Maize Journal (October 2022) 11(2): 117-128

RESEARCH PAPER

Genetic analysis of variability and trait association in tropical field corn (*Zea mays* L.)

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Abstract: Grain yield is a complex trait influenced by environment and yield components. Hence, the information on the extent of variability in different traits and on association of yield with its components is useful for breeding for higher yield. Present study was carried out to investigate the nature and magnitude of genetic variability, heritability, genotypic and phenotypic correlations among grain yield components and their direct and indirect effects on grain yield of maize in two seasons-*kharif* and *rabi*. In *kharif*, a total of 170 genotypes (54 lines, 2 testers, 108 single cross hybrids and 6 checks) and in *rabi* 110 genotypes (34 lines, 2 testers, 68 single cross hybrids and 6 checks) were evaluated in latice design. The analysis of variance revealed significant mean sum squares due to genotypes for all the traits implying the existence of sufficient genetic variability among the inbreds. The presence of variability for various traits was also revealed by Phenotypic and Genotypic Coefficient of Variation (GCV and PCV) for different traits. Grain yield recorded GCV and PCV of 39.81 & 25.89% and 40.41 & 28.72% during *kharif* and *rabi*, respectively. Hence, there is possibility of selection of inbreds with higher performance for various traits. Correlation analysis revealed significant positive genotypic correlation (p = 0.01) of yield with plant height (rg = 0.97 and 0.83), ear height (rg = 0.98 and 0.82), cob length (rg = 0.91 and 0.71) and number of kernels per row (rg = 0.94 and 0.73) during *kharif* and *rabi*, respectively. The results of path coefficient analysis revealed that most of the characters studied had positive direct effects on grain yield. During *kharif* cob length (2.028), kernel row number (0.341) and hundred seed weight (0.126) had positive direct effect on grain yield. In *rabi*, cob width (0.578) had maximum direct effect on grain yield followed by ear height (0.461), cob length (0.412), and plant height (0.146). The results of variability analysis read with the results of trait association implied that there is possibility of improvement of yield and yield components in the material studied and the significant positive association meant that combination of traits could be improved simultaneously.

Keywords: Maize · PCV · GCV · Heritability · Correlation · Path analysis

Introduction

Maize (*Zea mays* L.) ranks third in India after wheat and rice among the food crops. It is the most versatile, photo-insensitive and widely adapted crop. It is the only food cereal crop that can be grown in diverse seasons, ecologies and with diverse uses. Maize can be used as food, feed and industrial raw material. Despite the efforts to improve productivity of maize, its average productivity in India (3.20 t ha^{-1}) is far below the world average (5.81 t ha^{-1}) (Anonymous, 2021). Therefore, there is lot of scope for enhancement of maize productivity in India through appropriate breeding strategies.

Breeding is a continuous process as the ever burgeoning population demands progressive genetic gain in the traits of economic importance. Therefore, the main goal of any breeding programme is to develop new genotypes that outperform the existing ones with respect

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Received: 10 July 2022/ Accepted: 17 September 2022

to the target traits. Plant breeding programmes lay special emphasis on grain yield as it is one of the most essential trait for national food security. However, yield is a complex quantitative trait influenced by many component traits and environmental factors and hence, breeding for grain yield becomes a challenge. Moreover, the maize yield levels have attained a kind of plateau as a result of previous breeding efforts that have exploited major chunk of genetic variability in developing the excellent cultivars. Now there is a need to devise new strategies and to find the most important contributing traits (Belay, 2018). It is been long reported that the improvement in most significant component traits lead to increase in grain yield. Hence, There is an urgent need to focus on component traits along with grain yield in maize to achieve greater genetic gain in maize (Mohammadi *et al*., 2003). Therefore it is vital to identify the traits that have predominant role in enhancing grain yield through analysis of interrelationships, which will help in practicing direct and indirect selections to boost maize productivity.

Genetic improvement in economically important traits along with maintaining sufficient amount of variability is always the desired objective in maize breeding programme (Ahmed *et al*., 2011). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are useful is determining the amount of variability present in a given character. Heritability and genetic advance (GA) of individual trait helps to find the efficiency with which genotypic variability can be exploited by selection (Bilgin *et al*., 2010). The estimates of genetic parameters like heritability and genetic advance provides the information on the nature of the gene action involved in the control of quantitative traits and help to evaluate the efficiency of different breeding strategies to obtain genetic gains (Vashistha *et al*., 2013). Heritability is a measure of the phenotypic variance attributable to genetic causes and it aids in determining the breeding scheme for the trait improvement. Genetic advance shows the degree of gain obtained for the characters under a particular selection pressure (Niji, 2018).

The knowledge of interrelationships between grain yield and its components improves the efficiency of breeding programs through the use of appropriate selection indices (Belay, 2018). Correlation coefficient quantifies the mutual association between a pair of variables independent of other variables to be considered. If there is positive association of yield with one or more component traits, indirect selection for such traits can be practised and simultaneous selection of yield and component traits would be effective (Prasad and Shivani, 2017). However, negative association would make it difficult to exercise simultaneous selection for such characters for varietal development (Prasad and Shivani, 2017). It must be noted that the correlation provides an over all association of a component trait with the grain yield. This association consists of direct and indirect effects of component traits. Therefore, partitioning of correlation into direct and indirect effects would help in better understanding of the interrelationships, This can be done through path analysis which portions the correlation coefficient into direct and indirect effects of various traits on dependent variable. This helps in determining the cause- effect relationship and to identify the traits with significant effects on yield to be used as selection criteria. Keeping these in mind, present study was undertaken to investigate genetic variability, heritability, genetic advance, phenotypic and genotypic correlations between grain yield and other traits and determining the direct and indirect effects of morphological traits on grain yield.

Materials and methods

The basic material for the study included 54 inbred lines of maize selected from the newly developed tropical germplasm lines of ICAR-IARI's Regional Research Centre, Dharwad and 2 testers (LM-13 and LM-14) (Table 1). One hundred and eight single cross hybrids obtained from line × tester design (54 lines × 2 testers) were evaluated along with 56 (54 lines and 2 testers) parents and six checks viz., Bio-605 (National check), Bio-9544 (National check), NK-6240 (national check), 900M Gold (popular check), PMH-1 (hybrid between testers) and DKC-9178 (private check), using alpha lattice design.

The study was conducted in two seasons, *kharif* 2021 and *rabi* 2021. In *rabi*, 34 best lines were selected based on *kharif* performance and their crosses along with 6 checks (total of 110 genotypes) were evaluated using alpha lattice design with two rows of 3mlength in two replications. The field was divided into 11 blocks and each block had 10 entries. The plot size was 3.6 m^2 with spacing of 60cm x 20cm.

After thorough land preparation, sowing was done by hand dibbling of seeds with one seed per hill. The

Table 1. List of of the genotypes used in the experiment*

S.No.	Inbred	Source
1	BGD-48Y	IARI RRC, Dharwad
2	BLSB-7	
3	C-12	
4	C-14	
5	C-23	
6	C-2760	
7	C-2765	
8	C-67	
9	C-74	
10	C-78	
11	C-79	
12	C-83	
13	CDM-105	
14	CML-435	CIMMYT
15	CML-582	
16	D-2282_1	IARI RRC, Dharwad
17	DIM-204 B	
18	DT-2	
19	DT-5 _1	
20	GC-3	
21	JK-1553	
22	JK-1800	
23	JK-370	
24	MG-22	
25	PDM-10	IARI, New Delhi
26	PDM-6554	
27	PML-18 B	
28	PML-25	
29	PML-54	
30	TC-12	
31	UMI-1210	
32	BLSB-2 B	
33	PDM-6552	
34	PRJ-37	
35	C-11	IARI RRC, Dharwad
36	C-25	
37	C-30	
38	C-62	
39	C-8	
40	CML-565	CIMMYT
41	DDM-313	IARI RRC, Dharwad
42	DIM-316	
43	G-40	
44	KRN-114	
45	MG-50	IARI, New Delhi
46	PDM-134	
47	PDM-59	
48	PDM-6555	
49	PML-102 _1	
50	PML-45	
51	PML-46 _1	
52	PML-50	
53	PML-54-3	
54	PML-73	
55	LM-13	Tester1
56	LM-14	Tester2
Check		
C1	900M GOLD	Private check
C2	Bio-605	Early Check
C3	Bio-9544	Medium Check
C4	DKC-9178	Private check
C5	NK-6240	Late check
C6	PMH-1	Late check

*Also 108 hybrids derived from 54 x 2, L x T crosses were included. (listed in mean performance Table 2)

recommended dose of fertilizers (150 N, 75 P_2O_5 and 37.5 K_2O kg/ha) was given to the crop. The entire dose of P_2O_5, K_2O and one third of nitrogen was applied as basal dose and remaining two third of nitrogen was top dressed in two equal splits at fourth and seventh week after planting. Weeding, irrigation and other recommended cultural practices were followed to raise a healthy crop.

The observations were recorded from four randomly selected plants for plant height, ear height, number of kernel rows per cob (KRN), number of kernels per row (NK), cob girth (CG) and cob length (CL). Days to 50% flowering was recorded on whole plot basis. Hundred seed weight (HSW) was recorded in grams by weighing hundred seeds which were randomly selected. Grain yield (GY) was calculated using the whole plot yield and was converted to tonnes per hectare.

The various genetic parameters were estimated following the standard procedures reported earlier. The phenotypic and genotypic coefficients of variation (Burton and De Vane 1953), heritability (in the broad sense) (Lush, 1949 and Hanson *et al.*, 1956), genetic advance and genetic advance as per cent of mean (Johnson *et al.*, 1955) were computed.

Data from each season was subjected to ANOVA separately to know the significant genotypic differences. Correlation coefficients between different traits were determined as described by Singh and Chaudhary (1979). Path coefficients were determined following the method suggested by Dewey and Lu (1957). Data were analyzed using statistical packages *viz*., INDOSTAT (version 9.2) and MS-excel at the Department of Genetics and Plant Breeding, UAS, Dharwad.

Results

Mean performance of parents, hybrids and checks during *kharif* and *rabi* are presented in Table 2 and 3 respectively. During *kharif*, grain yield of the hybrids ranged from 5.6 to 12.85 t ha^{-1}. Out of 108 single cross hybrids, DDM-313 x LM-14 recorded highest yield of 12.85 t ha^{-1} followed by PML-25 x LM-14 (12.7 t ha^{-1}), PML-54-3 x LM-13 (12.55 t ha^{-1}). Inbred line PDM-134 recorded highest yield of 10.4 t ha^{-1} and TC-6 recorded lowest yield of 1.8 t ha^{-1}. Among checks, DKC-9178 recorded highest yield of 10.43 t ha^{-1}.

During *rabi*, among the sixty-eight cross combinations evaluated for grain yield, the test hybrid C-79 x LM-13 (10.06 t ha^{-1}) recorded the highest grain yield followed by C-78 x LM-13 (9.67 t ha^{-1}) and DT-2 x LM-13 (9.1 t ha^{-1}). However, the range varied from 4.23 to 10.06 t ha^{-1} and overall mean was 6.88 t ha^{-1}. JK-1553 recorded lowest (3.17 t ha^{-1}) and C-78 recorded highest (5.48 t ha^{-1}) yield among the lines. Similarly, in the checks; NK-6240 recorded the highest grain yield with mean of 7.46 t ha^{-1}.

The analysis of variance for all the 11 characters during *kharif* and *rabi* is presented in Table 4. The variance among genotypes was highly significant for all the traits *viz*., days to 50 per cent tasseling, days to 50 per cent silking, plant height (cm), cob girth (cm), number of kernel rows per cob, number of kernels per row, ear height (cm), cob length (cm), shelling percentage, hundred grain weight (g) and grain yield (t ha^{-1}).

Genetic variability

The ANOVA for *kharif* and *rabi* revealed significant sum of squares due to genotype (Table 4). The GCV values were lower than PCV values for all the traits during both the seasons (Table 5). The GCV and PCV values ranged from less than 10% to more than 20% for different traits. Grain yield recorded GCV and PCV of 39.81 & 25.89% and 40.41 & 28.72% during *kharif* and *rabi*, respectively. However, GCV and PCV were low for characters like shelling percentage (5.44, 3.08 and 7.00, 4.46), days to 50% tasseling (5.61, 4.21 and 6.25, 7.20) and days to 50% silking (5.36, 4.50 and 6.11, 7.29) during *kharif* and *rabi*, respectively. Hundred seed weight and kernels per row showed higher GCV and PCV during kharif and moderate during rabi. Whereas, cob width showed higher GCV and PCV during *kharif* and during *rabi*. The remaining traits had either lower GCV and moderate PCV or moderate GCV and higher PCV.

Heritability and genetic advance

The heritability of more than 66% was recorded for grain yield (97.07 & 81.29) and hundred seed weight (93.66 & 66.75) during *kharif* and *rabi*, respectively. The rest of the traits showed intermediate to higher values of heritability (Table 5). The least genetic advance as percent of mean (GAM) was observed for shelling percentage (8.70, 4.39) followed by days to 50% silking (9.71, 5.71) during *kharif* and *rabi*, respectively. Kernel row number showed intermediate (10.82, 17.32) and other traits like grain yield (80.81, 48.09), hundred seed weight (43.67, 23.41), plant height (24.99, 33.48), ear height (33.39, 41.17) recorded higher estimates of GAM in both seasons while kernels per row (35.40, 16.43), cob width (34.25, 14.55) and cob length (21.84, 15.88) showed variation in GAM between the season.

ANOVA for Line x Tester analysis during kharif and rabi 2021

Results of ANOVA of L x T for yield and yield related traits during *kharif* and *rabi* are presented in Table 6, which showed significant mean sum of squares due to lines, testers and crosses. During *kharif*, mean sum of squares (MSS) due to lines were significant for days to 50% flowering, ear height, kernel row number, hundred seed weight and grain yield and MSS due to testers was significant for most of the traits except days to 50% flowering, cob length, shelling percentage and hundred seed weight. The MSS due to crosses was significant for all traits except plant and ear height, cob length and kernel row number. During *rabi*, MSS due to lines and cross were significant for all

Table 2. Mean performance of Top 10 parents and hybrids during *kharif* 2021

S.No.	Genotype	DFT	DFS	PH	EH	CL	CW	KRN	KPR	HSW	SP	GY
	Parent											
1	PDM-134	58	60	205.3	96.5	16.7	4.5	13.6	31.6	37.0	73.7	6.4
2	PML-18 B	57	56	229.6	105.4	16.2	4.4	15.1	33.4	38.0	74.0	6.3
3	PML-46 _1	62	65	183.1	79.4	12.8	4.0	12.0	19.5	33.5	70.1	5.9
4	C-25	54	56	130.0	50.0	12.8	3.7	12.7	17.3	25.0	64.6	5.6
5	C-79	61	63	148.1	82.0	12.7	4.6	14.7	23.0	26.5	64.8	5.5
6	BGD-48Y	55	57	181.9	69.4	16.8	3.7	12.7	31.0	22.0	76.5	5.1
7	C-78	61	61	153.8	69.8	14.2	3.7	13.0	23.8	22.0	71.4	5.0
8	PML-73	62	64	134.4	64.4	10.8	4.2	16.0	20.7	23.5	68.3	4.9
9	PML-102 _1	53	55	174.6	78.8	12.0	4.2	12.0	20.8	41.5	74.5	4.8
10	LM-14	57	59	174.4	75.0	14.0	4.0	12.0	20.5	28.0	79.4	4.7
	Hybrid											
1	DDM-313 x LM-14	57	59	207.5	85.6	18.8	4.9	15.3	36.0	36.0	78.2	12.9
2	PML-25 x LM-14	59	62	228.8	103.1	16.9	4.5	13.7	31.7	40.0	76.1	12.7
3	PML-54-3 x LM-13	54	56	228.8	107.5	18.3	4.9	15.7	35.7	32.0	77.0	12.6
4	PML-45 x LM-13	58	60	224.4	98.1	18.9	4.6	13.3	36.0	37.5	75.9	12.4
5	PML-54-3 x LM-14	54	57	209.1	116.9	17.6	4.9	15.3	39.5	32.0	75.2	12.4
6	C-78 x LM-14	57	59	216.3	103.1	19.5	4.8	14.7	40.0	37.0	75.3	12.2
7	GC-3 x LM-14	54	57	211.3	91.3	17.9	5.0	14.0	32.8	39.5	70.3	12.2
8	PML-46 _1 x LM-14	54	56	211.3	97.5	19.9	4.7	13.3	39.8	34.5	75.5	12.2
9	PML-45 x LM-14	56	59	210.9	103.8	19.0	4.8	14.0	35.7	37.5	76.0	12.1
10	CML-582 x LM-14	57	59	223.8	100.6	14.6	4.8	14.3	24.7	36.5	76.5	11.9
	Checks											
1	900M GOLD	57	59	202.3	88.6	16.6	4.6	14.0	33.8	33.0	76.0	9.4
2	Bio-605	53	56	203.8	93.1	18.4	4.7	15.3	36.4	33.3	71.2	8.8
3	Bio-9544	56	58	190.8	86.3	17.3	4.5	13.9	34.0	34.8	79.6	8.2
4	DKC-9178	57	59	213.6	92.8	17.4	4.6	13.8	33.5	35.1	74.1	10.4
5	NK-6240	63	65	158.1	68.8	10.8	4.3	17.0	21.3	21.0	71.9	4.8
6	PMH-1	53	55	166.9	68.1	14.7	4.8	15.7	27.5	26.5	70.7	3.7
	CD (5 %)	9.54	9.61	17.6	9.7	3.08	0.48	1.78	8.72	5.23	4.83	1.19
	CD (1 %)	12.8	12.89	23.62	13.01	4.13	0.64	2.38	11.69	7.01	6.49	1.6
	CV (%)	6.46	6.32	6.08	6.61	11.29	6.47	6.2	17.43	3.52	11.26	12.96

DFT: Days to 50% tasseling; CG: Cob girth; GY: Grain yield; CL: Cob length
DFS: Days to 50% silking; KRN: Kernel row number; HSW: Hundred seed weight; EH: Ear height
PH: Plant height; NK: Number of kernels per row; Shelling %: Shelling percentage

the characters studied and MSS due to testers was significant for traits like cob width, kernel row number, hundred seed weight and grain yield.

Correlation among grain yield and other traits during kharif and rabi

The genotypic and phenotypic correlation for the traits considered during *kharif* and *rabi* are represented in Table 7 and Table 8, respectively. The results indicated that genotypic correlation was higher than phenotypic correlation for all the traits in both the seasons. In *kharif*, significant positive correlation coefficients were recorded for grain yield with plant height (rg = 0.972), ear height (rg = 0.98), cob length (rg = 0.91), number of kernels per row (rg = 0.937), hundred seed weight (rg = 0.835) and shelling percentage (rg = 0.684). While significant negative correlation was observed between grain yield

Table 3. Mean performance of genotypes for different traits during *rabi* 2021

S.No.	Parent	DFT	DFS	PH (cm)	EH (cm)	CL (cm)	CG (cm)	KRN	NK (per row)	Shelling (%)	HSW (g)	GY
1	LM-14	67	71	164.06	87.97	12.85	3.71	15.08	23.46	74.31	21.25	5.49
2	C-78	67	69	168.75	88.13	16.08	4.08	15	29.33	73.08	24.5	5.48
3	BGD-48Y	70	72	150	80.63	18.15	3.22	12.67	32.67	70.78	17.5	5.3
4	C-14	78	80	162.5	85.63	14.08	3.67	13.33	27.83	74.19	22.5	5.26
5	LM-13	77	79	164.22	79.06	13.4	3.65	13.33	22.71	74.4	29.25	4.94
6	PDM-6554	71	73	131.88	67.5	13.58	3.73	14.33	27.5	72.12	20.5	4.78
7	PDM-10	71	73	135.63	66.88	15.42	3.77	16.33	31.67	79.03	15	4.72
8	DT-2	70	68	126.88	53.75	16	3.48	13.33	31.17	71.29	23	4.69
9	GC-3	76	79	128.13	54.38	15.17	3.48	12.67	22.67	74.68	23.5	4.62
10	JK-1800	63	64	117.5	56.25	14	3.7	11.67	29.17	76.53	25.5	4.61
	Hybrid											
1	C-79 x LM-13	66	68	219.4	123.8	15.8	4.6	15.0	26.3	73.1	33.0	10.1
2	C-78 x LM-13	65	66	217.5	123.1	18.5	4.4	14.3	34.0	75.4	30.5	9.7
3	DT-2 x LM-13	69	69	198.8	105.6	16.2	4.2	15.0	30.0	79.7	23.5	9.1
4	PDM-10 x LM-13	70	72	199.4	115.6	17.3	4.2	15.3	34.2	80.0	24.5	9.1
5	C-2765 x LM-13	64	66	213.8	108.8	16.4	4.2	13.0	35.0	77.8	29.5	8.9
6	PDM-6554 x LM-14	65	67	208.8	116.3	16.5	4.3	15.7	28.2	71.2	24.5	8.9
7	C-14 x LM-13	72	75	218.1	120.0	17.2	4.1	13.0	33.2	77.2	28.5	8.6
8	C-67 x LM-13	70	72	216.9	118.1	14.7	3.7	14.3	28.8	75.5	25.5	8.5
9	C-78 x LM-14	72	74	204.4	119.4	18.7	4.5	16.0	35.2	76.5	25.5	8.2
10	C-2760 x LM-14	70	72	197.5	123.1	15.2	4.3	15.3	29.0	78.0	26.0	8.1
	Checks											
1	Bio-605	63	65	210.0	112.5	15.2	4.3	15.8	30.2	80.2	25.5	5.8
2	Bio-9544	70	72	186.6	116.3	14.5	4.0	14.7	32.1	78.1	22.5	6.6
3	NK-6240	73	74	194.1	116.3	15.5	4.3	15.0	27.6	77.2	26.5	7.5
4	900M-gold	72	75	203.8	119.1	14.1	4.5	16.3	29.5	77.1	22.5	6.8
5	PMH-1	71	73	203.44	115	14.58	4.01	16	25.33	74.57	24.75	5.83
6	GH-150125	73	77	203.13	98.13	16.92	4.42	14	27.68	74.26	25	5.89
	CD (5 %)	7.07	7.33	24.23	20.51	2.85	0.34	1.6	7.77	4.33	4.43	1.59
	CD (1 %)	9.4	9.74	32.19	27.24	3.78	0.45	2.13	10.32	5.75	5.89	2.12
	CV (%)	5.12	5.13	6.05	9.28	9.37	4.14	5.48	13.72	2.84	8.63	11.6

DFT: Days to 50% tasseling; CG: Cob girth; GY: Grain yield; CL: Cob length
DFS: Days to 50% silking; KRN: Kernel row number; HSW: Hundred seed weight; EH: Ear height
PH: Plant height; NK: Number of kernels per row; Shelling %: Shelling percentage

and days to 50% tasseling (rg= -0.328) and days to 50% silking (rg = -0.365).

In *rabi*, all the traits showed significant positive genotypic correlation ($p < 0.01$) in the desirable direction except number of kernels row number (KRN). The genotypic correlation coefficient was positive but not significant for KRN. The genotypic correlation of grain yield was highest with plant height (rg = 0.833) followed by ear height (rg = 0.817), number of kernels per row (rg = 0.727), Cob length (rg = 0.706), cob width (rg =0.691), shelling percentage (rg = 0.658) and hundred seed weight (rg = 0.591). Negative genotypic correlation was seen for days to 50% flowering.

Path coefficients for grain yield and related traits during kharif and rabi

The path coefficients of grain yield (dependent) with

Table 4. Mean sum of squares for different traits of maize

Traits	*Kharif* (2021)		*Rabi* (2021)	
	Genotypes (df = 169)	Error (df = 169)	Genotypes (df = 109)	Error (df = 109)
Days to 50% tasseling	22.52**	2.43	34.52**	16.90
Days to 50% silking	22.51**	2.90	38.82**	49.88
Plant height	2970.74**	945.69	2085.65**	122.75
Ear height	789.79**	189.99	986.14**	79.42
Cob length	19.39**	7.39	7.04**	2.19
Cob width	2.09**	0.46	0.26**	0.04
KRN	3.55**	1.30	4.65**	0.67
Kernels per row	100.33**	22.99	39.06**	16.28
Shelling percentage	42.96**	10.64	16.74**	2.83
Hundred seed weight	99.89**	3.27	28.23**	5.63
Yield	20.99**	0.31	5.34**	0.55

** = Significant at 1% level of significance

Table 5. Estimates of variances, PCV, GCV, heritability, genetic gain and GAM for yield and its components in maize

Traits	σ^2g	σ^2p	Mean	GCV	PCV	H^2	GA	GAM (%)
Days to 50% tasseling	10.05	28.48	56.48	5.61	6.25	80.52	5.86	10.37
(*kharif* /*rabi*)	8.81	25.71	70.43	4.21	7.20	34.27	3.58	5.08
Days to 50% silking	9.81	12.71	58.38	5.36	6.11	77.17	5.67	9.71
(*kharif* /*rabi*)	10.69	28.12	72.74	4.50	7.29	38.03	4.15	5.71
Plant height	1012.53	1958.21	188.58	16.87	23.47	51.71	47.14	24.99
(*kharif* /*rabi*)	981.45	1104.20	181.70	17.24	18.29	88.88	60.84	33.48
Ear height	299.90	489.89	83.59	20.72	26.48	61.22	27.91	33.39
(*kharif* /*rabi*)	453.36	532.78	98.28	21.67	23.49	85.09	40.46	41.17
Cob length	6.00	13.39	15.47	15.84	23.66	44.81	3.38	21.84
(*kharif* /*rabi*)	2.42	4.61	14.64	10.64	14.67	52.55	2.32	15.88
Cob width	0.82	1.28	4.35	20.78	25.96	64.05	1.49	34.25
(*kharif* /*rabi*)	0.11	0.15	3.95	8.31	9.77	72.26	0.58	14.55
KRN	1.13	2.43	13.78	7.71	11.31	46.43	1.49	10.82
(*kharif* /*rabi*)	1.99	2.66	14.51	9.72	11.24	74.76	2.51	17.32
Kernels per row	38.67	61.66	28.66	21.70	27.40	62.72	10.14	35.40
(*kharif* /*rabi*)	11.39	27.67	27.16	12.43	19.37	41.17	4.46	16.43
Shelling percentage	16.16	26.80	73.92	5.44	7.00	60.31	6.43	8.70
(*kharif* /*rabi*)	5.41	11.33	75.41	3.08	4.46	47.73	3.31	4.39
Hundred seed weight	48.31	51.58	31.73	21.90	22.63	93.66	13.86	43.67
(*kharif* /*rabi*)	11.30	16.93	24.17	13.91	17.03	66.75	5.66	23.41
Yield	10.34	10.65	8.08	39.81	40.41	97.07	6.53	80.81
(*kharif* /*rabi*)	2.39	2.95	5.98	25.89	28.72	81.29	2.87	48.09

σ^2g- genotypic variance PCV- genotypic coefficient of variation GCV- genotypic coefficient of variation
σ^2p- phenotypic variance H^2- heritability (bs) GA- genetic advance GAM(%)- Genetic advance as per cent of mean

independent variables are presented in Table 9 and Table 10 for *kharif* and *rabi*, respectively. The residual effects for *kharif* and *rabi* were 0.32 and 0.14, respectively. This reveled that during *kharif* cob length (2.028), kernel row number (0.341) and hundred seed weight (0.126) had positive direct effect on grain yield. Plant height (-1.038), cob width (-0.113), number of kernels per row (1.627) and days to 50% silking (-0.430) showed negative direct effect with grain yield. Hundred seed weight (0.126) and shelling percentage (0.089) showed positive direct effects on grain yield and it also showed positive indirect effects through all other traits except days to 50% flowering.

Table 6. ANOVA for Line x Tester for grain yield and its component traits in hybrids of maize (*Zea mays* L.)

Sources	d.f.	DFT	DFS	PH	EH	CL	CW	KRN	K/R	SP	HSW	GY
Kharif												
Replication	1	22.04**	81.89**	230992.8*	45573.64**	677.13*	1.95**	0.13	3069.53*	101.42*	532.04**	34.90**
Crosses	107	10.37**	9.23**	367.52	164.89	9.95	0.19**	1.4	33.67*	14.27*	25.57**	3.25**
Lines	53	15.89**	13.85**	391.93	176.54*	10.29	0.12	1.65**	34.27	15.57	33.56*	4.24**
Tester	1	3.37	0.782	1313.94*	3708.45**	5.74	7.68**	18.94**	425.04**	35.91	2.45	16.57**
Line x Tester	53	4.97**	4.76**	325.25	86.37	9.69	0.11	0.82	25.7	12.56	18.01**	2.01**
Error	107	2.28	2.69	433.7	127.95	9.94	0.09	1.33	23.03	9.36	2.97	0.38
Total	215	6.4	6.32	1473.13	357.7	13.05	0.15	1.36	42.5	12.23	16.67	1.97
Rabi												
Replication	1	14.24	7.07	21.24	9.01	1.73	0.04	0.26	120.13**	4.66	74.23**	0.82
Crosses	67	23.35**	28.30**	445.46**	351.45**	5.68**	0.13**	3.15**	36.19**	10.40**	16.52**	3.12**
Lines	33	26.12**	30.82**	686.20**	516.72**	7.38*	0.22**	4.15**	47.34*	12.15*	18.83**	3.55**
Tester	1	3.56	87.36	75.38	1819.90*	10.35	0.33**	12.16*	2.09	22.71	43.47*	18.39**
Line x Tester	33	21.18	23.98	215.93	141.75	3.84	0.04	1.88**	26.063	8.28	13.13*	2.22**
Error	67	12.56	13.48	147.41	105.58	2.04	0.03	0.643	15.14	4.71	4.93	0.64
Total	135	17.93	20.79	294.4	226.91	3.84	0.08	1.89	26.36	7.53	12.32	1..87

Table 7. Estimation of genotypic and phenotypic correlation for maize grain yield and related traits during *kharif* 2021

		DFT	DFS	PH	EH	CL	CW	KRN	NK	HSW	SP	GY
DFT	G	1										
	P	1										
DFS	G	0.998**	1									
	P	0.961**	1									
PH	G	-0.284**	-0.315**	1								
	P	-0.317**	-0.345**	1								
EH	G	-0.275**	-0.288**	0.961**	1							
	P	-0.305**	-0.329**	0.847**	1							
CL	G	-0.420**	-0.484**	0.921**	0.864**	1						
	P	-0.288**	-0.297**	0.539**	0.557**	1						
CW	G	-0.091	-0.080	0.312**	0.401**	0.360**	1					
	P	0.050	-0.031	0.183**	0.264**	0.278**	1					
KRN	G	-0.027	-0.008	0.550**	0.588**	0.345**	0.098	1				
	P	-0.023	-0.018	0.267**	0.361**	0.225**	0.176**	1				
NK	G	-0.399**	-0.449**	0.900**	0.894**	0.977**	0.393**	0.524**	1			
	P	-0.353**	-0.376**	0.663**	0.702**	0.765**	0.283**	0.352**	1			
HSW	G	-0.392**	-0.434	0.921**	0.852**	0.840**	0.330**	0.153*	0.779**	1		
	P	-0.368**	-0.391**	0.661**	0.670**	0.586**	0.261**	0.110*	0.619**	1		
SP	G	-0.543**	-0.568**	0.731**	0.724**	0.742**	0.414**	0.191**	0.748**	0.618**	1	
	P	-0.376**	-0.392**	0.388**	0.436**	0.457**	0.262**	0.125*	0.525**	0.462**	1	
GY	G	-0.328**	-0.365**	0.972**	0.980**	0.914**	0.300**	0.432**	0.937**	0.835**	0.684**	1
	P	-0.306**	-0.336**	0.739**	0.784**	0.627**	0.236**	0.306**	0.746**	0.798**	0.539**	1

Table 8. Estimation of genotypic and phenotypic correlation for maize grain yield and related traits during *rabi* 2021

		DFT	DFS	PH	EH	CL	CW	KRN	NK	HSW	SP	GY
DFT	G	1										
	P	1										
DFS	G	0.961**	1									
	P	0.962**	1									
PH	G	-0.389 **	-0.294 **	1								
	P	-0.191 **	-0.154 *	1								
EH	G	-0.423 **	-0.308 **	0.938 **	1							
	P	-0.197 **	-0.154 *	0.915 **	1							
CL	G	-0.366 **	-0.383 **	0.657 **	0.611 **	1						
	P	-0.295 **	-0.330 **	0.395 **	0.373 **	1						
CW	G	-0.443 **	-0.346 **	0.677 **	0.677 **	0.333 **	1					
	P	-0.316 **	-0.282 **	0.519 **	0.528 **	0.458**	1					
KRN	G	-0.267 **	-0.176	0.262 **	0.361 **	-0.038	0.510 **	1				
	P	-0.067	-0.035	0.141 *	0.204 **	0.033	0.395 **	1				
NK	G	-0.558 **	-0.520 **	0.657 **	0.670 **	0.854 **	0.379 **	0.051	1			
	P	-0.305 **	-0.338 **	0.309 **	0.339 **	0.805 **	0.433 **	0.079	1			
SP	G	-0.797 **	-0.617 **	0.566 **	0.588 **	0.454 **	0.583 **	0.332 **	0.656 **	1		
	P	-0.291 **	-0.251 **	0.357 **	0.362 **	0.329 **	0.398 **	0.194 **	0.458 **	1		
HSW	G	-0.276 **	-0.272 **	0.646 **	0.551 **	0.539 **	0.503 **	-0.189 *	0.274 **	0.368 **	1	
	P	-0.246 **	-0.248 **	0.488 **	0.415 **	0.479 **	0.484 **	-0.137 *	0.260 **	0.197 **	1	
GY	G	-0.545 **	-0.494 **	0.833 **	0.817 **	0.706 **	0.691 **	0.160	0.727 **	0.591 **	0.658 **	1
	P	-0.335 **	-0.348 **	0.705 **	0.684 **	0.647 **	0.642 **	0.111	0.607 **	0.394 **	0.567 **	1

Table 9. Direct (bold face) and indirect effects of different traits on grain yield during *kharif* 2021

	DFT	DFS	PH	EH	CL	CW	KRN	NK	HSW	SP
DFT	**0.481**	0.480	-0.136	-0.132	-0.202	-0.044	-0.013	-0.192	-0.188	-0.261
DFS	-0.430	**-0.430**	0.135	0.124	0.208	0.035	0.003	0.193	0.187	0.245
PH	0.295	0.327	**-1.038**	-0.997	-0.956	-0.324	-0.571	-0.935	-0.956	-0.759
EH	-0.373	-0.392	1.306	**1.360**	1.175	0.545	0.799	1.216	1.158	0.985
CL	-0.852	-0.981	1.868	1.752	**2.028**	0.730	0.699	1.981	1.704	1.505
CW	0.010	0.009	-0.035	-0.045	-0.041	**-0.113**	-0.011	-0.045	-0.037	-0.047
KRN	-0.009	-0.003	0.188	0.201	0.118	0.033	**0.341**	0.179	0.052	0.065
NK	0.649	0.731	-1.464	-1.454	-1.589	-0.640	-0.853	**-1.627**	-1.266	-1.217
HSW	-0.049	-0.055	0.116	0.107	0.106	0.042	0.019	0.098	**0.126**	0.078
SP	-0.048	-0.051	0.065	0.065	0.066	0.037	0.017	0.067	0.055	**0.089**

Residual effect = 0.3185

During *rabi*, cob width (0.578) had maximum direct effect on grain yield followed by ear height (0.461), cob length (0.412), and plant height (0.146). Cob width had highest direct effect but it showed negative indirect effects through kernel row number (KRN) (-0.273), number of kernels per row (NK) (-0.101), hundred seed weight (-0.034) and shelling percentage (-0.138). Though KRN and NK showed negative direct effects (-0.456 and -0.266 respectively), it possessed positive indirect on grain yield through cob length (0.016/0.352) and cob width (0.347/0.219). Hundred seed weight showed negative direct effect (-0.021) on grain yield but it has positive indirect effect through all other traits except NK (-0.073) and shelling percentage (-0.27). Shelling percentage had

Table 10. Direct (bold face) and indirect effects of different traits on grain yield *rabi* 2021

	DFT	DFS	PH	EH	CL	CW	KRN	NK	HSW	SP
DFT	**-0.121**	-0.156	-0.057	-0.195	-0.151	-0.256	0.122	0.149	0.046	0.076
DFS	-0.117	**-0.163**	-0.043	-0.142	-0.158	-0.200	0.080	0.138	0.035	0.074
PH	0.047	0.048	**0.146**	0.433	0.271	0.391	-0.119	-0.175	-0.033	-0.177
EH	0.051	0.050	0.137	**0.461**	0.252	0.391	-0.164	-0.178	-0.034	-0.151
CL	0.044	0.062	0.096	0.282	**0.412**	0.192	0.017	-0.227	-0.026	-0.147
CW	0.054	0.056	0.099	0.313	0.137	**0.578**	-0.273	-0.101	-0.034	-0.138
KRN	0.032	0.029	0.038	-0.166	0.016	0.347	**-0.456**	-0.014	-0.019	0.052
NK	0.068	0.085	0.096	0.309	0.352	0.219	-0.023	**-0.266**	-0.038	-0.075
HSW	0.034	0.044	0.095	0.254	0.222	0.291	0.086	-0.073	**-0.021**	-0.274
SP	0.097	0.100	0.083	0.271	0.187	0.337	-0.151	-0.175	-0.057	**-0.101**

Residual effect= 0.1441

negative direct effect (-0.101) on grain yield and its indirect effects *via* KRN (-0.175) and NK (-0.057) was also negative.

Discussion

Analysis of variance indicated significant mean sum of squares due to lines, testers, crosses for the traits studied indicating the presence of genetic variability among the yield attributing traits of maize genotypes, lines, testers and crosses studied (Table 4 and 6).

In the present study, high PCV and GCV was observed for most of the traits (Table 5). The GCV and PCV values ranged from low (less than 10%), moderate (10-20%) and high (more than 20%) during both *kharif* and *rabi* seasons. However, the GCV values were lower than PCV values which indicate the influence of environment for the expression of the trait. This is in line with the work of Magar *et al*. (2021); Wedwessen and Zeleke (2020). The low GCV was observed for shelling percentage and days to 50% flowering indicated that improvement through selection is less effective as they were highly affected by environment. This result is in parallel with the findings of Dutta *et al*. (2017) and Kumar *et al.* (2021).

During *kharif*, the difference between GCV and PCV was lower for traits, DFT, DFS, HSW, shelling percentage and yield. In contrast, higher difference was observed for PH, EH, CL, CW, KRN and NK which indicated that these characters are highly influenced by environment. During *rabi*, CL, NK and HSW showed higher difference between GCV and PCV and rest of the traits showed lower difference. The response to selection would be effective in those traits which are less influenced by environment.

Heritability is a measure of the phenotypic variance attributable to genetic causes and has predictive function in plant breeding. It provides information on the extent to which a particular morphogenetic trait can be transmitted to successive generation. Broad sense heritability (H^2), an estimate of the total contribution of the genetic variance to the total phenotypic variance of trait ranged from 44.81 to 97.07 (*kharif*) and 34.27 to 88.88 (*rabi*). Thus, in the present study, the estimates of heritability for various traits were found be either moderate (30-60%) or high (more than 60%), as defined by Johanson *et al*. (1955). According to Waqar *et al.* (2008) traits with high heritability can easily be fixed with simple selection resulting in quick progress. In consistent with these results Ghosh *et al*. (2014) and Bello *et al*. (2012) reported that traits with high heritability and moderately high genetic advance such as hundred seed weight, kernels per row, ear height and plant height indicate the importance of additive gene action where cautious selection may lead towards improvement for these traits.

According to Johnson *et al*. (1955), the observed GAM values were classified as low (less than 10%), moderate (10–20%), and high (greater than 20%). The genetic advance as percent of the mean (GAM) at 5% selection intensity ranged from 8.70% and 4.39% for shelling percentage to 80.81% and 48.09% for grain yield during *kharif* and *rabi*, respectively. The traits like grain yield (80.81, 48.09), hundred seed weight (43.67, 23.41), plant height (24.99, 33.48), ear height (33.39,41.17) showed high GAM in both seasons indicating possibility of genetic improvement in these traits. The results are in agreement with that of Dar *et al*. (2018) and Maruthi and Rani (2015).

Correlation among the characters may be the result of genetic association between the traits. Type of association of grain yield and its attributing traits is very important for a breeder. In the present study it is seen that genotypic correlation was higher than phenotypic correlation which indicates the presence of higher genetic association among the traits with yield. The results of correlation studies (Table 7 and 8) revealed that grain yield had significant genotypic and phenotypic association with cob position, cob length, cob width, KRN, NK, hundred seed weight and shelling percentage. The results are in parallel with the findings of Singh *et al*. (2017); Izzam *et al*. (2017) and Aman *et al*. (2020). This suggested that improvement in maize grain yield can be brought about through improvement of these traits which are linked with grain yield. Negative genotypic and phenotypic association of days to 50% flowering at both genotypic and phenotypic level were reported previously by Natraj *et al*. (2014).

Path coefficient analysis (Table 9 and 10) revealed that cob length, cob width, KRN, hundred seed weight, plant height and ear height had positive direct effect on grain yield. Positive direct of the traits on grain yield indicate the effectiveness of direct selection of these trait on grain yield (Varalakshmi *et al*., 2018). Cob width showed direct negative effect on grain yield (-0.113) during *kharif* and its genotypic correlation with grain yield was also significant (0.300) which explains the association between these traits. However, cob width showed negative indirect effect through other important traits like cob length, KRN, NK, HSW and shelling percentage with very low magnitude.

Plant height and ear height are important traits that effect the grain yield. Positive direct effect of both of these traits is undesirable. Taller plants need more nutrients to complete vegetative growth rather than reproductive stage which results in delayed maturation of cob. Plant having ear placement at higher position reduces the grain yield because of late pollination and lesser or no grain filling (Munawar *et al*., 2013). Cob length had positive direct effect on grain yield in both the seasons so, this may be used as reliable criteria for high yielding maize genotypes.

The residual effects recorded in the experiment were 0.3185 (*kharif*) and 0.1441 (*rabi*), which indicated that the traits studied in our experiment explained around 68.15 and 85.59 percent of variations during *kharif* and *rabi*, respectively. This indicated to include some more independent variable to explain more per cent variations in the grain yield in maize. Similar result with respect to residual effects was observed by Aman *et al*. (2020).

Conclusion

The genotypes included had significant genetic variability as reflected by ANOVA, GCV and PCV for the majority of traits studied and there is possibility of genetic enhancement through selection among the genotypes for grain yield and other traits of interest. Traits showing high heritability coupled with high genetic advance indicates that these traits can be improved through direct selection as the additive gene effects are predominant. Traits with a high genetic advance as percent of mean allow the improvement of these traits through selection. The combined interpretation of trait association analyses suggested placing more emphasis on traits like cob length, cob width, kernel row number, number of kernels per row, hundred seed weight to improve grain yield in maize, which showed high genotypic and phenotypic correlation with considerable direct and indirect effect on yield. Genotypic correlation explains the true association as they exclude environmental influence. Thus, the selection based on genotypic correlation is more reliable. These results might be confirmed by multi-environment testing of genotypes to come up with more accurate estimates for these genetic parameters, which would further aid in devising an appropriate breeding strategy.

References

Ahmad, S., Khan, Q., Ghaffar, S. & Ahmad, F. (2011). Genetic diversity analysis for yield and other Parameters in maize (*Zea mays* L.) genotypes. *Asian Journal of Agricultural Science*, **3**(5): 3388.

Aman, J., Bantte, K., Alamerew, S. & Sbhatu, D. B. (2020). Correlation and path coefficient analysis of yield and yield components of quality protein maize (*Zea mays* L.) hybrids at Jimma, Western Ethiopia. *International Journal of Agronomy*, pp 1–7. doi: https://doi.org/10.1155/2020/9651537.

Anonymous, 2021. *Agricultural statistics at a glance.*

Belay, N. (2018). Genetic variability, heritability, correlation and path coefficient analysis for grain yield and yield component in maize (*Zea mays* L.) hybrids. *Advances in Crop Science and Technology*, **6**: 399.

Bello, O. B., Ige, S. A., Azeez, M. A., Afolabi, M. S., Abdulmaliq, S.Y. & Mahamood, J. (2012). Heritability and genetic advance for grain yield and its component characters in maize (*Zea mays* L.). *International Journal of Plant Research*, **2**(5): 138–145.

Bilgin, O., Korkut, K. Z., Baser, I., Dalioglu, O., Ozturk, I., Kahraman, T. & Balkan, A. (2010). Variation and heritability for some semolina characteristics and grain yield and their relations in durum wheat (*Triticum durum* Desf.). *World Journal of Agricultural Sciences*, **6**: 301-308.

Burton, G. W. & De Vane, E. M. (1953). Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clonal material. *Agronomy Journal*, **51**: 515-518.

Dar, I. A., Lone, A., Kamaluddin, S. P. A., Hussan, S., Dar, M. S. & Alie, W. (2018). Genetic variability studies involving drought tolerance related traits in maize genotypes. *Journal of Agriculture and Ecology Research International*, **14**(2):1–13.

Dewey, D. R. & Lu, K. H. (1959). Correlation and path coefficients analysis of components of crested wheat grass seed production. *Agronomy Journal*, **51**: 515-518.

Dutta, R., Kumar, A., Satish, C. & Ngachan, S. V. (2017). Genetic divergence, path coefficient, principal component and cluster analyses of maize genotypes in the mid-altitudes of Meghalaya, *Maydica Electronic Publication*, **62**(1): 5.

Ghosh, A., Vaskar, S., Anindita, R., Amitava, G. & Sabyasachi, K. (2014). Genetic variability and character association of grain yield components in some inbred lines of maize (*Zea mays* L.). *Journal of Argo ecology and Natural Resource Management*, **1**(2): 34–39.

Hanson, G. H, Robinson, H. F. & Comstock, R. E. (1956). Biometrical studies of yield in segregating populations of Koren Lependeza. *Agronomy Journal*, **48**(1): 267-282.

Izzam, A., Rehman, H., Sohail, A., Ali, S., Manzoor, H. & Hussain, Q. (2017). Genetic variability and correlation studies for morphological and yield traits in maize (*Zea mays* L.). *Pure and Applied Biology*, **6**(4): 1234-1243.

Johnson, H. W., Robinson, H. F. & Cornstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, **47**: 314–318.

Kumar, B., Singh, V., Singh, S. B., Kumar, K., Jat, S. L., Kumar, S., Singh, B. K., Lahkar, C., Parihar, C. M., Dar, Z. A. & Rakshit, S. (2021). Multi-environment field testing to identify better performing and stable genotypes for water logging stress tolerance in tropical maize. *Maize Journal*, **10**(1): 18-23.

Lush, J. L. (1949). Heritability of quantitative characters in farm animals. In: Proceedings of the 8th *International Congress of Genetics* (*Hereditas Suppl*.). pp 356–375.

Magar, B. T., Acharya, S., Gyawali, B., Timilsena, K., Upadhayaya, J. & Shrestha, J. (2021). Genetic variability and trait association in maize (*Zea mays* L.) varieties for growth and yield traits. *Heliyon*, **7**(9): e07939.

Maruthi, R. T. & Rani, K. J. (2015). Genetic variability, heritability and genetic advance estimates in maize (*Zea mays* L.) inbred lines. *Journal of Applied and Natural Science*, **9411**(1): 149–154.

Mohammadi, S. A., Prasanna, B. M. & Singh, N. N. (2003). Sequential path model for determining interrelationships among grain yield and related characters in maize. *Crop Science*, **43**(5): 1690–1697.

Munawar, M., Shahbaz, M., Hammad, G. & Yasir, M. (2013). Correlation and path analysis of grain yield components in exotic maize (*Zea mays* L.) hybrids. *International Journal of Science: Basic and Applied Research*, **12**: 22-27

Nataraj, V., Shahi, J. P. & Agarwal, V. (2014). Correlation and path analysis in certain inbred genotypes of maize (*Zea mays* L.) at Varanasi. *International Journal of Innovative Research and Development*, **3** (1):14-17.

Niji, M. S. (2018). Genetic variability, heritability and character association studies in sweetcorn (*Zea mays* L. Saccharata). *Electronic Journal of Plant Breeding*, **9**(3): 1038-1044.

Prasad, B. V. V. V. & Shivani, D. (2017). Correlation and path analysis in maize (*Zea mays* L.). *Journal of Genetics, Genomics and Plant Breeding*, **1**(2): 1-7.

Singh, G., Kumar, R. & Jasmine. (2017). Genetic parameters and character association study for yield traits in maize (*Zea mays* L.). *Journal of Pharmacognosy and Phytochemistry*, **6**(5): 808–813.

Singh, R. K. & Chaudhary, B.D. (1979). Biometrical methods in quantitative genetic analysis, Kalyani Publishers, Ludhiana.

Varalakshmi, S., Wali, M. C., Deshpande, S. K. & Harlapur, S. I. (2018). Correlation and path coefficient analysis of single cross hybrids in maize (*Zea mays* L.), *International Journal of Current Microbiology and Applied Sciences*, **7**(4): 1840-1843.

Vashistha, A., Dixit, N. N., Sharma, D. & Marker, S. (2013). Studies on heritability and genetic advance estimates in maize genotypes. *Bioscience Discovery*, **4**(2): 65-168.

Waqar, M., Malik, F., Rashid, M., Munir, M. & Akram, Z. (2008). Evaluation and estimation of heritability and genetic advancement for yield related attributes in wheat lines. *Pakistan Journal of Botanies*, **40**(4): 1699-1702.

Wedwessen, T. & Zeleke, H. (2020). Genetic variability, heritability and genetic advance estimates in maize (*Zea mays* L.) inbred lines. *International Journal of Novel Research in Life Sciences*, **7**(2): 10-16.