Journal of Cereal Research

Volume 14 (3): 243-257

Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Research Article

Comparative Analysis of Genetic Parameters for Yield and Yield Attributing Traits in *Kharif* and *Rabi* Maize (*Zea mays* L.)

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Article history:

Received: 11 Sept., 2022

Revised: 04 Nov., 2022

Accepted: 27 Nov., 2022

Citation:

Kumar KVY, S Marker, R Bishnoi and SA Taranum. 2022. Comparative Analysis of Genetic Parameters for Yield and Yield Attributing Traits in *Kharif* and *Rabi* Maize (*Zea mays* L.). *Journal of Cereal Research* ***14 (3):*** *243-257. http://doi.org/10.25174/2582-2675/2022/126952*

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Abstract

The present investigation was carried out to assess the genetic variability parameters, correlation and path analysis in 30 maize genotypes for 15 quantitative traits in *rabi* and *kharif* seasons during 2019-20 at Sam Higginbottom University of Agriculture Technology and Sciences, Uttar Pradesh in Randomized Block Design replicated thrice. ANOVA for all quantitative characters revealed that treatment differences were highly significant in both the seasons under study at 1% level except for number of kernel rows per cob in *Kharif* season. Genotypes CML-193-1, CM-137 and CML-K5/ATM depicted highest grain yield in both the environments. The values of PCV were higher than GCV values for all the characters in both the seasons and large difference between the values of PCV and GCV of characters like grain yield per plant, cob weight, shank weight and anthesis-silking interval under both seasons, indicated that environmental factors significantly influenced the expression of these traits. All the traits studied had higher heritability, genetic advance at 5% selection intensity and genetic advance as percent of mean in *rabi* season than in *kharif* season, high expected genetic advance coupled with high heritability was observed for grain yield per plant, cob weight, plant height and ear height indicating the presence of large proportion of additive genetic action deciding these traits. Correlation and path coefficient studies suggest that selection based on characters cob girth, number of kernel rows per cob, cob weight and 100 kernel weight had positive correlation and direct effects with grain yield per plant. Therefore, it is concluded that effective selection must be attempted for these traits which would help in improvement of grain yield in maize genotypes suitable for different environments.

Key words: Variability parameters, Association analysis,Maize (*Zea mays* L.)

1. Introduction

Maize (*Zea mays* L.; 2n=20) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile crops having wider adaptability that can be grown in diverse seasons and ecologies, is also known as "Miracle Crop" and "Queen of the Cereals" because of its highest genetic yield potential. Maize plays a very important role in human and animal nutrition due to high nutritional significance enriched with abundant amount of starch, fibre, protein and fat along with micronutrients like vitamin B complex, Beta-carotene and essential minerals, i.e., magnesium, zinc, phosphorous, etc. Nutraceutical properties of phenolic and anthocyanin compounds in maize offer antioxidant activities that protects from various degenerative diseases (Shikha *et al.,* 2019). It is an important crop for large populations as human food, livestock feed, and strong demand for bioethanol, for production of sweeteners and non-food industrial products (i.e., bio-degradable packaging materials) and provides opportunity for value addition.

Currently, 1147.7 million MT of maize is being produced together by over 170 countries from an area of 193.7 million ha with an average productivity of 5.75 t/ha **(FAOSTAT, 2020).**In India, during the 2019-2020 cropping seasons, 9.7 million ha of land was covered with maize with national average productivity of 2.9 tonnes/ha and production of 28.6 million tonnes is still far below the world average 5.1 tons/ha (Department of Agriculture Cooperation, 2020). In Uttar Pradesh, it occupies an area 0.73 million hectares with an average productivity of 1.67 tonnes/ha and production of 1.23 million tonnes (The International Plant Nutrition Institute (IPNI), Regional Profiles-India, 2018).

It is well known that the yield of a crop depends on the prevailing climatic condition of a particular area. Seasonal variation in temperature is an important climatic factor which can have profound effects on the growth and yield of crops. Changes in seasonal temperature affect the grain yield, mainly through phenological development processes. Climate change is of great concern at present, and there is a growing interest in understanding its impact on growth and yield of crops, and also identifying suitable management options to sustain the crops' productivity under the changing climates scenario (Kalra *et al.,* 2003).

There is lack of acceptance of Quality Protein Maize (QPM) materials by farmers because of several crucial issues plaguing these materials. Therefore, Identification of elite lines from germplasm is essential for improving Quality Protein Maize for with respect to yield potential, quality attributes and resistance to multitude environmental stresses. Germplasm has to undergo a cumbersome pre-breeding process; Genetic variation can be unlocked from tropical maize germplasm through genetic approaches. It is important to understand the genetic variation present among the germplasm and the performance of these inbreds in different environmental conditions. An understanding of the nature and magnitude of variability for grain yield and its components among the inbred lines of maize and to ascertain the association among and between each components and yield is necessary for selecting an appropriate breeding procedure for evolving high yielding varieties. Therefore, present investigation was undertaken for the estimation of coefficient of variation, heritability and expected genetic advance for yield and yield attributing traits, the extent of correlation among traits at both phenotypic and genotypic levels, path coefficient analysis for direct and indirect effect of yield contributing traits on grain yield per plant in *rabi* and *kharif* which would be helpful for enhancing the maize grain productivity under respective environmental conditions.

2. Materials and Methods

The experimental materials for the present study was consist of 29 genotypes of Quality Protein Maize inbred lines, which were obtained from Directorate of Research, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, U.P. The Check variety HQPM- 5 was obtained from Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The experiment was carried out at Field Experimentation Center of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj (U.P) during *rabi* (2019-2020) and *kharif* (2020) season. Genotypes were grown under Randomized Block Design (RBD) with three replications.

Observations for 11 traits *viz.* plant height (cm), ear height (cm), tassel length (cm), cob girth (cm), cob length (cm), number of kernel rows per cob, number of kernels per row, cob weight (g), shank weight (g), 100 kernel weight (g) and grain yield per plant (g) were recorded from five randomly selected competitive plants from each plot in each replication, while days to first tassel emergence (50%), days to first silk emergence (50%), anthesis-silking interval and days to maturity were recorded on the plot basis. The mean values of the data were subjected to ANOVA (Fisher, 1936), Coefficient of Variation (Burton, 1952), Estimation of Heritability (Broad sense) (Burton and Devane, 1953), Genetic Advance (Johnson *et al.,* 1955), Genotypic and Phenotypic Correlation (Al Jibouri *et al.,* 1958) and Path coefficient Analysis (Dewey and Lu, 1959).

3. Results and Discussion

Analysis of variance for all fifteen quantitative characters revealed that treatment differences were highly significant in both the seasons under study at 1% level except for number of kernel rows per cob in *Kharif* season. A perusal of mean values of yield and yield contributing character revealed that among the thirty genotypes *viz*, VL-153237 (133.57), CML-193-1 (133.40), CM-13 (123.33), CM-137 (121.30), CML-163 (104.17) and CML-K5/ATM (103.03) were identified as best performers for yield and yield related characters in *rabi* season. In *Kharif* season, the genotypes CML-K5/ATM (70.76), CML-227 (67.71), CML-41-1 (55.83), VL-109266 (49.07), CML-193-1 (48.96) and CM-137 (48.07) were identified as best performers for yield and yield related characters. Mean performance was high for grain yield per plant for genotypes CML-193-1, CM-137 and CML-K5/ATM in both the environments.

Higher differences were observed between phenotypic and genotypic variance for traits viz., anthesis-silking interval, plant height, ear height, number of kernel rows, cob weight, shank weight, 100 kernel weight and grain yield indicating that the characters studied were greatly influenced by environment in both rabi and kharif season (Bello *et al.* 2012, Rajesh *et al.* 2013, Kumar *et al.* 2015, Supraja *et al.* 2019 and Khulbe *et al.* 2020). The characters namely anthesis-silking interval, grain yield per plant, ear height, cob weight and shank weight had higher PCV and GCV, moderate for plant height, tassel length and 100 kernel weight under both seasons. While days to first tassel emergence, days to first silk emergence and days to maturity had lower PCV and GCV irrespective of environmental condition. The remaining characters were having the fluctuating PCV and GCV values under each environment. Genetic material had high amount of genotypic and phenotypic coefficient of variation for maximum characters in both seasons which can be exploited in crop improvement programme. The findings were in accordance with earlier findings reported by Bello *et al.,* (2012), Rajesh *et al.,* (2013), Kumar *et al.,* (2015), Patil *et al.,* (2016), Rahman *et al.,* (2017) and Khan *et al.,* (2018).

Heritability of all characters was higher in *rabi* season than *kharif* season, which indicated more exploitable variation of genotypes are present in *rabi* season. Traits except cob length and number of kernel rows per cob were having sufficient level of heritability from very high to moderate broad sense heritability across both seasons. The level cob length and number of kernel rows per cob heritability was significantly changed with seasons, where, high and low heritability in *rabi* and *kharif* season respectively for cob length. Moderate and low heritability in *rabi* and *kharif* season respectively for number of kernel rows per cob due to seasonal effect. Similar finidings were obtained by Kumar *et al.,* (2015), Pandey *et al.,* (2017) and Khan *et al.,* (2018).

The traits had higher genetic advance at 5% selection intensity and genetic advance as percent of mean in *rabi* season than *kharif* season. This is because of higher magnitude of heritability for all the characters in *rabi* season compared to *kharif* season which indicate GA and GAM more responsive for all characters in *rabi* season over *kharif.* High expected genetic advance as per cent of mean coupled with high heritability was observed for grain yield per plant, cob weight, plant height and ear height. This indicate the genotypic variation present in the genetic material studied is probably due to additive genetic variance in both *rabi* and *kharif* season, which can be effectively exploited in crop improvement programme by proper selection. These obtained results are in accordance to similar findings with some deviation of Nagabhusan *et al.,* (2011), Badawy *et al.,* (2012), Rajesh *et al.,* (2013), Bekele and Rao (2014), Beulah *et al.,* (2018), Hassan *et al.,* (2018), Bartaula *et al.,* (2019) and Supraja *et al.,* (2019).

Genotypic correlation coefficients were higher than phenotypic correlation coefficients and in same direction indicating the masking effect of environment on the association of characters except for days to silk emergence and anthesis-silking interval in *rabi* season. Grain yield per plant showed phenotypically and genotypically significant positive correlation with plant height, ear height, tassel length, days to maturity, cob length, cob girth, kernel rows per cob, kernels per row, cob weight, shank weight, 100 kernel weight. Therefore, characters under study except anthesis-silking interval had contribution in increasing yield in *rabi* environment. It was observed that grain yield per plant had significant and positive correlation at both phenotypic and genotypic level with cob girth, cob weight and 100 kernel weight in *kharif* season. Trait number of kernel rows per cob exhibited high significant positive correlation and anthesis silking interval had significant negative association at genotypic level with grain yield per plant at genotypic level in *kharif.* Similar findings were also reported by with some deviation of Aditi *et al.,* (2014), Hussain *et al.,* (2014), Kumar *et al.,* (2015), Vijay *et al.,* (2015), Gurpinder *et al.,* (2016) and Varalakshmi *et al.,* (2018).

The path coefficient analysis revealed that highest positive direct effect on grain yield per plant at genotypic level was exhibited by days to silking followed by cob weight, number of kernels per row, tassel length, cob girth and 100 kernel weight. While, days to first tassel emergence (50%) followed by anthesis-silking interval, cob length and plant height had negative direct effect on grain yield per plant in *rabi* season. Similar results in maize have earlier been reported by Rafiq *et al.,* (2010), Vijay *et al.,* (2015) and Gurpinder *et al.,* (2016).

It revealed that highest positive direct effect on grain yield per plant at genotypic level was exhibited by cob weight followed by 100 kernel weight and cob length. While, cob girth, days to first tassel emergence (50%) followed by number of kernels per row, anthesis-silking interval, shank weight and ear height showed high negative direct effect on grain yield per plant in *kharif* maize. Correlation and path coefficient studies reveal that characters cob girth, number of kernel rows per cob, cob weight and 100 kernel weight had positive correlation and direct effects with grain yield per plant. Similar findings were reported with some deviation by Langade *et al.,* (2013), Kumar *et al.,* (2015), Vijay *et al.,* (2015), Patil *et al.,* (2016), Takhar *et al.,* (2017) and Varalakshmi *et al.,* (2018).

Table 4.1 Analysis of variance for quantitative characters of maize in *rabi* and *kharif* seasons

Source of Variation	**Replication**		**Treatment**		**Error**	
df	**2**		**29**		**58**	
Environment	**Rabi**	**Kharif**	**Rabi**	**Kharif**	**Rabi**	**Kharif**
Days to first tassel emergence (50%)	9.10	21.23	352.93**	25.78**	1.72	6.47
Days to first silk emergence (50%)	12.90	18.74	323.06**	22.87**	2.85	6.72
Anthesis-silking interval	0.90	0.31	5.60**	1.73**	0.45	0.46
Plant height	318.67	38.54	2259.37**	1406.50**	49.25	87.80
Ear height	10.67	26.77	841.74**	351.69**	26.02	12.81
Tassel length	0.06	21.44	114.62**	105.50**	12.03	9.08
Days to maturity	13.33	14.63	102.19**	46.96**	3.37	12.13
Cob length	1.74	1.54	30.03**	8.48**	2.96	2.85
Cob girth	0.28	1.11	9.76**	3.60**	1.04	0.92
Number of kernel rows per cob	2.80	1.73	5.94**	2.22	1.51	2.15
Number of kernels per row	14.74	18.41	86.66**	32.77**	8.95	8.76
Cob weight	1577.47	420.39	2891.38**	522.91**	238.67	37.81
Shank weight	30.89	4.63	105.22**	35.44**	4.97	2.49
100 kernel weight	12.27	0.66	70.09**	31.31**	3.43	7.22
Grain yield per plant	269.15	379.92	2379.50**	463.94**	109.94	35.67

* at 5% level and ** at 1% level of significance respectively

Table 4.2(a): Mean performance of genotypes for quantitative characters in *Rabi* season

Sr. No.	Genotype	Days to first Tassel Emergence (50%)	Days to first Silk Emergence (50%)	Anthesis Silking Interval	Plant Height (cm)	Cob Height (cm)	Tassel Length (cm)	Days to Maturity	Cob Length (cm)	Cob Girth (cm)	Number of Kernel Rows Per Cob	Number of Kernels Per Row	Cob Weight (g)	Shank Weight (g)	100 Kernel Weight (g)	Grain Yield Per Plant (g/plant)
1	**CML-161-1**	124	126.33	2.33	178.63	82.93	37.32	161	14.07	14.03	14	19.33	74.93	15.83	29.37	60.933
2	**CML-193-1**	121.67	125	3.33	187.3	44.64	32.82	166.67	17.07	15.27	15.33	27	165.9	32.4	26.13	133.4
3	**VL-153237**	123.67	126.33	1.67	181.33	61.07	36.6	164.33	18.1	14.87	15.33	27	153.6	23.23	31.57	133.57
4	**VL-109403**	102.33	107.33	5	118.44	39.31	27.2	159.67	15.07	12.97	14	23.33	117.97	16.4	18	68.57
5	**VL-109352**	98.33	104	5.67	144.63	45.38	33.67	152.33	13.97	14.57	14.67	21.33	110.27	16.47	26.73	91.73
6	**VL-1016951**	111.67	114	2.33	166.93	43.35	31.43	163.33	16.37	13.73	13.33	26	122.9	23.83	31.97	97.9
7	**VL-109325-1**	99.67	104.33	4.67	131.49	35.4	29.33	156.33	10.7	13.8	15.33	15	58.03	10.27	26.07	47.37
8	**CML-40**	121.33	125.67	4.33	178.24	48.5	37.65	150.67	17.4	14.4	12.67	22	99.9	18.73	26.6	80.93
9	**CML-41-1**	113	115.33	2.33	181.88	53.60	38.95	163.67	17.93	13.43	14	31.67	124.4	23.83	27.47	98.4
10	**CML-227**	132	135.67	3.67	148.63	54.29	28.42	169.67	13.87	13	14.67	20	69.63	12.43	25.37	47.37
11	**CML-358 (ii)**	97.33	103	5.67	72.15	10.24	14.37	153.33	6.33	8.27	11.33	12.67	48.43	12.7	17.3	35.73
12	**CML-359 (ii)**	119.33	122	2.67	128.08	33.41	23.68	159	7.2	8.83	10.67	13.67	83.2	16.67	21.13	66.53
13	**CML-439**	100.67	105.33	4.67	146.19	37.3	28.55	156.33	13.63	11.57	11.33	26	107.13	20.13	24.93	86.43
14	**CML-224-1**	108.33	112.67	4.33	138.23	31.53	31.42	162.33	12.13	13.73	12.67	25	91.1	18.6	27.37	72.87
15	**CML-265-HMT**	113.67	118	4.33	110.63	11.01	22.42	154.67	10.8	9.67	12	17	58	7.03	18.23	37.47
16	**CML-K5/ATM**	122.67	124	1.33	160.31	51.39	28.25	169.33	14.87	14.87	14	23.67	123.5	19	31.23	103.03
17	**CML-K5/ATM CO571**	111.67	114	2.33	126.26	34.42	23.92	160	13.87	12.83	13.33	24	101.4	21.07	23.3	79
18	**CM-13**	114.33	117.67	3.33	161.51	43.34	27.65	167.33	17.73	15.67	13.33	27.67	132.87	24.93	36.5	123.33
19	**CIM-44 (i)**	134.33	136.67	2.33	135.22	31.72	30.82	169.67	16.13	12.13	15.33	20.67	75.6	26.6	26.33	48.97
20	**CIM-44 (ii)**	124.33	128	3.67	162.13	59.51	33.5	163.67	15.9	11.67	13.33	26.33	67.93	11.03	23.73	55.77

21	**CM-137**	126.67	130.33	3.67	156	66.06	33.58	170.33	18.87	14.6	14	31.33	147.63	26.33	28.73	121.3
22	**CM-138 (i)**	115.33	118	2.67	124.05	29.09	43.72	161	14.43	10.97	14.67	26.33	55.77	10.3	15.87	44.53
23	**CM-600**	122	126.67	4.67	162.88	53.74	29	169	15.03	11.83	12	27.33	87.73	18.27	26.37	68.17
24	**VL-109266**	126	127.33	1.33	181.18	58.72	31.08	163.67	18.93	14.17	16	32	129.7	29.47	27.9	101.27
25	**VL-1016416**	130.67	131.67	1	175.42	51.28	39.25	169.67	14.43	12.83	13.33	19.33	80.77	20.97	24.93	58.3
26	**VL-111381**	126.33	128.67	2.33	176.1	47.18	38.68	169.33	18.07	14.17	16	32	124.4	22	28.03	98.77
27	**VL-1016399**	108.67	110.33	1.67	166.04	36.36	25.05	162.33	11.3	12.97	15.33	18	75.73	19.1	23.73	56.63
28	**CML-163**	125	129.33	4.33	151.88	37.7	31.33	166.67	13.8	13.6	12.67	25	127.63	20.47	30.37	104.17
29	**VL-1016922**	101.67	103.67	2	150.07	43.14	31.22	156	16.67	13.67	13.33	29.33	106.77	16.4	33.93	87.03
30	**CHECK**	104.33	105.67	1.33	201.86	86.56	39.85	156.67	17.73	13.87	14	28.67	114.33	23.53	29.97	97.33
	Mean	116.03	119.23	3.17	153.46	45.41	31.36	162.27	14.75	13.07	13.73	23.96	101.24	19.27	26.31	80.23
	Range Min.	97.33	103	1	72.15	10.24	14.37	150.67	6.33	8.27	10.67	12.67	48.43	7.03	15.87	35.73
	Range Max.	134.33	136.67	5.67	201.86	86.56	43.72	170.33	18.93	15.67	16	32	165.9	32.4	36.5	133.57
	C.D. at 5%	2.14	2.76	1.09	11.47	8.34	5.67	2.99	2.81	1.67	2.01	4.89	25.25	3.64	3.03	17.14
	C.V.	1.13	1.42	21.22	4.57	11.24	11.06	1.13	11.66	7.80	8.96	12.49	15.26	11.57	7.04	13.07
	S.E.	0.76	0.97	0.39	4.05	2.95	2.00	1.06	0.99	0.59	0.71	1.73	8.92	1.29	1.07	6.05

Table 4.2(b): Mean performance of genotypes for quantitative characters in *Kharif* season

Sr. No.	Genotype	Days to first Tassel Emergence (50%)	Days to first Silk Emergence (50%)	Anthesis Silking Interval	Plant Height (cm)	Cob Height (cm)	Tassel Length	Days to Maturity	Cob Length (cm)	Cob Girth (cm)	Number of Kernel Rows Per Cob	Number of Kernels Per Row	Cob Weight (g)	Shank Weight (g)	100 Kernel Weight (g)	Grain Yield Per Plant (g/plant)
1	**CML-161-1**	58	59.33	1.33	162.99	53.72	41.61	95.67	16	11.4	13.33	25.67	52.69	11.12	21.72	41.57
2	**CML-193-1**	56	57.33	1.33	154.79	36.1	38.14	90	14.17	12.3	13.33	25.67	60.23	11.27	28.38	48.96
3	**VL-153237**	55.33	59.67	4.33	164.03	33.73	42.2	93	15.6	11.37	12	25.33	49.09	12.38	31.82	36.66
4	**VL-109403**	53.33	55.67	2.33	144.09	42.92	36.69	89	13.63	10.77	13.33	24	48.13	9.37	23.42	38.76

5	VL-109352	51	53	2	164.69	43.68	39.79	88.33	12.83	11.2	12.67	19.33	50.15	12.47	27.47	37.68
6	VL-1016951	46.33	50	3.67	158.84	42.35	34.74	80.33	15.97	13.63	12	25.67	42.36	18.59	24.33	23.77
7	VL-109325-1	48.33	51	2.67	144.36	43.46	36.09	83	11.33	11.23	12	17.33	50.23	7.19	21.91	43.03
8	CML-40	50	51.67	1.67	178.39	54.13	46.02	86.33	15.27	11.23	12.67	23.67	43.48	12.33	23.74	31.16
9	CML-41-1	50	51.67	1.67	152.42	42.41	37.83	83.33	14.5	12.5	12.67	23.33	66.97	11.13	25.34	55.83
10	CML-227	52.33	54.33	2	180.55	51.94	44.71	87.67	14.33	13.53	13.33	26	85.2	17.49	29.55	67.71
11	CML-358 (ii)	52.33	54	1.67	102.26	20.29	33.19	81.67	10.23	10.07	10.67	20.67	36.48	3.73	18.73	32.75
12	CML-359 (ii)	52	54	2	125.54	30.85	34.3	92.33	10.53	8.07	11.33	17.33	34.94	3.68	16.45	31.26
13	CML-439	47	48	1	141.88	32.18	36.21	91	14.83	10.03	12	29	43.12	9.1	20.54	34.02
14	CML-224-1	52.67	54.33	1.67	148.83	46.09	36.38	87	15.4	11.5	13.33	25	36.39	10.30	22.94	26.09
15	CML-265-HMT	53.67	55	1.33	97.93	23.89	23.21	87.33	15.23	11.2	12	26.67	57.27	13.05	24.97	44.22
16	CML-K5/ATM	54.67	55.67	1	160.09	48.43	27.95	88.33	16.5	12.63	13.33	26.33	82.37	11.62	24.87	70.76
17	CML-K5/ATM CO571	53	54.67	1.67	162.56	37.64	33.59	88.33	13.03	10.7	12.67	20.33	44.58	9.98	20.69	34.60
18	CM-13	52.67	53.67	1	171.02	45.19	39.33	82.67	13.2	11.57	12.67	24	45.52	12.14	26.70	33.38
19	CIM-44 (i)	53	54.67	1.67	156.41	54.89	34.39	93.33	17.13	11.93	13.33	26.67	61.67	14.25	27.19	47.42
20	CIM-44 (ii)	54	56	2	164.14	51.99	51.09	89.33	14.03	10.8	13.33	25.33	41.06	16.55	24.51	24.51
21	CM-137	52.67	54.33	1.67	155.59	51.48	37.56	91.33	14.23	10.23	10	25.67	56.62	8.55	23.94	48.07
22	CM-138 (i)	51.67	53.33	1.67	163.68	45.41	44.46	86.67	15.87	10.37	12.67	22	44.05	9.36	22.59	34.69
23	CM-600	55.67	56.67	1	170.44	58.86	34.01	92.67	15.87	10.47	12	20.67	33.92	13.98	25.79	19.93
24	VL-109266	59	60	1	139.27	40.15	26.69	93	12.57	10.5	12.67	18.67	60.59	11.52	22.67	49.07
25	VL-1016416	56	57.67	1.67	122.78	26.01	26.59	94.67	13.6	10.43	12.67	21.67	32.65	9.59	20.06	23.06
26	VL-111381	54.67	55.67	1	162.64	49.08	39.43	90.33	12.63	10.03	12	28	44.54	10.46	24.33	34.08
27	VL-1016399	55.67	57	1.33	192.09	57.02	39.13	88	13.63	11.2	12	22	43.77	10.25	20.56	33.52
28	CML-163	53.33	55.67	2.33	178.83	59.06	38.56	86.67	15.67	11.3	11.33	28.33	56.41	15.53	25	34.80
29	VL-1016922	49.33	51.67	2.33	163.88	54.53	34.8	93.33	14.07	11.17	13.33	28.67	41.20	14.81	25.20	26.06
30	CHECK	54.33	55.67	1.33	181.26	61.29	37.26	91.33	14.57	11.27	13.33	26.67	69.28	14.79	25.64	54.48
	Mean	52.93	54.71	1.78	155.54	44.63	36.87	88.87	14.22	11.15	12.47	23.99	50.49	11.55	24.04	38.73

Range Min.	46.33	48	1	97.93	20.29	23.21	80.33	10.23	8.07	10	17.33	32.65	3.68	16.45	19.93
Range Max.	59	60	4.33	192.09	61.29	51.09	95.67	17.13	13.63	13.33	29	85.2	18.59	31.82	70.76
C.D. at 5%	4.16	4.24	1.11	15.32	5.85	4.93	2.38	2.76	1.56	-	4.84	10.05	2.58	4.39	9.76
C.V.	4.81	4.74	38.17	6.02	8.02	8.17	1.64	11.88	8.59	11.75	12.34	12.18	13.65	11.18	15.42
S.E.	1.47	1.49	0.39	5.41	2.07	1.74	0.84	0.98	0.55	0.85	1.71	3.55	0.91	1.55	3.45

Table 4.3: Genetic variability parameters for quantitative characters of maize in both *rabi* and *kharif* seasons.

Genetic characters		**Season**	**Days to 50% Tasseling**	**Days to 50% Silking**	**Anthesis Silking Interval**	**Plant Height**	**Ear Height**	**Tassel Length**	**Days to Maturity**	**Cob Length**	**Cob Girth**	**Number of Kernel Rows Per Cob**	**Number of Kernels Per Row**	**Cob Weight**	**Shank Weight**	**100 Kernel Weight**	**Grain Yield Per Plant**
Genotypic variance		***Rabi***	117.07	106.74	1.72	736.71	271.91	34.19	32.94	9.03	2.91	1.48	25.90	884.23	33.42	22.22	756.51
Kharif		6.44	5.38	0.42	439.57	112.96	32.11	14.94	1.88	0.89	0.03	8.01	161.70	10.98	8.03	142.76	
Phenotypic variance		***Rabi***	118.79	109.59	2.17	785.96	297.93	46.23	36.31	11.98	3.95	2.99	34.85	1122.9	38.39	25.65	866.46
Kharif		12.91	12.10	0.88	527.37	125.77	41.19	17.07	4.73	1.81	2.17	16.76	199.51	13.47	15.25	178.42	
Coefficient of variation (%)	**GCV**	***Rabi***	9.33	8.67	41.38	17.69	36.32	18.65	3.54	20.37	13.05	8.85	21.25	29.37	30.00	17.92	34.28
		Kharif	4.79	4.24	36.62	13.48	23.82	15.37	4.35	9.64	8.47	1.26	11.79	25.18	28.69	11.79	30.85
	PCV	***Rabi***	9.39	8.78	46.51	18.27	38.01	21.68	3.71	23.47	15.20	12.58	24.65	33.10	32.16	19.25	36.69
		Kharif	6.79	6.36	52.89	14.76	25.13	17.41	4.65	15.29	12.06	11.82	17.07	27.97	31.77	16.25	34.49
	ECV	***Rabi***	1.13	1.42	21.22	4.57	11.24	11.06	1.13	11.66	7.80	8.96	12.49	15.26	11.57	7.04	13.07
		Kharif	4.81	4.74	38.17	6.02	8.02	8.17	1.64	11.88	8.59	11.75	12.34	12.18	13.65	11.18	15.42
Heritability		***Rabi***	98.6	97.4	79.2	93.7	91.3	74.0	90.7	75.3	73.7	49.4	74.3	78.7	87.1	86.6	87.3
Kharif		49.8	44.5	47.9	83.4	89.8	78.0	87.5	39.7	49.3	1.10	47.8	81.0	81.6	52.7	80.0	

Genetic Advance	***Rabi***	22.13	21.00	2.40	54.13	32.45	10.36	11.26	5.37	3.01	1.76	9.04	54.36	11.11	9.04	52.94
Kharif		3.69	3.19	0.93	39.43	20.75	10.31	7.45	1.78	1.37	0.03	4.03	23.58	6.17	4.24	22.02
Genetic advance as percent mean	***Rabi***	19.07	17.62	75.85	35.28	71.47	33.04	6.94	36.42	23.07	12.81	37.73	53.69	57.66	34.36	65.99
Kharif		6.97	5.83	52.22	25.35	46.49	27.95	8.38	12.51	12.25	0.28	16.79	46.70	53.37	17.63	56.85

Table 4.4 (a): Phenotypic correlation (r_p, above diagonal) and genotypic correlation (r_g, below diagonal) coefficients among yield and yield components of maize in *Rabi* season.

Traits	DT50	DS50	ASI	PH	EH	TL	DM	CL	CG	NKRC	NKPR	CW	SW	KW	GYPP
DT50	1	0.99**	-0.37**	0.39**	0.32**	0.28**	0.72**	0.35**	0.15	0.20	0.17	0.14	0.29**	0.17	0.12
DS50	0.99**	1	-0.25*	0.34**	0.28**	0.26*	0.69**	0.32**	0.13	0.17	0.15	0.12	0.26*	0.14	0.11
ASI	-0.44**	-0.34**	1	-0.52**	-0.41**	-0.31**	-0.37**	-0.32**	-0.25*	-0.31**	-0.23*	-0.19	-0.37**	-0.33**	-0.19
PH	0.41**	0.35**	-0.59**	1	0.78**	0.58**	0.33**	0.67**	0.61**	0.33**	0.51**	0.51**	0.55**	0.61**	0.57**
EH	0.34**	0.30**	-0.45**	0.81**	1	0.49**	0.27**	0.55**	0.51**	0.28**	0.39**	0.33**	0.32**	0.51**	0.39**
TL	0.35**	0.31**	-0.44**	0.74**	0.67**	1	0.18	0.54**	0.42**	0.32**	0.41**	0.27**	0.23*	0.25*	0.28**
DM	0.76**	0.74**	-0.42**	0.37**	0.29**	0.22*	1	0.37**	0.29**	0.25*	0.34**	0.29**	0.43**	0.32**	0.27**
CL	0.39**	0.37**	-0.45**	0.78**	0.68**	0.74**	0.42**	1	0.68**	0.44**	0.79**	0.56**	0.56**	0.51**	0.59**
CG	0.18	0.16	-0.29**	0.75**	0.61**	0.54**	0.33**	0.77**	1	0.54**	0.49**	0.61**	0.50**	0.66**	0.65**
NKRC	0.31**	0.26*	-0.49**	0.51**	0.39**	0.55**	0.43**	0.59**	0.66**	1	0.29**	0.19	0.28**	0.19	0.22**
NKPR	0.19	0.17	-0.35**	0.63**	0.53**	0.63**	0.39**	0.91**	0.59**	0.38**	1	0.56**	0.51**	0.43**	0.61**
CW	0.15	0.13	-0.25*	0.60**	0.44**	0.27**	0.34**	0.77**	0.77**	0.37**	0.78**	1	0.74**	0.55**	0.93**
SW	0.32**	0.28**	-0.45**	0.62**	0.39**	0.24*	0.47**	0.67**	0.60**	0.39**	0.61**	0.82**	1	0.51**	0.74**
KW	0.19	0.15	-0.38**	0.67**	0.55**	0.32**	0.33**	0.64**	0.82**	0.26*	0.54**	0.64**	0.54**	1	0.66**
GYPP	0.13	0.10	-0.28**	0.63**	0.46**	0.32**	0.29**	0.72**	0.77**	0.28**	0.74**	0.99**	0.77**	0.71**	1

KEY- *=Significant at 0.05 probability level; **=Significant at 0.01 probability level; DT50 (Days to first tassel emergence [50%]); DS 50 (Days to first silk emergence [50%]); ASI (Anthesis Silking Interval); PH (Plant height); EH (Ear height); TL (Tassel Length); DM (Days to maturity); CL (Cob length); CG (Cob girth); NKRC (Number of kernel rows per cob); NKPR (Number of kernels per row); CW (Cob weight); SW (Shank Weight); KW (100 Kernel Weight) and GYPP (Grain yield per plant).

Table 4.4 (b) Phenotypic correlation (r_p, above diagonal) and genotypic correlation (r_g, below diagonal) coefficients among yield and yield components of maize in *Kharif* season.

Traits	DT	DS	ASI	PH	EH	TL	DM	CL	CG	NKRC	NKPR	CW	SW	KW	GYPP
DT	1	0.97**	-0.25*	0.02	0.04	-0.09	0.45**	0.07	-0.13	0.06	0.01	0.11	-0.05	0.05	0.13
DS	0.97**	1	0.01	0.02	0.02	-0.06	0.43**	0.09	-0.09	0.03	0.02	0.08	-0.01	0.10	0.09
ASI	-0.45**	-0.21*	1	0.01	-0.09	0.14	-0.14	0.07	0.15	-0.12	0.03	-0.12	0.16	0.16	-0.16
PH	0.05	0.08	0.09	1	0.81**	0.63**	0.04	0.34**	0.28**	0.16	0.21*	0.22*	0.47**	0.31**	0.09
EH	0.12	0.09	-0.13	0.87**	1	0.43**	0.14	0.38**	0.22*	0.19	0.27*	0.26*	0.49**	0.22*	0.12
TL	-0.20	-0.13	0.31**	0.63**	0.48**	1	-0.08	0.14	0.06	0.02	0.16	-0.03	0.19	0.19	-0.09
DM	0.65**	0.65**	-0.21*	0.05	0.15	-0.13	1	0.16	-0.27**	0.13	0.11	-0.03	0.002	0.03	-0.03
CL	0.03	0.04	0.04	0.45**	0.51**	0.07	0.21*	1	0.39**	0.26*	0.64**	0.28**	0.53**	0.41**	0.15
CG	-0.16	-0.08	0.32**	0.46**	0.33**	0.15	-0.44**	0.67**	1	0.44**	0.27*	0.49**	0.57**	0.46**	0.37
NKRC	1.27**	1.28**	-0.42**	1.79**	1.45**	1.24**	1.08**	1.71**	1.41**	1	0.12	0.23*	0.32**	0.16	0.18
NKPR	-0.18	-0.21*	-0.04	0.28**	0.33**	0.15	0.16	0.58**	0.49**	1.14**	1	0.25*	0.47**	0.31**	0.14
CW	0.18	0.16	-0.13	0.25*	0.27**	-0.04	-0.006	0.34**	0.68**	1.38**	0.36**	1	0.36**	0.43**	0.95
SW	-0.01	0.06	0.25*	0.58**	0.56**	0.26*	0.007	0.72**	0.78**	2.08**	0.58**	0.35**	1	0.59**	0.09
KW	0.12	0.24*	0.39**	0.55**	0.39**	0.36**	0.04	0.57**	0.79**	2.10**	0.55**	0.57**	0.75**	1	0.29**
GYPP	0.19	0.14	-0.24*	0.09	0.11	-0.12	0.004	0.13	0.50**	0.94**	0.18	0.96**	0.07	0.39**	1

Table 4.5 (a) Direct and indirect effects of component traits attributing to grain yield of maize at phenotypic level in *Rabi* season.

Traits	DT	DS	ASI	PH	EH	TL	DM	CL	CG	NKRC	NKPR	CW	SW	KW
DT	-2.908	-2.882	1.086	-1.153	-0.930	-0.826	-2.087	-1.004	-0.436	-0.583	-0.497	-0.399	-0.860	-0.494
DS	2.786	2.811	-0.704	0.960	0.784	0.719	1.965	0.898	0.359	0.477	0.415	0.339	0.728	0.380
ASI	0.123	0.083	-0.330	0.172	0.135	0.102	0.122	0.107	0.081	0.102	0.077	0.065	0.123	0.108
PH	0.031	0.027	-0.041	0.078	0.061	0.045	0.026	0.052	0.048	0.026	0.039	0.040	0.043	0.048
EH	-0.002	-0.001	0.002	-0.004	-0.005	-0.003	-0.001	-0.003	-0.003	-0.001	-0.002	-0.002	-0.002	-0.003

TL	-0.008	-0.007	0.009	-0.017	-0.014	-0.029	-0.005	-0.016	-0.012	-0.009	-0.012	-0.008	-0.007	-0.007
DM	-0.054	-0.053	0.028	-0.025	-0.021	-0.014	-0.076	-0.028	-0.022	-0.019	-0.026	-0.022	-0.033	-0.024
CL	-0.035	-0.032	0.033	-0.067	-0.056	-0.055	-0.037	-0.101	-0.069	-0.045	-0.080	-0.056	-0.057	-0.051
CG	0.003	0.003	-0.005	0.013	0.011	0.009	0.006	0.014	0.021	0.011	0.011	0.013	0.011	0.014
NKRC	0.006	0.005	-0.009	0.009	0.008	0.009	0.007	0.013	0.016	0.029	0.008	0.005	0.008	0.005
NKPR	0.027	0.023	-0.037	0.079	0.062	0.065	0.053	0.124	0.078	0.045	0.156	0.087	0.079	0.068
CW	0.095	0.084	-0.137	0.357	0.232	0.189	0.199	0.386	0.422	0.128	0.389	0.695	0.517	0.379
SW	0.026	0.023	-0.033	0.048	0.028	0.020	0.038	0.049	0.044	0.025	0.045	0.066	0.088	0.045
KW	0.032	0.026	-0.062	0.116	0.096	0.047	0.059	0.096	0.125	0.035	0.082	0.103	0.096	0.189
GYPP	0.123	0.107	-0.199	0.568	0.390	0.279	0.269	0.588	0.653	0.221	0.606	0.927	0.735	0.658
Partial R^2	-0.357	0.301	0.066	0.044	-0.002	-0.008	-0.021	-0.059	0.014	0.006	0.094	0.644	0.065	0.125

Table 4.5(b): Direct and indirect effects of component traits attributing to grain yield of maize at genotypic level in *Rabi* season.

Traits	DT	DS	ASI	PH	EH	TL	DM	CL	CG	NKRC	NKPR	CW	SW	KW
DT	-13.999	-13.914	6.133	-5.679	-4.778	-4.863	-10.582	-5.597	-2.578	-4.296	-2.779	-2.107	-4.505	-2.591
DS	13.577	13.659	-4.597	4.832	4.145	4.233	10.083	4.982	2.149	3.589	2.263	1.797	3.852	2.031
ASI	0.752	0.578	-1.718	1.018	0.773	0.763	0.722	0.765	0.503	0.839	0.593	0.430	0.768	0.653
PH	-0.158	-0.138	0.231	-0.389	-0.316	-0.289	-0.143	-0.303	-0.293	-0.199	-0.246	-0.235	-0.240	-0.259
EH	0.034	0.03	-0.045	0.081	0.099	0.067	0.029	0.067	0.061	0.039	0.052	0.043	0.038	0.055
TL	0.171	0.153	-0.219	0.366	0.331	0.492	0.106	0.363	0.267	0.272	0.309	0.134	0.12	0.156
DM	-0.174	-0.17	0.097	-0.084	-0.066	-0.049	-0.230	-0.096	-0.076	-0.098	-0.092	-0.079	-0.107	-0.076
CL	-0.508	-0.464	0.566	-0.988	-0.859	-0.937	-0.531	-1.271	-0.977	-0.760	-1.153	-0.984	-0.847	-0.812
CG	0.036	0.031	-0.057	0.147	0.119	0.106	0.064	0.150	0.195	0.129	0.116	0.150	0.118	0.161
NKRC	-0.001	-0.001	0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.004	-0.002	-0.002	-0.002	-0.001
NKPR	0.115	0.096	-0.201	0.366	0.306	0.364	0.231	0.527	0.344	0.218	0.581	0.453	0.352	0.313

CW	0.153	0.134	-0.254	0.613	0.445	0.277	0.348	0.787	0.781	0.379	0.792	1.017	0.835	0.645
SW	0.069	0.061	-0.096	0.133	0.083	0.053	0.100	0.144	0.130	0.085	0.130	0.177	0.215	0.117
KW	0.059	0.048	-0.122	0.213	0.177	0.101	0.106	0.204	0.263	0.084	0.172	0.203	0.174	0.319
GYPP	0.127	0.103	-0.279	0.625	0.457	0.315	0.299	0.72	0.767	0.277	0.737	0.998	0.771	0.711
Partial R^2	-1.778	1.412	0.479	-0.243	0.045	0.155	-0.069	-0.915	0.149	-0.001	0.428	1.014	0.166	0.227

Table 4.5(c): Direct and indirect effects of component traits attributing to grain yield of maize at phenotypic level in *Kharif* season.

Traits	DT	DS	ASI	PH	EH	TL	DM	CL	CG	NKRC	NKPR	CW	SW	KW
DT	-0.086	-0.083	0.022	-0.001	-0.003	0.008	-0.038	-0.006	0.011	-0.005	-0.001	-0.009	0.004	-0.005
DS	0.086	0.089	0.001	0.002	0.001	-0.005	0.038	0.008	-0.009	0.002	0.002	0.007	-0.001	0.009
ASI	0.002	-0.0001	-0.007	0	0.001	-0.001	0.001	-0.001	-0.001	0.001	-0.0002	0.001	-0.001	-0.001
PH	0	0	0	-0.002	-0.002	-0.001	-0.0001	-0.001	-0.001	-0.0003	-0.0004	-0.0004	-0.001	-0.001
EH	-0.0003	-0.0001	0.001	-0.005	-0.007	-0.003	-0.001	-0.003	-0.002	-0.001	-0.002	-0.002	-0.003	-0.002
TL	0.001	0.0004	-0.001	-0.005	-0.003	-0.007	0.001	-0.001	-0.0004	-0.0001	-0.001	0.0002	-0.001	-0.001
DM	-0.001	-0.001	0.0004	-0.0001	-0.0004	0.0003	-0.003	-0.001	0.001	-0.0004	-0.0003	0.0001	0	-0.0001
CL	0.0001	0.0002	0.0002	0.001	0.001	0.0003	0.0004	0.002	0.001	0.001	0.001	0.001	0.001	0.001
CG	-0.001	-0.001	0.001	0.002	0.002	0.001	-0.002	0.003	0.007	0.003	0.002	0.004	0.004	0.003
NKRC	0.002	0.001	-0.004	0.006	0.007	0.001	0.005	0.009	0.016	0.036	0.004	0.008	0.012	0.006
NKPR	0.0001	0.0002	0.0003	0.002	0.003	0.002	0.001	0.007	0.003	0.001	0.011	0.003	0.005	0.003
CW	0.115	0.085	-0.125	0.231	0.269	-0.029	-0.028	0.291	0.517	0.243	0.262	1.047	0.375	0.448
SW	0.016	0.003	-0.051	-0.145	-0.151	-0.059	-0.001	-0.166	-0.179	-0.101	-0.145	-0.112	-0.312	-0.183
KW	0.001	0.001	0.002	0.004	0.003	0.002	0.0003	0.005	0.006	0.002	0.004	0.005	0.007	0.012
GYPP	0.134	0.094	-0.161	0.089	0.119	-0.093	-0.027	0.149	0.371	0.182	0.136	0.952	0.089	0.289
Partial R^2	-0.011	0.008	0.0011	-0.0002	-0.0008	0.0007	0.0001	0.0003	0.003	0.007	0.0014	0.997	-0.028	0.004

Table 4.5(d): Direct and indirect effects of component traits attributing to grain yield of maize at genotypic level in *Kharif* season.

Traits	DT	DS	ASI	PH	EH	TL	DM	CL	CG	NKRC	NKPR	CW	SW	KW
DT	-0.215	-0.208	0.096	-0.010	-0.025	0.043	-0.140	-0.006	0.034	-0.274	0.039	-0.039	0.002	-0.025
DS	0.033	0.034	-0.007	0.003	0.003	-0.005	0.023	0.002	-0.003	0.044	-0.007	0.006	0.002	0.008
ASI	0.074	0.034	-0.165	-0.014	0.022	-0.050	0.035	-0.006	-0.053	0.069	0.007	0.021	-0.042	-0.066
PH	0.003	0.005	0.005	0.063	0.054	0.039	0.003	0.028	0.029	0.112	0.018	0.016	0.036	0.034
EH	-0.017	-0.013	0.019	-0.123	-0.143	-0.069	-0.022	-0.07	-0.047	-0.207	-0.047	-0.039	-0.080	-0.056
TL	0.009	0.006	-0.013	-0.027	-0.020	-0.042	0.005	-0.003	-0.006	-0.053	-0.006	0.002	-0.011	-0.015
DM	-0.058	-0.058	0.019	-0.004	-0.014	0.011	-0.089	-0.019	0.039	-0.096	-0.015	0.0005	-0.001	-0.003
CL	0.003	0.005	0.004	0.051	0.058	0.008	0.024	0.113	0.076	0.193	0.065	0.038	0.081	0.065
CG	0.065	0.034	-0.133	-0.189	-0.135	-0.060	0.181	-0.277	-0.412	-0.582	-0.202	-0.281	-0.319	-0.327
NKRC	0.013	0.013	-0.004	0.018	0.015	0.013	0.011	0.017	0.014	0.01	0.012	0.014	0.021	0.021
NKPR	0.032	0.038	0.007	-0.050	-0.059	-0.027	-0.029	-0.104	-0.088	-0.206	-0.180	-0.064	-0.104	-0.099
CW	0.212	0.189	-0.150	0.297	0.317	-0.048	-0.007	0.392	0.797	1.609	0.416	1.168	0.412	0.668
SW	0.002	-0.009	-0.037	-0.084	-0.081	-0.038	-0.001	-0.104	-0.112	-0.301	-0.083	-0.051	-0.144	-0.108
KW	0.035	0.071	0.118	0.161	0.117	0.108	0.011	0.169	0.235	0.621	0.162	0.169	0.221	0.296
GYPP	0.192	0.142	-0.240	0.090	0.106	-0.118	0.004	0.129	0.502	0.942	0.177	0.959	0.074	0.392
Partial R^2	-0.041	0.005	0.039	0.006	-0.015	0.005	-0.0003	0.015	-0.207	0.009	-0.032	1.120	-0.011	0.116

Conclusion

Genotypes CML-193-1, CM-137 and CML-K5/ATM depicted highest grain yield in both the seasons. Traits except cob length and number of kernel rows per cob were having sufficient level of heritability from very high to moderate broad sense heritability across both seasons. High heritability coupled with high genetic advance as per cent of mean was observed for cob weight, plant height and ear height in both seasons. Correlation and path coefficient analysis revealed that selection based on characters cob girth, number of kernel rows per cob, cob weight and 100 kernel weight may bring out desired improvement towards high yielding genotypes suitable for multitude environment stresses.

Acknowledgement

The authors are highly thankful to the Directorate of Research and Department of Genetics and Plant breeding, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj for providing the necessary resources for the present study.

Author contributions

Conceptualization of research (KVYK, SM, RB & SAT); Designing of the experiments (KVYK, SM, RB & SAT); Contribution of experimental materials (KVYK, SM, RB & SAT); Execution of field/lab experiments and data collection (KVYK, SM, RB & SAT); Analysis of data and interpretation (KVYK, SM, RB & SAT); Preparation of the manuscript (KVYK, SM, RB & SAT).

Conflict of interest: No

Declaration

The authors declare no conflict of interest.

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