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RESEARCH ARTICLE

Genetic analysis and character association studies for yield and different phenotypic characters in maize (*Zea mays* L.)

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SUMMARY

The present study was conducted to investigate genetic variability, correlation, path coefficient and genetic diversity in maize. The analysis of variance indicated highly significant differences among genotypes for all the traits studied except ear diameter (significant at $p>0.05$). Kernel yield per plant, length of peduncle, leaf angle between blade and stem, angle between main axis and lateral branches, number of primary lateral branches of tassel, registered high to moderately high genetic variability, heritability and genetic advance. Significant and positive genotypic and phenotypic association were observed for kernel yield with plant length, width of leaf blade, ear length, ear diameter without husk, shelling percentage and 100 kernel weight. Path analysis revealed the improvement in kernel yield through positive direct effects of time of anthesis, ear placement, ear length, number of rows of grain, length of peduncle and shelling percentage.

Key Words : Maize, Variability, Yield, Divergence, Genotypes

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Maize (*Zea mays* L.*)* is the third most important cereal grain in the world after wheat and rice. The varieties and hybrids developed from the indigenous germplasm were not very successful in improving the productivity which is far below that of the world average. Poor yield levels along with poor nutritional status of maize grain present a challenging proposition to plant breeders for improvement of this crop. In this context, assessing the existing variability and selection of genotypes with due selection pressure on yield component characters is of prime importance to either exploit heterosis or to generate productive recombinants. Therefore, in the present investigation an attempt was made for assessing 56 genotypes for genetic variability and diversity, where yield is considered as important criterion.

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MATERIALS AND METHODS

For the present investigation 56 maize genotypes (Table A) supplied from Main Maize Research Station, Anand Agricultural University, Godhra (Panchmahal) were selfed. The experiment was laid out in Randomized Block Design (RBD) with three replications. During the present investigation eighteen phenotypic traits were considered *viz.,* (1) leaf angle between blade and stem, (2) time of anthesis, (3) angle between main axis and lateral branches, number of primary lateral branches, (4) length of main axis above lowest side branch, (5) length of main axis above upper side branch, (6) length of side branches, (7) plant length, (8) width of blade, (9) time of silk emergence, (10) cob placement, (11) width of blade, (12) cob diameter without husk, (13) length of peduncle, (14)

Table A: List of genotypes used in the study

Sr. No.	Genotypes	Pedigree
1.	GWC-9101	GM-1×Pool-31
2.	GWC-9103	Across-8223×FMS
3.	GWC-9401	African Tall×CLQC-40×EH 2922
4.	GWC-9412	GDRM-186
5.	GWC-9413	GDRM-187
6.	GWC-9601	Landrace collection
7.	GWC-9602	Dahod Landrace
8.	GWC-9603	Dahod Landrace
9.	GWC-9604	Dahod Landrace
10.	GWC-9610	Dahod Landrace
11.	GWC-9611	Dahod Landrace
12.	GWC-9612	Dahod Landrace
13.	GWC-9623	Dahod Landrace
14.	GWC-9631	CLQC-40×EH-2922×WRF-15
15.	GWC-9634	CLQC-40×EG-2922×CM-600
16.	GWC-9701	Local collection
17.	GWC-9802	Across 8844
18.	GWC-0203	Shahada local Dahod
19.	GWC-0204	Mandvi-gantoli Mangrol L. C.
20.	GWC-0207	Kadipani Kwat
21.	GWC-0208	Panvad-chhota-Udaipur
22.	GWC-0301	SZM-421
23.	GWC-0302	Telani-II, Banswara oily domestic
24.	GWC-0310	CLQ1632×CML146
25.	GWC-0311	Chandan-1 Torana
26.	GWC-0316	TL 2002A13213X4
27.	GWC-0320	Dhania seeds
28.	GWC-0323	Dudhmogar improved variety
29.	GWC-0325	Population-30 (9-39-2 × CL04935)
30.	GWC-0400	EC 531828
31.	GWC-0401	EC 533467
32.	GWC-0402	EC 533471
33.	GWC-0501	GWH-0214 F_4
34.	GWC-0502	GWH-0216 F_4
35.	GWC-0503	GWH-0218 F_4
36.	GWC-0505	GWH-0326 F_4
37.	GWC-0506	GWH-9902 F_4
38.	GWC-0507	Ganga Safed-2 F_4
39.	GWC-0703	Population-30 (AF02B5001-16 × 394)
40.	GWC-0510	IC 130760
41.	GWC-0605	Q1SADV1, non QPM Hyb.
42.	GWC-0606	VP 047, non QPM Hyb.
43.	GWC-0608	VP 042, non QPM Hyb.

Table A : Contd......

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44.	GWC-0609	Lsynzine
45.	GWC-0702	Population-30 (AF02B5001-16×394)
46.	GWC-0704	Population-30 (AF02B5001-210×394)
47.	Farmsameri	Improved Desi sameri
48.	GM-2	(4119×4123) × DRM-6
49.	GM-6	GDRM-187
50.	Narmada Moti	IC-9001
51.	African tall	Selection from 7 varieties
52.	Sweta	GBPUAT Pantnagar
53.	Manokarma	Nepal local selection
54.	Chhindwada	Chhindwada Land race
55.	D-822	GBPUAT Pantnagar
56.	Amber (Popcorn)	BICY

number of rows of grain, (15) cob length, (16) kernel yield per plant, (17) shelling percentage and (18) weight of 100 kernels. The data were validated by statistical analysis such as analysis of variance, correlation coefficients and path analysis. The analysis of variance (Panse and Sukhatme, 1967), phenotypic and genotypic variances and their respective co-efficients of variation (Johnson *et al*., 1955) were carried out. Genetic advance and broad sense heritability estimates were also computed as per standard statistical procedures.

RESULTS AND DISCUSSION

The mean performances (Table 1 and 2) of the 56 maize genotypes for 18 phenotypic characters were subjected to statistical analysis. Analysis of variance revealed highly significant differences among all the entries with respect to the characters studied except ear diameter without husk, indicating considerable variability in the experimental material. Many earlier workers including Tiwari and Verma (1999), Mahmood *et al*. (2004), Saleem *et al.* (2007) and Akbar *et al.* (2008) reported high variability for different traits in maize. Thus, it is inferred that the range of variability observed among the genotypes studied provides scope for exploiting these characters as morphological markers as well as for yield enhancement. In the present work range, mean and the estimates of genotypic (s_g^2) and phenotypic (s_p^2) variances for each character were obtained from the analysis of variance. The phenotypic coefficient of variation was found to be very high for angle between main axis and lateral branches of tassel (21.58), length of peduncle (24.98) and kernel yield per plant (22.37). Moderate PCV was recorded for length of main axis above lowest side branch of tassel (11.53), length of main axis above upper side branch of tassel (12.6), angle between leaf blade and stem (17.17), number of primary lateral branches of tassel (19.11), length of side branches of tassel (12.93), plant length (12.09), ear placement (13.0), width of leaf blade (10.6),

Table 1 (a) : Mean performances of maize genotypes

Sr. No.	Genotypes	Leaf: Angle between blade and stem	Tassel: Time of anthesis	Tassel: Angle between main axis and lateral branches	Tassel: Number of primary lateral branches	Tassel: Length of main axis above lowest side branch (cm)	Tassel: Length of main axis above upper side branch (cm)	Tassel: Length of side branches (cm)	Plant Length: (cm)	Ear placement (cm)
		1	2	3	4	5	6	7	8	9
1.	GWC-9101	47.90	42.67	42.90	12.56	35.75	21.83	22.98	204.87	0.38
2.	GWC-9103	38.87	48.67	28.27	11.38	31.00	19.83	20.58	173.89	0.39
3.	GWC-9401	42.97	43.00	39.00	10.53	32.75	22.33	20.83	175.94	0.38
4.	GWC-9412	46.07	43.67	42.00	11.27	32.42	22.53	18.67	189.44	0.35
5.	GWC-9413	39.93	47.33	38.40	13.80	32.17	21.92	22.17	142.11	0.44
6.	GWC-9601	38.33	43.67	23.50	12.64	33.35	26.58	22.98	207.53	0.36
7.	GWC-9602	39.53	47.00	35.27	14.29	40.17	28.50	22.67	195.97	0.41
8.	GWC-9603	42.00	47.00	23.53	10.13	34.75	22.87	23.56	189.71	0.37
9.	GWC-9604	47.22	51.00	33.27	10.71	34.50	21.28	20.08	175.44	0.35
10.	GWC-9610	35.17	56.00	27.33	11.71	33.17	20.50	19.42	193.33	0.38
11.	GWC-9611	44.00	55.00	33.33	10.47	33.67	21.00	20.58	176.53	0.42
12.	GWC-9612	53.27	50.00	38.00	13.89	34.08	20.50	18.62	215.20	0.41
13.	GWC-9623	45.87	45.00	46.27	15.13	31.25	21.33	19.95	174.50	0.39
14.	GWC-9631	34.13	55.33	26.53	13.09	30.14	21.32	19.33	196.56	0.40
15.	GWC-9634	42.73	49.33	37.00	12.10	33.83	23.70	21.73	210.00	0.37
16.	GWC-9701	31.20	49.67	25.20	11.00	34.42	24.33	19.50	173.77	0.39
17.	GWC-9802	43.76	46.67	29.07	10.04	32.87	21.67	21.00	186.80	0.37
18.	GWC-0203	45.57	50.00	40.30	12.71	35.57	24.83	24.50	205.97	0.40
19.	GWC-0204	48.83	46.67	32.47	15.20	35.75	20.75	22.50	211.67	0.42
20.	GWC-0207	43.75	46.67	29.73	14.16	31.28	23.42	22.58	203.42	0.35
21.	GWC-0208	34.20	56.33	29.27	11.81	35.75	22.82	23.42	201.67	0.35
22.	GWC-0301	41.07	54.67	33.23	10.24	30.22	21.32	23.42	191.44	0.43
23.	GWC-0302	35.13	49.00	31.07	11.91	35.42	23.58	22.33	193.00	0.40
24.	GWC-0310	39.57	49.33	39.37	11.82	39.37	24.50	23.58	208.96	0.37
25.	GWC-0311	30.27	47.33	37.90	12.58	36.67	25.03	24.00	215.07	0.43
26.	GWC-0316	41.82	50.00	43.13	9.91	32.66	21.89	22.08	186.11	0.35
27.	GWC-0320	49.62	48.67	32.40	9.53	38.55	22.00	22.50	210.72	0.44
28.	GWC-0323	37.67	50.00	36.73	10.69	35.58	21.75	21.58	168.67	0.35
29.	GWC-0325	41.98	54.00	35.20	8.51	35.10	22.08	18.67	167.22	0.36
30.	GWC-0400	41.98	53.33	36.40	10.36	34.67	24.83	26.08	214.06	0.37
31.	GWC-0401	40.42	46.67	35.13	12.09	33.39	24.14	21.92	196.29	0.39
32.	GWC-0402	42.53	54.00	50.73	11.44	37.33	24.00	25.83	192.08	0.35
33.	GWC-0501	36.73	44.67	29.07	9.36	33.20	21.00	20.69	194.35	0.34
34.	GWC-0502	39.20	49.67	32.67	11.82	36.73	22.25	21.75	193.33	0.34

Table 1a: Contd............

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35.	GWC-0503	38.58	51.67	27.93	10.91	39.98	22.83	25.58	188.06	0.40
36.	GWC-0505	38.47	49.67	35.13	11.73	37.75	21.33	22.47	180.56	0.38
37.	GWC-0506	36.53	48.33	30.67	13.56	36.33	23.58	26.77	212.55	0.38
38.	GWC-0507	39.87	58.33	31.70	11.30	38.33	24.42	22.17	176.53	0.43
39.	GWC-0703	39.62	45.33	37.40	11.90	37.92	25.53	23.75	230.39	0.37
40.	GWC-0510	34.93	49.33	34.13	8.35	36.25	22.53	22.10	167.92	0.38
41.	GWC-0605	41.43	45.00	27.93	9.80	35.08	19.42	21.36	212.77	0.41
42.	GWC-0606	31.07	50.00	31.83	11.49	38.08	25.58	26.75	215.56	0.35
43.	GWC-0608	37.00	47.67	32.27	13.13	38.13	25.58	23.67	204.83	0.34
44.	GWC-0609	39.60	58.67	31.87	10.91	36.58	24.08	22.58	219.67	0.38
45.	GWC-0702	39.20	43.67	28.90	9.69	35.67	22.67	22.64	173.89	0.25
46.	GWC-0704	41.00	49.00	31.57	4.87	35.25	26.42	23.42	196.01	0.32
47.	Farm sameri	58.83	48.67	43.20	10.53	36.25	20.92	22.33	193.61	0.37
48.	GM-2	48.87	45.00	27.60	10.58	32.47	19.77	21.58	180.53	0.36
49.	GM-6	46.87	46.33	54.00	13.16	38.92	24.92	25.42	225.00	0.40
50.	N. Moti	42.73	50.33	33.73	13.96	39.58	22.58	24.75	218.44	0.40
51.	African tall	45.27	57.67	31.27	15.20	43.83	24.08	28.50	232.92	0.42
52.	Sweta	34.73	49.33	23.83	14.00	31.67	19.42	20.92	225.00	0.34
53.	Manokarma	37.10	54.33	45.53	13.02	34.33	20.92	21.67	193.50	0.37
54.	Chhindwada	36.33	54.00	38.07	12.40	36.67	24.67	21.75	194.42	0.35
55.	D-822	38.27	49.00	31.00	13.00	32.00	20.62	21.36	197.36	0.39
56.	Amber	40.40	48.00	33.67	11.22	35.75	20.25	20.08	164.73	0.38
	General mean	40.89	49.48	34.23	11.67	35.25	22.75	22.38	195.35	0.38
	Minimum	30.27	42.67	23.5	4.87	30.14	19.42	18.62	142.11	0.25
	Maximum	58.83	58.67	54.0	15.2	43.83	28.5	28.5	232.92	0.44
	S. E.±	4.46	2.54	3.56	1.20	2.95	2.05	1.95	14.43	0.04
	C.D. (P=0.05)	8.85	5.03	7.06	2.38	5.85	4.07	3.87	28.6	0.07
	C.V. %	13.38	6.29	12.74	12.6	10.26	11.07	10.7	9.04	11.69

Table1(b): Mean performances of maize genotypes

Sr. No.	Genotypes	Leaf: width of blade (cm)	Ear: Time of silk emergence	Ear: Length of peduncle (cm)	Ear: Length (cm)	Ear: Diameter without husk (cm)	Ear: No. of rows of grain	Kernel yield per plant (g)	Shelling percentage	Kernel: 100 kernel weight (g)
		10	11	12	13	14	15	16	17	18
1.	GWC-9101	7.21	51.00	15.00	15.60	2.98	13.47	96.67	80.88	26.78
2.	GWC-9103	6.33	57.00	5.20	13.57	2.89	14.07	85.33	89.87	23.18
3.	GWC-9401	7.17	51.33	10.89	16.30	2.87	13.20	117.67	83.41	28.04
4.	GWC-9412	7.00	52.00	10.33	16.43	3.07	14.53	95.67	87.50	28.22
5.	GWC-9413	6.94	55.67	13.78	11.50	2.96	13.63	93.67	80.41	22.92
6.	GWC-9601	7.96	50.67	10.89	15.47	3.13	15.07	116.00	79.83	27.48
7.	GWC-9602	7.79	55.67	10.00	14.23	3.18	13.47	125.00	83.14	26.62
8.	GWC-9603	7.86	55.67	7.56	14.27	2.76	12.53	74.33	68.86	20.50
9.	GWC-9604	6.13	59.00	6.67	13.97	2.77	13.07	60.67	71.54	22.52
10.	GWC-9610	7.45	64.00	9.56	12.98	2.76	12.27	66.00	72.67	23.65

Table 1b: Contd…………………

Table 1b: Contd…………..

11.	GWC-9611	7.33	63.00	10.44	15.23	2.97	12.87	82.33	80.93	25.43
12.	GWC-9612	6.80	57.67	10.56	16.13	2.92	11.87	106.00	87.80	27.02
13.	GWC-9623	6.26	52.67	9.22	13.93	3.02	14.73	91.00	87.06	23.50
14.	GWC-9631	8.29	64.00	5.89	12.30	2.74	15.07	81.67	87.89	21.91
15.	GWC-9634	7.00	56.67	12.33	15.25	2.80	12.67	77.67	86.96	21.25
16.	GWC-9701	6.67	57.33	9.44	12.67	2.79	12.67	90.33	86.68	28.00
17.	GWC-9802	6.83	54.67	14.67	13.57	2.81	13.07	80.67	79.85	28.25
18.	GWC-0203	6.83	58.00	8.78	15.67	2.91	14.00	83.80	66.85	26.68
19.	GWC-0204	6.85	54.67	9.22	14.60	2.80	13.07	106.00	86.90	23.36
20.	GWC-0207	7.04	54.67	10.11	15.03	3.15	14.27	109.00	84.97	27.15
21.	GWC-0208	7.67	64.00	13.44	16.67	2.94	14.33	97.00	74.10	28.59
22.	GWC-0301	7.54	62.33	7.89	14.80	2.94	12.13	115.33	85.89	27.23
23.	GWC-0302	7.98	57.00	8.89	15.97	3.09	14.80	118.00	87.43	26.60
24.	GWC-0310	7.96	57.00	8.67	15.53	2.98	12.53	115.00	89.22	26.29
25.	GWC-0311	6.75	55.33	10.89	15.40	2.97	12.80	105.00	78.27	27.98
26.	GWC-0316	7.01	58.00	10.17	14.60	2.96	12.27	91.00	64.58	26.38
27.	GWC-0320	8.42	57.00	9.33	16.70	3.04	13.20	133.67	86.72	29.83
28.	GWC-0323	6.37	57.67	7.78	12.57	3.09	14.00	118.33	83.74	30.48
29.	GWC-0325	6.65	61.67	7.89	16.50	2.98	12.67	67.33	48.28	23.93
30.	GWC-0400	8.44	60.67	9.89	16.37	2.85	12.53	113.00	89.43	31.44
31.	GWC-0401	8.24	54.33	9.78	15.63	2.99	14.13	111.67	76.26	28.69
32.	GWC-0402	8.08	62.33	13.11	16.50	3.04	13.87	112.47	89.68	30.16
33.	GWC-0501	7.18	52.67	10.22	13.57	3.24	12.53	81.67	89.34	24.25
34.	GWC-0502	6.04	57.00	9.44	14.90	2.83	12.67	112.00	89.45	23.46
35.	GWC-0503	8.04	59.33	9.44	18.10	3.23	15.07	136.33	89.46	31.64
36.	GWC-0505	7.00	57.33	7.56	14.97	2.84	13.87	79.67	78.79	20.52
37.	GWC-0506	7.12	57.00	9.67	17.03	3.19	14.93	165.33	90.62	23.21
38.	GWC-0507	7.60	66.00	6.89	14.13	2.86	14.40	95.33	88.04	20.73
39.	GWC-0703	7.96	53.00	12.67	16.53	3.11	13.47	132.67	83.67	26.69
40.	GWC-0510	6.71	57.33	7.22	14.83	2.95	13.47	83.00	79.69	26.88
41.	GWC-0605	7.95	52.67	10.22	14.73	2.79	12.27	125.33	88.88	27.96
42.	GWC-0606	7.96	57.67	8.11	15.50	2.96	13.07	99.33	85.05	29.18
43.	GWC-0608	8.28	55.00	13.78	16.43	3.17	14.80	93.00	85.75	27.45
44.	GWC-0609	7.33	66.67	12.44	16.07	3.20	14.13	142.00	91.92	31.79
45.	GWC-0702	6.92	51.33	10.89	15.00	2.97	15.33	72.67	78.79	23.15
46.	GWC-0704	7.30	57.00	7.89	14.23	2.99	12.53	76.67	86.87	24.42
47.	Farm sameri	7.00	56.33	10.33	14.17	2.79	12.53	91.00	81.41	25.34
48.	GM-2	7.63	52.67	7.44	14.30	3.02	15.60	100.67	89.75	21.03
49.	GM-6	8.04	55.00	11.56	17.47	3.01	14.00	109.33	90.13	26.25
50.	N. Moti	8.13	58.33	12.78	17.50	2.97	13.33	136.33	86.12	26.32
51.	African tall	7.75	65.33	11.22	18.37	3.09	12.53	115.00	90.38	30.64
52.	Sweta	7.33	57.67	11.89	14.07	2.98	13.20	99.33	86.11	25.44
53.	Manokarma	6.67	62.33	9.67	14.07	3.00	14.53	93.67	84.02	28.91
54.	Chhindwada	7.54	61.67	6.44	14.23	3.03	15.07	103.67	91.18	24.86
55.	D-822	6.71	57.00	7.44	15.47	2.90	14.00	89.67	86.34	24.52
56.	Amber	6.96	56.00	6.78	14.57	2.79	13.60	122.40	86.21	21.77
	General mean	7.32	57.41	9.82	15.11	2.96	13.56	101.66	83.31	26.00
	Minimum	6.04	50.67	5.20	11.5	2.74	11.86	60.67	48.28	20.50
	Maximum	8.44	66.67	15.0	18.37	3.24	15.6	165.33	91.92	31.79
	S. E.$\pm$	0.459	2.47	0.977	0.96	0.15	0.94	8.29	6.05	2.35
	C.D. (P=0.05)	0.91	4.9	1.93	1.91	0.305	1.87	16.44	11.99	4.67
	C.V. %	7.67	5.27	12.18	7.81	6.35	8.54	9.99	8.90	11.11

ear length (11.42), shelling percentage (11.93) and 100 kernel weight (14.66). The characters which exhibited high GCV were length of peduncle (21.81) and kernel yield per plant (20.02). Whereas, for the traits, angle between leaf blade and stem (17.17) and number of primary lateral branches of tassel (14.37), angle between main axis and lateral branches of tassel (17.41) the GCV was found to be moderate and all the other traits exhibited low GCV values. The present result is in accordance with the results of Satyanarayan and Saikumar (1996) and Ramgopal (1999) where similar outcomes for plant height, ear height, ear length and 100 grain weight were recorded. Najeeb *et al.* (2009) reported moderate GCV and high PCV for plant height and ear height. Low PCV and GCV were recorded for time of anthesis, time of silk emergence, ear diameter without husk and number of rows of grain, respectively. High heritability was found for kernel yield per plant, length of peduncle, time of silk emergence, angle between main axis and lateral branches of tassel and time of anthesis. Similar observations were reported by Rafique *et al.* (2004) for ear diameter, time of anthesis and silk emergence. He also reported very high heritability for kernel yield per plant. However, Salami *et al.* (2007) reported low heritability for these traits. In the present investigation ear diameter without husk recorded low heritability. In accordance with present work Tiwari and Verma (1999) also reported low to moderate estimates of heritability for this trait. In the characters, where high heritability was associated with high genetic advance, the variation was mostly due to additive gene effects. In the present study high heritability coupled with low genetic advance was observed for time of anthesis and time of silk emergence, respectively suggesting that variability in this character is due to non additive gene action. The predominance of non additive gene action suggests that it is not possible to improve these traits through simple selection. It is general experience that a character with a high genotypic variance and high heritability coupled with a greater genetic gain would respond better to selection in positive direction. Although there was sufficient variability existing for various bio-metric and morphological characters in the 56 maize genotypes investigated, the heritability values were high only in few cases and were either moderate or low in others. Therefore, utility of these characters as morphological markers will be restricted unless modified selection procedures are resorted to. In the present study, the genotypic and phenotypic correlation coefficients were estimated among 13 characters of 56 genotypes to find out the association of kernel yield per plant and other yield related characters and also between the various morphological characters (Table 3). Kernel yield in maize is a character influenced by many number of component characters. It exhibits direct and indirect effects with these characters. It was observed that kernel yield per plant exhibited positive and highly significant genotypic and phenotypic correlation

Table 2: Analysis of variance for eighteen characters in maize

Source of variation	Mean sum of squares		
	Replications	Genotypes	Error
d. f.	2	55	110
Leaf: Angle between blade and stem	80.25	88.02**	29.96
Tassel: Time of anthesis	21.28	48.15**	9.69
Tassel: Angle between main axis and lateral branches	23.48	125.64**	19.04
Tassel: Number of primary lateral branches	1.22	10.59**	2.16
Tassel: Length of main axis above lowest side branch (cm))	41.8	23.41**	13.09
Tassel: Length of main axis above upper side branch (cm)	10.6	11.95**	6.35
Tassel: Length of side branches (cm)	11.82	13.64**	5.74
Plant Length: (cm)	178.5	1048.03**	312.4
Plant: Ratio height of insertion of upper ear to plant length	0.00917	0.00332**	0.00195
Leaf: Width of blade (cm)	1.355	1.175**	0.316
Ear: Time of silk emergence	22.56	47.60**	9.15
Ear: Length of peduncle (cm)	0.43	15.21**	1.43
Ear: Length (cm)	0.84	6.14**	1.39
Ear: Diameter without husk (cm)	0.0177	0.0526*	0.0355
Ear: No. of rows of grain	1.47	2.79**	1.34
Kernel yield per plant (g)	350.5	1345.88**	103.24
Shelling percentage	36.79	186.78**	54.9
Kernel: 100 kernel weight (g)	24.4	26.91**	8.35

*and ** indicate significance of values at P=0.05 and 0.01, respectively with plant length, width of leaf blade, ear length, ear diameter without husk, shelling percentage and 100 kernel weight, respectively. However, ear placement showed only highly significant genotypic correlation with kernel yield per plant. This indicates that simultaneous selection for these traits might bring an improvement in grain yield. In confirmation with these results, Sadek *et al.* (2006) reported highly significant correlation of kernel yield with plant length, ear height, ear length, ear diameter and 100 kernel weight. Malik *et al.* (2005) reported significant correlation between kernel yield and characters *viz.* leaf width, plant height, ear height and 100 kernel weight. During the study, the time of anthesis exerted positive and highly significant correlation with cob placement and time of silk emergence at genotypic level. However, it exhibited significant phenotypic correlation with time of silk emergence but non significant correlation with ear placement. Cob diameter without husk also showed negative and significant genotypic correlation with time of anthesis. Mahmood *et al.* (2004), Lone *et al.* (2010) and Saleem *et al.* (2007) also observed positive and significant correlation between time of anthesis and time of silk emergence. The path coefficient analysis, which takes into account the cause and effect relation between the variables, is unique in partitioning the association into direct and indirect effects through other independent variables. Path coefficient also measures the relative importance of causal factors involved, the extent and nature of relationship prevailing among yield contributing characters and analyse various paths they follow finally culminating in the end product *i.e.* yield. The direct and indirect effects of various characters on kernel yield per plant as revealed by path analysis are described in Table 4. The genotypic correlation between the character and kernel yield was positive (0.014), however, of low magnitude. The direct effect of this character and kernel yield was negative. High and positive indirect effect of this character *via* time of silk emergence was observed, followed by ear placement, ear length, length of peduncle, ear diameter without husk and width of leaf blade. However, the negative indirect effect of the character, time of anthesis was also of high magnitude, which was followed by number of rows of grain. Number of grain rows per cob had positive and non significant genotypic correlation with kernel yield. However, it exhibited high direct effect on kernel yield but its negative indirect contribution through time of anthesis followed by ear diameter without husk, ear placement, width of leaf blade, length of peduncle with kernel yield. Whereas it recorded positive indirect effects through time of silk emergence, leaf angle between blade and stem, ear length and plant length. Bahoush and Abbasdokht (2008) reported similar results that number of grain rows had positive indirect effect *via* ear length and negative *via* cob placement. The genotypic correlation between shelling percentage and kernel yield was highly significant. However, the direct effects of this character on kernel yield was very low but its positive high indirect contribution through time of silk emergence, number of rows of grain, ear placement and ear length resulted in highly significant correlation with kernel

Table 3: The estimates of genotypic (σ_g^2) and phenotypic (σ_p^2) variance and other genetic parameters for different characters in maize

Characters	General mean	Range	σ_g^2	σ_p^2	GCV (%)	PCV (%)	H^2 (%)	GA (% mean)
Leaf: Angle between blade and stem	40.89	30.27- 58.83	19.35	49.31	10.76	17.17	0.392	13.88
Tassel: Time of anthesis	49.48	42.67 - 58.67	12.82	22.51	7.23	9.59	0.569	11.24
Tassel: Angle between main axis and lateral branches	34.23^0	23.5^0 - 54.0^0	35.53	54.57	17.41	21.58	0.651	28.94
Tassel: Number of primary lateral branches	11.67	4.87 - 15.2	2.81	4.97	14.37	19.11	0.565	22.24
Tassel: Length of main axis above lowest side branch (cm)	35.25	30.14 - 43.83	3.44	16.53	5.26	11.53	0.208	4.94
Tassel: Length of main axis above upper side branch (cm)	22.75	19.42 - 28.5	1.87	8.22	6.00	12.60	0.227	5.90
Tassel: Length of side branches(cm)	22.38	18.62 - 28.5	2.63	8.38	7.25	12.93	0.314	8.34
Plant Length (cm)	195.35	142.11 - 232.92	245.22	557.60	8.02	12.09	0.440	10.95
Ear placement (cm)	0.38	0.25 - 0.44	0.00045	0.0024	5.67	13.0	0.190	5.10
Leaf: Width of blade (cm)	7.32	6.04 - 8.44	0.28	0.60	7.31	10.60	0.475	10.38
Ear: Time of silk emergence	57.41	50.67 - 66.67	12.81	22.97	6.24	8.16	0.583	9.80
Ear: Length of peduncle (cm)	9.82	5.20 - 15.0	4.59	6.02	21.81	24.98	0.762	39.22
Ear: Length (cm)	15.11	11.5 - 18.37	1.58	2.98	8.33	11.42	0.532	12.51
Ear: Diameter without husk (cm)	2.96	2.74 - 3.24	0.005	0.041	2.55	6.85	0.138	1.93
Ear: No. of rows of grain	13.56	11.87 - 15.6	0.48	1.82	5.14	9.96	0.266	5.45
Kernel yield per plant (g)	101.66	60.67 - 165.33	414.21	517.45	20.02	22.37	0.800	36.90
Shelling percentage (%)	83.31	48.28 – 91.92	43.95	98.87	7.96	11.93	0.445	10.93
Kernel: 100 kernel weight (g)	26.0	20.5 - 31.79	6.19	14.54	9.57	14.66	0.426	12.85

Table 4 : Genotypic and phenotypic correlations between Kernel yield and other component characters in maize

Characters		Kernel yield per plant (g)	Leaf Angle between blade and stem	Tassel: Time of anthesis	Plant Length (cm)	Ear Placement (cm)	Leaf: Width of blade (cm)	Ear: Time of silk emergence	Ear: Length of peduncle (cm)	Ear: Length (cm)	Ear: Diameter without husk (cm)	Ear: No. of rows of grain	Shelling percentage	Kernel: 100 kernel weight (g)
Kernel yield per plant (g)	r_g	1.000	0.014	0.057	0.527**	0.507**	0.456**	0.052	0.217	0.586**	0.873**	0.238	0.502**	0.550**
	r_p	1.000	0.041	0.010	0.326**	0.164	0.323**	0.006	0.175	0.377**	0.319**	0.118	0.523**	0.386**
Leaf Angle between blade and stem	r_g		1.000	0.234	0.025	0.290*	0.140	0.231	0.186	0.274*	0.146	0.259	0.070	0.106
	r_p		1.000	0.172	0.091	0.064	0.024	0.170	0.075	0.112	0.125	0.141	0.093	0.023
Tassel: Time of anthesis	r_g			1.000	0.115	0.395**	0.162	0.999**	0.237	0.072	0.332*	0.158	0.057	0.138
	r_p			1.000	0.011	0.109	0.072	0.991**	0.119	0.039	0.022	0.061	0.007	0.153
Plant Length (cm)	r_g				1.000	0.325*	0.566**	0.104	0.394**	0.763**	0.551**	0.255	0.455**	0.453**
	r_p				1.000	0.051	0.385**	0.009	0.292**	0.355**	0.088	0.089	0.170	0.299**
Ear placement (cm)	r_g					1.000	0.288*	0.428**	0.102	0.141	0.311*	0.310*	0.219	0.202
	r_p					1.000	0.084	0.123	0.003	0.023	0.062	0.168	0.056	0.029
Leaf: Width of blade (cm)	r_g						1.000	0.161	0.204	0.532**	0.498**	0.225	0.272*	0.400**
	r_p						1.000	0.078	0.186*	0.297**	0.133	0.052	0.191*	0.230*
Ear: Time of silk emergence	r_g							1.000	0.238	0.057	0.301*	0.157	0.067	0.121
	r_p							1.000	0.123	0.036	0.007	0.055	0.004	0.147
Ear: Length of peduncle (cm)	r_g								1.000	0.372**	0.552**	0.176	0.043	0.469**
	r_p								1.000	0.229*	0.108	0.010	0.019	0.322**
Ear: Length (cm)	r_g									1.000	0.805**	0.117	0.094	0.564**
	r_p									1.000	0.231*	0.038	0071	0.341**
Ear: Diameter without husk (cm)	r_g										1.000	0.953**	0.468**	0.905**
	r_p										1.000	0.209*	0.137	0.234*
Ear: No. of rows of grain	r_g											1.000	0.402**	0.003
	r_p											1.000	0.087	0.100
Shelling percentage	r_g												1.000	0.202
	r_p												1.000	0.133
Kernel: 100 kernel weight (g)	r_g													1.000
	r_p													1.000

* and ** indicate significance of values at P=0.05 and 0.01, respectively

yield. However, it also exhibited negative indirect effects *via* time of anthesis followed by ear diameter, plant length and width of leaf blade. This character showed highly significant genotypic correlation with kernel yield but had very low negative direct effect on kernel yield. Similar results as reported by Ojo *et al.* (2006) for shelling percentage had positive indirect effect *via* number of rows of grain and negative indirect effect *via* plant height and 100 kernel weight. From the path analysis study, it was observed that, the time of anthesis had highest and positive direct effect on kernel yield per plant followed by cob placement, ear length, number of rows of grain, length of peduncle and shelling percentage. Whereas, time of silk emergence had the highest direct and negative influence on kernel yield per plant followed by leaf angle between blade and stem, ear diameter without husk, leaf width of blade and plant length. Although the genotypic correlation of time of anthesis and silk emergence with kernel yield was of lower magnitude and these two characters had direct effects on kernel yield opposite in direction, it tend to reduce the magnitude of correlation negative in direction, their direct effect on kernel yield was high. However, since selection for time of anthesis and silk emergence traits will not improve the kernel yield *per se* because of non significant correlation with kernel yield and also an association among themselves in opposite direction . The direct and indirect effects of various characters such as those taken in up in this study, on kernel yield have been studied by many workers such as Sadek *et al.* (2006), Saleem *et al.* (2007), Akbar *et al.* (2008), Bahoush and Abbasdokht (2008) and Najeeb *et al.* (2009). The results obtained in this investigation are validated with the findings of the workers cited above.The overall path analysis based on genotypic correlations revealed that kernel yield per plant, 100 kernel weight, shelling percentage, plant length, ear length, ear diameter, ear placement and width of leaf blade were the

Table 5: Genotypic path coefficient analysis showing direct (Diagonal) and indirect effects of different characters on kernel yield in maize

Characters	Leaf: Angle between blade and stem	Tassel: Time of anthesis	Plant Length: (cm)	Ear Placement (cm)	Leaf: Width of blade (cm)	Ear: Time of silk emergence	Ear: Length of peduncle (cm)	Ear: Length (cm)	Ear: Diameter without husk (cm)	Ear: No. of rows of grain	Shelling percentage	Kernel: 100 kernel weight (g)	Genotypic correlation with Kernel yield per plant (g)
	1	2	3	4	5	6	7	8	9	10	11	12	
Leaf: Angle between blade and stem	-1.308	-2.796	-0.012	0.589	0.104	2.985	0.175	0.439	0.136	-0.320	0.011	0.010	0.014
Tassel: Time of anthesis	0.306	11.962	-0.056	0.801	-0.121	-12.932	-0.223	0.114	0.310	-0.196	-0.009	-0.014	-0.057
Plant Length: (cm)	-0.033	1.372	-0.486	0.659	-0.421	-1.351	0.370	1.221	-0.514	-0.315	0.070	-0.044	0.527**
Ear Placement (cm)	-0.380	4.719	-0.158	2.030	-0.214	-5.542	-0.096	0.226	0.290	-0.383	0.034	-0.020	0.507**
Leaf: Width of blade (cm)	0.183	1.937	-0.275	0.584	-0.745	-2.086	0.192	0.851	-0.464	0.278	0.042	-0.039	0.456**
Ear: Time of silk emergence	0.302	11.956	-0.051	0.870	-0.120	-12.939	-0.224	0.091	0.280	-0.194	-0.010	-0.012	-0.052
Ear: Length of peduncle (cm)	-0.243	-2.835	-0.191	-0.207	-0.152	3.082	0.939	0.595	-0.515	-0.217	0.007	-0.046	0.217
Ear: Length (cm)	-0.359	0.856	-0.371	0.286	-0.396	-0.734	0.349	1.600	-0.751	0.145	0.014	-0.055	0.586**
Ear: Diameter without husk (cm)	0.191	-3.973	-0.268	-0.631	-0.371	3.890	0.518	1.288	-0.933	1.179	0.072	-0.089	0.873**
Ear: No. of rows of grain	0.338	-1.894	0.124	-0.629	-0.167	2.034	-0.165	0.188	-0.889	1.237	0.062	0.000	0.238
Shelling percentage	-0.092	-0.683	-0.221	0.444	-0.202	0.870	0.040	0.151	-0.436	0.498	0.153	-0.020	0.502**
Kernel: 100 kernel weight(g)	0.139	1.656	-0.220	0.411	-0.298	-1.566	0.441	0.902	-0.844	-0.003	0.031	-0.098	0.550**

major characters which exerted considerable direct effect, thus revealing the scope for considering these characters in selection. Therefore, selection for characters having high total genotypic correlation and direct and indirect effects on kernel yield per plant will effectively decide the improvement in kernel yield. The low residual effect signifies the appropriateness of chosen characters in representing the total variability. Yield is the result of combined effect of several metric characters and environment. Understanding the interaction of characters among themselves and with the environment has been of great importance in plant breeding. Correlation between different characters of plant could arise because of linkage, pleiotropy or developmentally influenced functional relationships. Correlation studies provide information on the nature and extent of association between any two characters. From this, it would be possible to bring about genetic upgradation in one character by the selection of the other of a pair. The correction coefficient, measures the relationship existing between pairs of characters. But a dependent character is an interaction product of many mutually associated component characters and change in any one will disturb whole network of cause and effect system.

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