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Genetic variability, association and path coefficient studies in quality protein maize inbreds

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Abstract
Fifty inbreds of quality protein maize were grown at the EB-II section of OUAT, Bhubaneswar during rabi season in a randomized block design with two replications for heritability, genetic advance, correlation and path coefficient studies in 15 quantitative characters. Analysis of variance revealed highly significant differences among the inbreds for all the characters under study indicating existence of wide genetic variations. Coefficients of variation at genotypic and phenotypic levels and heritability (broad sense) with expected genetic advance (as per cent of mean) were high for ear height, number of kernels, 100-kernel weight and grain yield indicating selection for these characters would be more reliable. In the present study, all the component traits except days to 50% tasseling, days to 50% silking, days to 75% dry husk and shelling % exhibited significant positive association with grain yield at genotypic and phenotypic levels. The characters like leaf length, leaf breadth, plant height, ear height, ear size, number of kernels and 100-kernel weight exhibited significantly strong positive association with grain yield. Analysis of path coefficients indicated that the highest direct contribution to grain yield was manifested by 100-kernel weight at genotypic level and by number of kernels per ear at phenotypic level. The high direct contribution to grain yield was also manifested by number of kernels per row, number of kernel rows per ear, number of kernels/ear, days to 50% tasseling and days to 75% dry husk at genotypic level and by 100-kernel weight, days to 50% tasseling and days to 75% dry husk at phenotypic level. Hence, the studies revealed the importance of number of kernels and 100-kernel weight as selection criteria for improvement of grain yield in quality protein maize.

Keywords: Variability, character association, path coefficient, grain yield, maize

Introduction
In recent years, improvement of the nutritional value of maize grain protein has been the focus of several maize breeding programmes. Knowledge of genetic variation among QPM (quality protein maize) and normal maize varieties is important for an efficient selection and development of new hybrids. In this context, the genetic architecture of yield and its component traits under QPM genetic background requires critical analysis. The present study comprised of 50 quality protein maize inbreds developed from diverse base populations at different locations was undertaken to study the comparative performance for 15 different yield and yield contributing traits. The nature of association of these characters among themselves was studied through phenotypic and genotypic correlations and path coefficient analysis.

Materials and Methods
Fifty inbreds of quality protein maize (*Zea mays* L.) were evaluated at EB-II section of OUAT, Bhubaneswar during rabi season in a randomized block design with two replications. Each plot consisted of 2 rows of 4 m length with inter- and intra-row spacings of 60 cm and 25 cm, respectively. Five plants were chosen at random from each plot for recording observations on 15 economic traits (Table 1). Plot means were taken for analysis of variance and covariance (Panse and Sukhatme, 1967) [6]. From the variance and covariance components, coefficients of variation at phenotypic (PCV) and genotypic levels (Burton, 1952) [1], heritability in broadsense (H) (Lush, 1940) [4] and expected genetic advance (GA) (Johnson *et al*., 1955) [3] were computed. The genotypic and phenotypic correlation coefficients (Miller *et al*., 1958) [5], which were used for path coefficient analysis at genotypic and phenotypic levels (Dewey and Lu, 1959) [2] were also estimated.

Results and Discussion
The phenotypic coefficients of variations (PCV) ranged from 4.66% for days to 75% dry husk to 28.47% for grain yield/plant (Table 1).

The PCV estimates showed that the phenotypic variability was low (below 10%) for days to 75% dry husk, shelling %, days to 50% tasseling, days to 50% silking and ear girth (4.66-7.60%), moderate (10-20%) for number of kernel rows/ear, leaf length, plant height, ear length, leaf breadth, number of kernels/row, 100-kernel weight and number of kernels/ear (10.41% to 17.80%) and high (above 20%) for ear height and grain yield per plant (20.91 to 28.47%). The genotypic coefficient of variation (GCV) ranged between 4.65% for days to 75% dry husk to 27.57% for grain yield/plant and followed almost a similar trend as phenotypic coefficient of variation except for the characters like leaf length and number of kernel rows/ear. Majority of traits showed smaller difference between PCV and GCV indicating little influence of the environment, therefore, selection on the basis of phenotypic values for most of the characters was expected to be effective. But low values of GCV for days to 50% tasseling, days to 50% silking, days to 75% dry husk, leaf length, shelling % and ear girth indicated the limited scope for improvement of these traits.

The heritability in broadsense (H) estimates ranged from 72.80% for leaf length to 99.57% for days to 75% dry husk. The character like leaf length showed moderate heritability (<80%) and the characters like ear girth, number of kernels/ear, shelling %, number of kernel rows/ear, ear length, leaf breadth, number of kernels/row, days to 50% tasseling, days to 50% silking, days to 75% dry husk, plant height, ear height, 100-kernel weight and grain yield/plant exhibited very high heritability (>80%). The expected genetic advance (GA) for different characters, expressed as percentage of population means, ranged from 8.17% for days to 75% dry husk to 46.98% for grain yield/plant. The relative expected genetic advance was low (below 20%) for days to 50% tasseling, days to 50% silking, days to 75% dry husk, leaf length, ear girth, number of kernel rows per ear and shelling %; moderate (20-30%) for leaf breadth, plant height, ear length, number of kernels/row, number of kernels/ear, 100-kernel weight and high (above 30%) for ear height and grain yield/plant. High heritability coupled with high genetic advance (expressed as per cent of population mean) was observed for ear height and grain yield/plant, which indicated that these characters controlled by additive gene action and phenotypic selection for these characters would be effective.

Table 1: Genetic parameters of variability for grain yield and ancillary agro-economic traits in 50 maize in breds

	Character	Mean	Range	PCV (%)	GCV (%)	H (%)	GA	GA (as % of mean)
1.	Days to 50% tasseling	76.17	63.50-82.00	6.09	6.08	99.47	8.12	10.67
2.	Days to 50% silking	76.56	64.50-82.50	6.15	6.13	99.22	8.23	10.74
3.	Days to75% dry husk	110.53	96.50-120.5	4.66	4.65	99.57	9.02	8.17
4.	Leaf length (cm)	59.80	47.00-78.50	10.91	9.31	72.80	8.36	13.98
5.	Leaf breadth (cm)	7.75	5.50-10.50	14.71	13.86	88.75	1.78	22.98
6.	Plant height (cm)	150.37	82.13-191.15	14.07	13.58	93.28	34.72	23.09
7.	Ear height (cm)	66.49	27.10-103.72	20.91	20.02	91.67	22.43	33.74
8.	Ear length (cm)	14.26	9.31-18.40	14.39	13.51	88.10	3.18	22.32
9.	Ear girth (cm)	13.72	10.80-16.50	7.60	6.82	80.44	1.48	10.76
10.	No. of kernel rows/ear	13.79	9.80-19.20	10.41	9.60	85.12	2.15	15.59
11.	No. of kernels/row	26.23	16.50-37.10	16.18	15.27	89.05	6.65	25.35
12.	No. of kernels/ear	335.19	207.50-428.63	17.80	16.02	81.01	85.07	25.38
13.	100-kernel weight (g)	24.52	16.05-33.36	16.72	16.04	92.08	6.64	27.09
14.	Shelling %	79.12	60.95-86.95	5.49	5.06	85.10	6.50	8.22
15.	Grain yield/plant (g)	96.98	50.50-177.50	28.47	27.57	93.75	45.56	46.98

At the genotypic level, the grain yield per hectare was positively and significantly correlated with leaf length (0.347), leaf breadth (0.380), plant height (0.347), ear height (0.293), cob length (0.372), cob girth (0.552), number of kernels per row (0.502), number of kernels per ear (0.598), 100-kernel weight (0..376) and grain yield per plant(0.629). Its correlations with days to 50% tasseling, days to 50% silking, 75% dry husk and shelling % were negative but non-significant (Table 2). At the phenotypic level, almost a similar trend was observed and the grain yield per hectare was positively and significantly correlated with leaf length (0.279), leaf breadth (0.344), plant height (0.330), ear height (0.279), cob length (0.338), cob girth (0.494), number of kernels per row (0.472), number of kernels per ear (0.541), 100-kernel weight (0.355) and grain yield per plant (0.604). However, its correlations with days to 50% tasseling, days to 50% silking, 75% dry husk and shelling % were negative but non-significant (Table 3). The characters like 100-kernel weight, number of kernels per ear, days to 50% tasseling, days to 75% dry husk and number of kernels per row had direct positive effects on grain yield at phenotypic level (Table 4).

Hence, the studies on variability and character association in maize suggested that among the 15 traits studied, number of kernels and kernel weight were the most important components of grain yield and can be used effectively as selection criteria for improvement of grain yield in quality protein maize.

Table 2: Estimation of genotypic (rg) correlation co-efficients among sixteen agro-economic traits of 50 maize in breds

	Character	Correlation	Days to 50% silking	Days To 75% dry husk	Leaf length	Leaf breadth	Plant height	Ear height	Ear length	Ear girth	No. of kernel rows/ ear	No. of Kernals / row	No. of Kernals/ ear	100-kernel weight	Shelling %	Grain yield/ plant	Grain yield (q/ha)
1.	Days to 50% tasseling	rg	0.992	0.818	-0.428	-0.329	0.222	0.289	-0.059	-0.416	-0.015	-0.359	-0.358	-0.179	-0.182	-0.291	-0.246
2.	Days to 50% silking	rg		0.836	-0.423	-0.326	0.226	0.272	-0.069	-0.372	-0.007	-0.357	-0.353	-0.201	-0.227	-0.301	-0.247
3.	Days to75% dry husk	rg			-0.191	-0.296	0.392	0.327	0.135	-0.039	0.076	-0.201	-0.209	0.067	-0.204	0.009	-0.068
4.	Leaf length (cm)	rg				0.497	0.248	0.191	0.641	0.663	0.174	0.657	0.380	0.472	0.055	0.539	0.347*
5.	Leaf breadth (cm)	rg					-0.021	-0.033	0.432	0.490	-0.154	0.555	0.227	0.403	-0.184	0.407	0.380**
6.	Plant height (cm)	rg						0.871	0.353	0.271	-0.126	0.316	0.307	0.348	0.236	0.431	0.347*
7.	Ear height (cm)	rg							0.215	0.099	-0.023	0.209	0.252	0.168	0.314	0.285	0.293*
8.	Ear length (cm)	rg								0.465	-0.207	0.767	0.486	0.699	0.033	0.722	0.372**
9.	Ear girth (cm)	rg									0.301	0.551	0.604	0.622	-0.009	0.772	0.552**
10.	No. of kernel rows/ear	rg										-0.097	0.396	-0.317	0.207	0.043	0.010
11.	No. of kernels/row	rg											0.790	0.518	0.262	0.806	0.502**
12.	No. of kernels/ear	rg												0.208	0.476	0.744	0.598**
13.	100-kernel weight (g)	rg													0.088	0.769	0.376**
14.	Shelling %	rg														0.188	-0.048
15.	Grain yield/plant (g)	rg															0.629**

* r ≥ 0.279 (Significant at 5%)
**r ≥ 0.361 (Significant at 1%)

Table 3: Estimation of phenotypic (rp) correlation co-efficients among sixteen agro-economic traits of 50 maize in breds

	Character	Correlation	Days to 50% silking	Days to 75% dry husk	Leaf length	Leaf breadth	Plant height	Ear height	Ear length	Ear girth	No. of kernel rows/ ear	No. of Kernals/ row	No. of Kernals/ ear	100-kernel weight	Shelling %	Grain yield/ plant	Grain yield (q/ha)
1.	Days to 50% tasseling	rp	0.987	0.813	-0.355	-0.310	0.211	0.273	-0.053	-0.369	-0.014	-0.335	-0.314	-0.176	-0.163	-0.277	-0.239
2.	Days to 50% silking	rp		0.829	-0.364	-0.313	0.216	0.257	-0.063	-0.337	-0.016	-0.334	-0.330	-0.195	-0.207	-0.295	-0.244
3.	Days to75% dry husk	rp			-0.161	-0.279	0.372	0.309	0.123	-0.035	0.074	-0.186	-0.180	0.063	-0.185	0.012	-0.065
4.	Leaf length (cm)	rp				0.491	0.189	0.155	0.550	0.513	0.151	0.542	0.298	0.340	-0.005	0.470	0.279*
5.	Leaf breadth (cm)	rp					-0.013	-0.014	0.380	0.429	-0.121	0.492	0.221	0.351	-0.181	0.396	0.344*
6.	Plant height (cm)	rp						0.855	0.326	0.249	-0.128	0.281	0.252	0.322	0.210	0.395	0.330*
7.	Ear height (cm)	rp							0.203	0.110	-0.034	0.194	0.206	0.157	0.285	0.260	0.279*
8.	Ear length (cm)	rp								0.417	-0.174	0.757	0.354	0.616	0.032	0.634	0.338*
9.	Ear girth (cm)	rp									0.310	0.502	0.490	0.548	-0.008	0.684	0.494**
10.	No. of kernel rows/ear	rp										-0.089	0.345	-0.300	0.179	0.068	0.008
11.	No. of kernels/row	rp											0.653	0.459	0.237	0.715	0.472**
12.	No. of kernels/ear	rp												0.161	0.448	0.688	0.541**
13.	100-kernel weight (g)	rp													0.050	0.684	0.355*
14.	Shelling %	rp														0.182	-0.017
15.	Grain yield/plant (g)	rp															0.604**

* r ≥ 0.279 (significant at 5%)
** r ≥ 0.361 (significant at 1%)

Table 4: Path coefficient analysis indicating direct (diagonal) and indirect effects of various characters on grain yield/plant at phenotypic level

Characters	Path Coeff.	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Leaf length	Leaf breadth	Plant height	Ear height	Ear length	Ear girth	No. of kernel rows/ ear	No. of kernals/ row	No. of kernals /ear	100-kernel weight	Shelling %	Correlation with grain yield/plant (r)
Days to 50% tasseling	Pp	0.350	-0.556	0.193	-0.0001	-0.006	0.008	0.011	0.002	-0.006	-0.001	-0.062	-0.151	-0.082	0.023	-0.277
Days to 50% silking	Pp	0.346	-0.564	0.197	-0.0001	-0.006	0.008	0.011	0.002	-0.006	-0.001	-0.062	-0.159	-0.091	0.030	-0.295
Days to75% dry husk	Pp	0.285	-0.467	0.238	0.0000+	-0.005	0.014	0.013	-0.004	-0.001	0.004	-0.034	-0.087	0.029	0.026	0.012
Leaf length	Pp	-0.124	0.205	-0.038	0.0003	0.009	0.007	0.006	-0.017	0.009	0.009	0.100	0.144	0.159	0.001	0.470
Leaf breadth	Pp	-0.109	0.176	-0.065	0.0001	0.019	-0.001	-0.001	-0.012	0.007	-0.007	0.091	0.107	0.164	0.026	0.396
Plant height	Pp	0.074	-0.122	0.088	0.0001	-0.0002	0.039	0.036	-0.010	0.004	-0.008	0.052	0.122	0.151	-0.030	0.395
Ear height	Pp	0.096	-0.145	0.073	0.0000+	-0.0003	0.033	0.042	-0.006	0.002	-0.002	0.036	0.099	0.073	-0.041	0.260
Ear length	Pp	-0.019	0.036	0.029	0.0001	0.007	0.013	0.008	-0.031	0.007	-0.010	0.140	0.171	0.288	-0.005	0.634
Ear girth	Pp	-0.129	0.190	-0.008	0.0001	0.008	0.010	0.005	-0.013	0.017	0.019	0.093	0.236	0.256	0.001	0.684
No. of kernel rows/ear	Pp	-0.005	0.009	0.018	0.0000+	-0.002	-0.005	-0.001	0.005	0.005	0.060	-0.016	0.166	-0.140	-0.026	0.068
No. of kernels/row	Pp	-0.117	0.188	-0.044	0.0001	0.009	0.011	0.008	-0.024	0.009	-0.005	0.185	0.315	0.215	-0.034	0.715
No. of kernels/ear	Pp	-0.110	0.186	-0.043	0.0001	0.004	0.010	0.009	-0.011	0.008	0.021	0.121	0.482	0.075	-0.064	0.688
100-kernel weight	Pp	-0.062	0.110	0.015	0.0001	0.007	0.012	0.007	-0.019	0.009	-0.018	0.085	0.078	0.468	-0.007	0.684
Shelling %	Pp	-0.057	0.117	-0.044	0.0000+	-0.003	0.008	0.012	-0.001	-0.0001	0.011	0.044	0.216	0.023	-0.143	0.182

PR =0.375 R^2 % =85.95

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