate indicating the involvement of non-additive gene action in the expression of the trait. The high heritability exhibited was due to the favourable influence of environment rather than genotypes and further suggesting the importance of dominance and epistatic effects in the inheritance of the trait and selection would be less effective. Low heritability and high GAM were observed for phytic acid. Low heritability and low GAM were observed for days to 50 % anthesis.

In hybrids estimates of heritability ranged from 33.2 % for phytic acid to 98.4 % for dietary fibre and estimates of GAM ranged from 5.97 % for 1000-grain weight to 33.94 % for several grains per row. High heritability coupled with high GAM was observed for traits like ASI, plant height, number of grains per row, number of grains per cob, shelling percentage, grain yield per plant, protein, dietary fibre and β-carotene indicating that the genetic variance for these traits is probably owing to their high additive gene effects and thus there is a better scope for improvement of these traits through direct selection. Similar results were observed by Sumathi *et al.* (2005) and Nataraj *et al*. (2014).

Table 1. Analysis of variance for yield, yield attributing and grain quality traits in maize inbred lines.

Source of variation	Df	Days to 50% anthesis	Days to 50% silking	Anthesis to silking interval	Plant height	Ear height	Number of grains per row	Number of grains per cob	Shelling percent	1000-grain weight	Grain yield per plant
Replication	1	2.63	4.26	0.08	157.06	38.34	11.50	13982.70	27.70	6528.34	9.86
Treatment	22	30.74**	22.96**	2.40	2372.75**	621.12**	154.33**	37755.01**	33.88**	8194.52**	639.76**
Error	22	10.22	5.71	0.99	16.97	21.48	5.04	3768.55	3.77	938.25	23.86

** Significant at 1% level (P = 0.01)

Table 1. Contd….

Source of variation	Df	Protein	Carbohydrate	Dietary fiber	β-Carotene	Phytic acid
Replication	1	1.43	4.86	0.06	0.04	0.12
Treatment	22	1.38**	7.63**	1.62**	1.11**	5.09**
Error	22	0.33	0.59	0.07	0.14	1.16

** Significant at 1% level (P = 0.01)

Table 2. Analysis of variance for yield, yield attributing and grain quality traits in maize hybrids

Source of variation	Df	Days to 50% anthesis	Days to 50% silking	Anthesis to silking interval	Plant height	Ear height	Number of grains per row	Number of grains per cob	Shelling percent	1000-grain weight	Grain yield per plant
Replication	1	0.03	0.47	0.11	0.47	24.73	10.61	1972.97	0.015	2863.05	19.88
Treatment	16	22.55**	20.94**	0.99	1034.37**	153.52**	93.86**	17388.31**	19.07**	5581.99**	595.68**
Error	16	3.37	3.78	0.24	37.53	8.86	8.11	3425.09	3.46	743.12	14.81

** Significant at 1% level (P = 0.01)

Table 2. Contd….

Source of variation	Df	Protein	Carbohydrate	Dietary fiber	β-Carotene	Phytic acid
Replication	1	0.0049	4.44	0.001	0.001	0.188
Treatment	16	3.001**	10.83**	1.285**	0.462**	7.179**
Error	16	0.260	1.02	0.010	0.082	0.658

** Significant at 1% level (P = 0.01)

Table 3. Genetic variability parameters for yield, yield attributing and grain quality traits in maize (*Zea mays* L.) inbred lines.

Sl. No.	Character	Mean ± SE	Range		Coefficient of variation		h^2 (%) (Broad sense)	GAM (5%)
			Minimum	Maximum	PCV (%)	GCV (%)		
1	Days to 50% anthesis	57.15 ± 2.26	48.50	63.50	7.91	5.60	50.1	8.17
2	Days to 50% silking	59.87 ± 1.69	52.50	65.50	6.32	4.90	60.1	7.83
3	Anthesis to silking interval	3.26 ± 0.70	1.50	6.00	39.98	25.72	62.4	34.09
4	Plant height (cm)	168.41 ± 2.91	108.00	245.50	20.52	20.37	98.6	41.68
5	Ear height (cm)	80.30 ± 3.27	54.50	106.00	22.32	21.56	93.3	42.90
6	Number of grains per row	25.15 ± 1.58	10.00	38.00	35.49	34.35	93.7	68.48
7	Number of grains per cob	336.56± 43.40	105.00	580.50	42.81	38.73	81.8	72.18
8	Shelling percentage	78.10 ± 1.37	71.95	84.93	5.55	4.96	80	9.15
9	1000-grain weight (g)	289.47 ±21.65	185.00	411.00	23.34	20.80	79.5	38.20
10	Grain yield per plant(g)	44.72 ± 3.45	21.25	76.25	40.72	39.23	92.8	77.86
11	Protein (%)	9.53 ± 0.41	7.94	11.35	9.75	7.60	60.7	12.20
12	Carbohydrates (%)	65.25 ± 0.54	61.79	69.38	3.10	2.87	85.6	5.48
13	Dietary fiber (g/100g)	4.06 ± 0.19	2.07	5.30	22.71	21.65	90.9	42.52
14	β-carotene (mg/100g)	1.73 ± 0.27	0.29	3.00	45.90	40.16	76.5	72.38
15	Phytic acid(mg/100g)	5.08 ± 0.76	1.93	8.89	34.77	27.52	52.7	44.88

Table 4. Genetic variability parameters for yield, yield attributing and grain quality traits in maize (*Zea mays* L.) hybrids.

Sl. No.	Character	Mean ± SE	Range		Coefficient of variation		h^2 (%) (Broad sense)	GAM (5%)
			Minimum	Maximum	PCV (%)	GCV (%)		
1	Days to 50% anthesis	50.82 ± 1.29	43.00	56.00	7.08	6.09	74.1	10.79
2	Days to 50% silking	53.76 ± 1.37	47.00	59.50	6.54	5.44	69.4	9.35
3	Anthesis to silking interval	2.94 ± 0.34	2.00	4.00	26.72	20.82	60.7	33.42
4	Plant height (cm)	206.17 ± 4.33	153.00	215.00	11.22	10.82	93	21.51
5	Ear height (cm)	96.97 ± 2.10	83.00	115.00	9.29	8.77	89.1	17.05
6	Number of grains per row	36.44 ± 2.01	26.50	46.00	19.59	17.96	84.1	33.94
7	Number of grains per cob	595.20 ± 41.38	340.50	731.00	17.13	14.03	67.1	23.06
8	Shelling percentage	80.23 ± 1.31	75.18	86.90	4.18	3.48	69.3	25.82
9	1000-grain weight (g)	343.17 ± 19.27	256.00	420.00	16.38	14.33	76.5	5.97
10	Grain yield per plant(g)	153.0 ± 2.72	121.50	185.00	11.41	11.13	95.1	22.38
11	Protein (%)	9.49 ± 0.36	7.75	11.65	13.45	12.33	84	23.29
12	Carbohydrates (%)	67.95 ± 0.71	62.42	71.60	3.58	3.26	82.7	6.10
13	Dietary fiber (g/100g)	6.25 ± 0.07	4.80	7.70	12.87	12.77	98.4	26.10
14	β-carotene (mg/100g)	2.55 ± 0.20	1.77	3.46	20.41	17.06	69.8	29.37
15	Phytic acid(mg/100g)	8.01 ± 0.57	4.75	11.19	24.71	22.54	33.2	12.35

High heritability coupled with moderate GAM was observed for traits like days to 50 % anthesis and ear height indicating that the improvement of these traits is possible only through direct and restricted selection. High heritability with low GAM was observed for traits like days to 50 % silking, 1000-grain weight and carbohydrate content. This indicates that the predominance of non-additive gene action and hence an improvement of such trait is complicated. Similar results were observed by Lal and Singh (2014). Moderate heritability with moderate GAM was observed for traits like phytic acid which indicates that intermediate expression of both additive and dominant gene effects.

CONCLUSION

It can be concluded that in inbred lines important traits like plant height, number of grains per row, number of grains per cob, 1000-grain weight, grain yield per plant, dietary fibre and β-carotene exhibited high PCV and GCV along with high heritability and GAM and in hybrids, PCV and GCV values were high for ASI, phytic acid and high heritability coupled with high GAM were observed for traits like ASI, plant height, number of grains per row, number of grains per cob, shelling percentage, grain yield per plant, protein, dietary fibre and β-carotene. This shows the presence of considerable variation among the inbred lines and hybrids for these traits and the possibilities of improvement of these traits through selection.

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