Biological Forum – An International Journal **15(10): 47-54(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Correlation and Path Coefficient Analyses for Grain Yield and its Contributing Traits in Quality Protein Maize (*Zea mays* L.)

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(Received: 09 July 2023; Revised: 14 August 2023; Accepted: 12 September 2023; Published: 15 October 2023)
(Published by Research Trend)

ABSTRACT: The study on quality protein maize for sixteen different characters *viz.*, days to tasseling, days to silking, days to maturity, plant height (cm), cob length (cm), cob diameter (cm), number of grain rows per cob, number of grains per row, cob yield per plant (g), grain yield per plant (g), shelling %, 100 kernel weight (g), protein content (%), lysine content (%), tryptophan content (%), seed vigour index was conducted by making crosses among ten diverse inbred lines in half diallel fashion grown in Randomized Block Design in three replication during *Rabi* 2020-21 at Student's Instructional Farm, C. S. Azad University of Agriculture and Technology- 208002, Kanpur, U.P. to assess the correlation and path coefficients. At genotypic and phenotypic level grain yield per plant exhibited significant positive correlation with plant height, cob length, cob diameter, number of grain rows per cob, number of grains per row, cob yield per plant, shelling percent, 100 kernel weight and tryptophan content while negatively significant correlation with days to tasseling, days to silking and lysine content in F_1 generation while In F_2 generation, correlation coefficients at genotypic level higher than the corresponding phenotypic correlation coefficient for all the characters. Seven characters *viz.*, plant height, cob diameter, number of grain rows per cob, number of grains per row, cob yield per plant, protein content and tryptophan content showed positive and significant correlation with grain yield per plant. Lysine content showed negatively significant correlation with grain yield per plant while remaining characters showed non-significant values of correlation. At genotypic level cob yield per plant (0.7170) followed by shelling % (0.6912), days to tasseling (0.2839), lysine content (0.0567), seed vigor index (0.0368), tryptophan content (0.0280) and cob length (0.0082) had highest positive direct effect on grain yield per plant whereas at phenotypic level cob yield per plant (0.7796) followed by shelling % (0.4604), number of grains per row (0.0401), cob length (0.0400), days to tasseling (0.0400), number of grain rows per cob (0.0377), tryptophan content (0.0261), 100 kernel weight (0.0219) and lysine content (0.0064) had highest positive direct effect on grain yield per plant. Hence these characters may be considered for selection and improvement of grain yield in quality protein maize.

Keywords: QPM, correlation, path coefficient, genotype and phenotype.

INTRODUCTION

Maize is a major cereal crop which plays a very important role in human and animal nutrition in a number of developed and developing countries, worldwide. With its high content of carbohydrates, fats, proteins, some of the important vitamins and minerals, maize acquired a well-deserved reputation as a "poor man's nutri-cereal". Several million people, particularly in the developing countries, derive their protein and calorie requirements from maize. QPM holds superior nutritional and biological value and is essentially interchangeable with normal maize in cultivation and kernel phenotype. The studies indicated that the QPM protein contains, in general, 55 per cent more tryptophan, 30 per cent more lysine and 38 per cent less leucine than that of normal maize. As Indian population continues to grow but malnutrition is a big challenge for the country. To meet the challenge, it is crucial to focus on enhancing the production of QPM specifically by developing new high yielding maize varieties with high amount of nutrients like protein (Prasanna *et al.*, 2001). Achieving improvement in yield can be done through direct selection for grain yield and its component traits. Grain yield is usually controlled by polygenes and highly influenced by its component traits. Hence, identifying relative correlation and contribution of component characters to grain yield can be facilitated by understanding the association of the characters.

MATERIALS AND METHODS

Ten genetically diverse inbred lines were crossed in all possible combinations excluding reciprocal during *Rabi* 2019-20 at Student's Instructional Farm, C. S. Azad University of Agriculture and Technology- 208002, Kanpur, U.P. Basic material consisting of ten morphological diverse genotypes *viz.*, HKI-193-1, HKI-163, CML-141, CML-157, CML-150, VQL-3, VQL-30, VQL-1, VQL-8 and VQL-12. For sixteen characters *viz.*, Days to tasselling, Days to silking, Days to maturity, Plant height (cm), Cob length (cm), Cob diameter (cm), Number of grain rows per cob, Number of grains per row, Cob yield per plant (g), Grain yield per plant (g), Shelling %, 100 kernel weight (g), Protein content (%), Lysine content (%), Tryptophan content (%), Seed vigor index observations were recorded from the five randomly selected plants from each genotype.

Estimation of correlation and path coefficient

(i) Estimation of correlation coefficient

Phenotypic and genotypic correlation coefficients were calculated as per formula suggested by Al-Jibouri *et al.* (1956). The phenotypic correlation coefficient was worked out by using the following formula:

$$r_{PH}(Xy) = \frac{COV_{PH}(XY)}{\sqrt{V_{PH}(X)\, V_{PH}(Y)}}$$

The genotypic correlation coefficient was worked out by using the following formula:

$$R_0(XY) = \frac{COV_0(XY)}{\sqrt{V_{PH}(X)\, V_{PH}(Y)}}$$

(ii) Estimation of Path Analysis:

Path coefficient analysis suggested by Dewey and Lu (1959) was carried out to know the direct and indirect effect of the morphological traits on plant yield.

The following set of simultaneous equations were formed and solved for estimating various direct and indirect effects.

$r_{1y} = a + r_{12}b + r_{13}c + \ldots\ldots\ldots + r_{1Ii}$

$r_{2y} = a + r_{21}a + b + r_{23}c + \ldots\ldots + r_{2Ii}$

$r_{3y} = r_{31}a + r_{32}b + c + \ldots\ldots\ldots + r_{3Ii}$

$r_{1y} = r_{11}a + r_{12}b + r_{13}c + \ldots\ldots + I$

where,

r_{1y} to I_{1y} = Coefficient of correlation between causal factors from 1 to I with dependent characters y.

RESULT AND DISCUSSION

(i). Correlation coefficient

Correlation study was carried out between all the sixteen characters at genotypic and phenotypic levels. The phenotypic and genotypic correlation coefficient of F_1 and F_2 generation computed among the sixteen characters under study has been presented in Table 1 and Table 3 respectively.

Genotypic correlation coefficient. In F_1 generation, at genotypic level grain yield per plant showed positive and significant correlation with plant height, cob length, cob diameter, number of grain rows per cob, number of grains per row, cob yield per plant, shelling percent, 100 kernel weight and tryptophan content while negatively significant correlation with days to tasseling, days to silking and lysine content. Its association with characters *viz.*, days to maturity, protein content and seed vigor index showed non-significant values similar results were observed by Begum *et al.* (2016) and Borkhatariya *et al.* (2022).

In F_2 generation, correlation coefficients at genotypic level higher than the corresponding phenotypic correlation coefficient for all the characters likely observed by Rafiq *et al.* (2010). Seven characters *viz.* plant height, cob diameter, number of grain rows per cob, number of grains per row, cob yield per plant, protein content and tryptophan content showed positive and significant correlation with grain yield per plant. Sood *et al.* (2015) got the same result as lysine content showed negatively significant correlation with grain yield per plant while remaining characters showed non-significant values of correlation.

Phenotypic correlation coefficient. At phenotypic level all the characters showed similar association as genotypic ones in direction but lower in magnitude in both F_1 and F_2 generation.

(ii). Path coefficient analysis

The path coefficient analysis was estimated on genotypic as well as phenotypic level (Table 2 and 4) to resolve the direct and indirect effects of different characters on grain yield per plant.

The path analysis is simple regression coefficient which split correlation coefficient values into direct and indirect effect.

Genotypic path coefficient. At genotypic level cob yield per plant (0.7170) followed by shelling % (0.6912), days to tasseling (0.2839), lysine content (0.0567), seed vigor index (0.0368), tryptophan content (0.0280) and cob length (0.0082) had highest positive direct effect on grain yield per plant; while number of grains per row (-0.1613), 100 kernel weight (-0.0510), number of grain rows per cob (-0.0288), plant height (-0.0658), cob diameter (-0.0499), days to silking (-0.1563), protein content (-0.0306) and days to maturity (-0.0739) showed negative and direct effect on grain yield per plant in F_1. Estimates of residual effect in this path was (-0.01264).

The result observed were in accordance with the findings of Yahaya *et al.* (2021) and Rojaria *et al.* (2023) reported for grain yield in maize.

High indirect positive effect on grain yield per plant was exhibited by cob yield per plant *via* number of grains per row (0.6869) followed by 100 kernel weight (0.5631), days to maturity (0.0111), plant height (0.3274), cob length (0.1684), cob diameter (0.3213), number of grain rows per cob (0.3346), shelling % (0.0624), tryptophan content (0.2134); shelling % *via* number of grains per row (0.3720) followed by 100 kernel weight (0.2559) and cob length (0.1536); days to tasseling *via* plant height (0.1113), number of grain rows per cob (0.0564) and cob length (0.0469).

Table 1: Genotypic and phenotypic correlations-F1.

Parent/Hybrids		Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	No. Of grain rows per cob	No. Of grains per row	Cob yield (g/plant)	Shelling %	100 kernel wt.(g)	Protein content (%)	Lysine content (%)	Tryptophan content (%)	Seed vigour index	Grain yield (g/plant)
Days to tasseling	G	1.000	0.995**	0.627**	0.392**	0.165*	0.497**	0.199*	-0.225**	-0.144	-0.203**	0.030	0.372**	0.150	0.312**	0.194*	-0.211**
	P	1.000	0.975**	0.627**	0.282**	0.128	0.456**	0.127	-0.175*	-0.143	-0.136	0.046	0.312**	0.137	0.272**	0.179*	-0.204**
Days to silking	G			0.670**	0.389**	0.132	0.500**	0.200*	-0.241**	-0.141	-0.201**	0.043	0.386**	0.170*	0.391**	0.185*	-0.209**
	P			0.674**	0.277**	0.100	0.461**	0.120	-0.200**	-0.135	-0.121	0.046	0.339**	0.158*	0.331**	0.156*	-0.196*
Days to maturity	G				0.098	0.113	0.191*	-0.041	-0.126	0.011	-0.067	0.192*	0.076	0.162*	0.347**	-0.097	-0.026
	P				0.055	0.081	0.173*	-0.039	-0.091	0.014	-0.023	0.148	0.052	0.145	0.290**	-0.082	-0.022
Plant height	G					0.443**	0.459**	0.232**	0.360**	0.322**	0.209**	0.369**	0.294**	-0.102	0.388**	0.217**	0.350**
	P					0.348**	0.366**	0.147	0.241**	0.230**	0.119	0.190*	0.211**	-0.090	0.270**	0.141	0.247**
Cob length	G						0.333**	0.257**	0.228**	0.166*	0.222**	0.120	0.148	0.138	0.258**	-0.016	0.262**
	P						0.315**	0.236**	0.194*	0.158*	0.194*	0.111	0.136	0.131	0.222**	-0.032	0.264**
Cob diameter	G							0.334**	0.293**	0.316**	0.082	0.163*	0.422**	-0.140	0.346**	0.353**	0.286**
	P							0.275**	0.255**	0.296**	0.074	0.137	0.390**	-0.140	0.315**	0.324**	0.267**
No. Of grain rows / cob	G								0.228**	0.329**	0.209**	0.294**	0.162*	0.051	0.193*	0.142	0.406**
	P								0.174*	0.257**	0.123	0.232**	0.119	0.019	0.119	0.076	0.310**
No. Of grains per row	G									0.675**	0.538**	0.475**	0.129	-0.431**	0.154*	0.118	0.794**
	P									0.595**	0.416**	0.380**	0.107	-0.383**	0.123	0.099	0.713**
Cob yield per plant	G										0.061	0.554**	-0.016	-0.278**	0.210**	-0.124	0.844**
	P										-0.004	0.446**	-0.013	-0.249**	0.188*	-0.131	0.826**
Shelling %	G											0.370**	-0.056	-0.368**	0.075	-0.035	0.586**
	P											0.282**	-0.068	-0.311**	0.048	-0.045	0.494**
100 kernel wt.	G												-0.074	-0.217**	0.168*	-0.122	0.629**
	P												-0.059	-0.179*	0.175*	-0.093	0.527**
Protein content	G													0.068	0.554**	0.299**	-0.077
	P													0.064	0.488**	0.248**	-0.072
Lysine content	G														0.185*	0.042	-0.378**
	P														0.158*	0.036	-0.346**
Tryptophan content	G															0.057	0.211**
	P															0.036	0.179*
Seed vigour index	G																-0.134
	P																-0.137
Grain yield per plant	G																1.000
	P																1.000

*, ** significant at 5% and 1% level, respectively

Table 2: Genotypic and phenotypic path with Grain yield per plant (g)-F1.

Parent/Hybrids		Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	No. Of grain rows per cob	No. Of grains per row	Cob yield (g/plant)	Shelling %	100 kernel wt.(g)	Protein content (%)	Lysine content (%)	Tryptophan content (%)	Seed vigour index	Grain yield (g/plant)
Days to tasseling	G	**0.2839**	-0.1555	-0.0463	-0.0258	0.0014	-0.0248	-0.0057	0.0362	-0.1460	-0.1403	-0.0015	-0.0114	0.0085	0.0087	0.0071	-0.211**
	P	**0.0400**	-0.0441	-0.0140	-0.0026	0.0051	-0.0058	0.0048	-0.0070	-0.1117	-0.0626	0.0010	-0.0139	0.0009	0.0071	-0.0009	-0.204**
Days to silking	G	0.2825	**-0.1563**	-0.0496	-0.0256	0.0011	-0.0250	-0.0058	0.0388	-0.1432	-0.1391	-0.0022	-0.0118	0.0097	0.0109	0.0068	-0.209**
	P	0.0390	**-0.0452**	-0.0150	-0.0026	0.0040	-0.0058	0.0045	-0.0080	-0.1056	-0.0559	0.0010	-0.0151	0.0010	0.0087	-0.0008	-0.196*
Days to maturity	G	0.1778	-0.1048	**-0.0739**	-0.0065	0.0009	-0.0095	0.0012	0.0203	0.0111	-0.0462	-0.0098	-0.0023	0.0092	0.0097	-0.0036	-0.026
	P	0.0251	-0.0305	**-0.0223**	-0.0005	0.0032	-0.0022	-0.0015	-0.0037	0.0112	-0.0108	0.0032	-0.0023	0.0009	0.0076	0.0004	-0.022
Plant height	G	0.1113	-0.0608	-0.0073	**-0.0658**	0.0036	-0.0229	-0.0067	-0.0581	0.3274	0.1442	-0.0188	-0.0090	-0.0058	0.0109	0.0080	0.350**
	P	0.0113	-0.0125	-0.0012	**-0.0092**	0.0140	-0.0046	0.0055	0.0096	0.1794	0.0547	0.0042	-0.0094	-0.0006	0.0071	-0.0007	0.247**
Cob length	G	0.0469	-0.0206	-0.0083	-0.0291	**0.0082**	-0.0166	-0.0074	-0.0367	0.1684	0.1536	-0.0061	-0.0045	0.0078	0.0072	-0.0006	0.262**
	P	0.0051	-0.0045	-0.0018	-0.0032	**0.0400**	-0.0040	0.0089	0.0078	0.1235	0.0894	0.0024	-0.0061	0.0008	0.0058	0.0002	0.264**
Cob diameter	G	0.1410	-0.0782	-0.0141	-0.0302	0.0027	**-0.0499**	-0.0096	-0.0473	0.3213	0.0567	-0.0083	-0.0129	-0.0080	0.0097	0.0130	0.286**
	P	0.0182	-0.0209	-0.0039	-0.0034	0.0126	**-0.0127**	0.0104	0.0102	0.2310	0.0339	0.0030	-0.0174	-0.0009	0.0082	-0.0016	0.267**
No. Of grain rows / cob	G	0.0564	-0.0312	0.0030	-0.0153	0.0021	-0.0167	**-0.0288**	-0.0368	0.3346	0.1447	-0.0150	-0.0050	0.0029	0.0054	0.0052	0.406**
	P	0.0051	-0.0054	0.0009	-0.0014	0.0095	-0.0035	**0.0377**	0.0070	0.2006	0.0565	0.0051	-0.0053	0.0001	0.0031	-0.0004	0.310**
No. Of grains per row	G	-0.0638	0.0376	0.0093	-0.0237	0.0019	-0.0146	-0.0066	**-0.1613**	0.6869	0.3720	-0.0243	-0.0040	-0.0244	0.0043	0.0043	0.794**
	P	-0.0070	0.0091	0.0020	-0.0022	0.0078	-0.0032	0.0066	**0.0401**	0.4642	0.1916	0.0083	-0.0048	-0.0025	0.0032	-0.0005	0.713**
Cob yield per plant	G	-0.0408	0.0220	-0.0008	-0.0212	0.0014	-0.0158	-0.0095	-0.1090	**0.7170**	0.0424	-0.0283	0.0005	-0.0158	0.0059	-0.0046	0.844**
	P	-0.0057	0.0061	-0.0003	-0.0021	0.0063	-0.0038	0.0097	0.0239	**0.7796**	-0.0019	0.0098	0.0006	-0.0016	0.0049	0.0006	0.826**
Shelling %	G	-0.0576	0.0315	0.0049	-0.0137	0.0018	-0.0041	-0.0060	-0.0868	0.0624	**0.6912**	-0.0189	0.0017	-0.0209	0.0021	-0.0013	0.586**
	P	-0.0054	0.0055	0.0005	-0.0011	0.0078	-0.0009	0.0046	0.0167	-0.0031	**0.4604**	0.0062	0.0030	-0.0020	0.0013	0.0002	0.494**
100 kernel wt.	G	0.0085	-0.0067	-0.0142	-0.0242	0.0010	-0.0081	-0.0085	-0.0767	0.5631	0.2559	**-0.0510**	0.0023	-0.0123	0.0047	-0.0045	0.629**
	P	0.0018	-0.0021	-0.0033	-0.0018	0.0044	-0.0017	0.0087	0.0152	0.3475	0.1301	**0.0219**	0.0026	-0.0012	0.0046	0.0005	0.527**
Protein content	G	0.1055	-0.0604	-0.0056	-0.0193	0.0012	-0.0211	-0.0047	-0.0208	-0.0164	-0.0389	0.0038	**-0.0306**	0.0039	0.0155	0.0110	-0.077
	P	0.0125	-0.0153	-0.0012	-0.0020	0.0055	-0.0049	0.0045	0.0043	-0.0100	-0.0312	-0.0013	**-0.0446**	0.0004	0.0128	-0.0012	-0.072
Lysine content	G	0.0426	-0.0266	-0.0119	0.0067	0.0011	0.0070	-0.0015	0.0695	-0.2827	-0.2543	0.0111	-0.0021	**0.0567**	0.0052	0.0016	-0.378**
	P	0.0055	-0.0072	-0.0032	0.0008	0.0052	0.0018	0.0007	-0.0154	-0.1942	-0.1433	-0.0039	-0.0028	**0.0064**	0.0041	-0.0002	-0.346**
Tryptophan content	G	0.0885	-0.0610	-0.0256	-0.0255	0.0021	-0.0173	-0.0056	-0.0249	0.2134	0.0516	-0.0086	-0.0170	0.0105	**0.0280**	0.0021	0.211**
	P	0.0109	-0.0150	-0.0065	-0.0025	0.0089	-0.0040	0.0045	0.0049	0.1467	0.0223	0.0038	-0.0218	0.0010	**0.0261**	-0.0002	0.179*
Seed vigour index	G	0.0550	-0.0289	0.0072	-0.0143	-0.0001	-0.0176	-0.0041	-0.0190	-0.1266	-0.0239	0.0063	-0.0092	0.0024	0.0016	**0.0368**	-0.134
	P	0.0072	-0.0071	0.0018	-0.0013	-0.0013	-0.0041	0.0029	0.0040	-0.1023	-0.0205	-0.0020	-0.0111	0.0002	0.0009	**-0.0048**	-0.137

Residual are -0.01264

Residual are 0.06445

*, ** significant at 5% and 1% level, respectively

Table 3: Genotypic and phenotypic correlations-F2.

Parent/Hybrids		Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	No. Of grain rows per cob	No. Of grains per row	Cob yield (g/plant)	Shelling %	100 kernel wt.(g)	Protein content (%)	Lysine content (%)	Tryptophan content (%)	Seed vigour index	Grain yield (g/plant)
Days to tasseling	G	1.000	0.994**	0.646**	0.014	0.081	-0.020	0.015	-0.475**	-0.167	0.225**	-0.120	-0.132	-0.029	-0.250**	0.028	-0.018
	P	1.000	0.980**	0.642**	0.008	0.081	-0.015	-0.003	-0.250**	-0.072	0.108	-0.080	-0.116	-0.026	-0.209*	0.024	-0.001
Days to silking	G			0.658**	0.019	0.089	-0.031	0.010	-0.485**	-0.171*	0.217*	-0.123	-0.122	-0.030	-0.239**	0.028	-0.032
	P			0.667**	-0.002	0.093	-0.031	-0.002	-0.271**	-0.083	0.128	-0.111	-0.112	-0.024	-0.199*	0.046	0.006
Days to maturity	G				-0.114	0.064	-0.077	-0.047	-0.446**	-0.091	0.060	-0.413**	-0.159	-0.005	-0.229**	0.163	-0.061
	P				-0.078	0.065	-0.072	-0.064	-0.280**	-0.027	0.019	-0.330**	-0.151	-0.001	-0.194*	0.161	-0.017
Plant height	G					0.409**	0.601**	0.430**	0.426**	0.466**	0.146	0.143	0.431**	0.070	0.620**	-0.103	0.749**
	P					0.285**	0.472**	0.201*	0.235**	0.277**	0.070	0.179*	0.345**	0.072	0.447**	-0.124	0.447**
Cob length	G						0.259**	0.073	-0.024	0.118	-0.013	0.069	0.360**	0.352**	0.337**	0.162	0.159
	P						0.230**	0.060	-0.014	0.109	-0.027	0.060	0.331**	0.328**	0.294**	0.103	0.134
Cob diameter	G							0.228**	0.300**	0.169*	0.215*	0.175*	0.319**	0.183*	0.245**	-0.060	0.421**
	P							0.157	0.194*	0.110	0.150	0.154	0.300**	0.181*	0.221**	-0.064	0.294**
No. Of grain rows / cob	G								0.113	0.720**	-0.143	0.083	0.142	-0.442**	0.422**	0.051	0.822**
	P								0.110	0.449**	-0.109	0.012	0.076	-0.341**	0.313**	0.050	0.505**
No. Of grains per row	G									0.508**	-0.402**	0.070	0.268**	0.216*	0.437**	-0.417**	0.290**
	P									0.183*	-0.129	0.034	0.144	0.115	0.252**	-0.237**	0.121
Cob yield per plant	G										-0.646**	-0.029	0.092	-0.514**	0.385**	0.022	0.717**
	P										-0.675**	0.012	0.036	-0.383**	0.261**	0.046	0.702**
Shelling %	G											-0.018	0.255**	0.459**	0.013	-0.106	0.069
	P											-0.051	0.172*	0.325**	0.027	-0.080	0.049
100 kernel wt.	G												0.258**	0.149	0.090	0.037	-0.044
	P												0.216*	0.128	0.068	0.023	-0.030
Protein content	G													0.370**	0.498**	0.036	0.367**
	P													0.344**	0.462**	0.019	0.224**
Lysine content	G														0.168*	0.046	-0.247**
	P														0.149	0.046	-0.208*
Tryptophan content	G															-0.240**	0.517**
	P															-0.191*	0.382**
Seed vigour index	G																-0.048
	P																-0.001
Grain yield per plant	G																1.000
	P																1.000

*, ** significant at 5% and 1% level, respectively

Table 4: Genotypic and phenotypic path with Grain yield per plant (g)-F2.

Parent/Hybrids		Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	No. of grain rows per cob	No. of grains per row	Cob yield (g/plant)	Shelling %	100 kernel wt.(g)	Protein content (%)	Lysine content (%)	Tryptophan content (%)	Seed vigour index	Grain yield (g/plant)
Days to tasseling	G	**-0.2147**	0.1905	0.0105	0.0007	0.0007	0.0002	0.0012	-0.0061	-0.1987	0.1914	0.0007	-0.0027	0.0001	0.0076	0.0003	-0.018
	P	**-0.0292**	0.0152	0.0065	0.0000	0.0012	0.0000	0.0000	-0.0007	-0.0968	0.1032	-0.0003	-0.0011	0.0004	0.0006	0.0003	-0.001
Days to silking	G	-0.2155	**0.1897**	0.0107	0.0009	0.0007	0.0003	0.0008	-0.0062	-0.2035	0.1844	0.0007	-0.0025	0.0001	0.0072	0.0003	-0.032
	P	-0.0287	**0.0155**	0.0067	0.0000	0.0014	0.0001	0.0000	-0.0007	-0.1111	0.1225	-0.0005	-0.0010	0.0004	0.0005	0.0005	0.006
Days to maturity	G	-0.1388	0.1248	**0.0162**	-0.0055	0.0005	0.0008	-0.0037	-0.0057	-0.1086	0.0507	0.0024	-0.0032	0.0000	0.0069	0.0018	-0.061
	P	-0.0188	0.0103	**0.0100**	-0.0005	0.0010	0.0002	-0.0001	-0.0008	-0.0357	0.0179	-0.0014	-0.0014	0.0000	0.0005	0.0019	-0.017
Plant height	G	-0.0030	0.0036	-0.0019	**0.0480**	0.0033	-0.0061	0.0340	0.0055	0.5534	0.1245	-0.0008	0.0087	-0.0002	-0.0188	-0.0011	0.749**
	P	-0.0002	0.0000	-0.0008	**0.0058**	0.0042	-0.0013	0.0004	0.0006	0.3713	0.0672	0.0007	0.0032	-0.0011	-0.0012	-0.0014	0.447**
Cob length	G	-0.0173	0.0168	0.0010	0.0196	**0.0081**	-0.0026	0.0058	-0.0003	0.1407	-0.0109	-0.0004	0.0073	-0.0008	-0.0102	0.0018	0.159
	P	-0.0024	0.0014	0.0007	0.0016	**0.0147**	-0.0006	0.0001	0.0000	0.1460	-0.0260	0.0003	0.0031	-0.0050	-0.0008	0.0012	0.134
Cob diameter	G	0.0043	-0.0059	-0.0012	0.0289	0.0021	**-0.0101**	0.0180	0.0039	0.2012	0.1830	-0.0010	0.0065	-0.0004	-0.0074	-0.0007	0.421**
	P	0.0004	-0.0005	-0.0007	0.0027	0.0034	**-0.0027**	0.0003	0.0005	0.1472	0.1439	0.0006	0.0028	-0.0028	-0.0006	-0.0007	0.294**
No. Of grain rows / cob	G	-0.0033	0.0020	-0.0008	0.0207	0.0006	-0.0023	**0.0790**	0.0015	0.8547	-0.1217	-0.0005	0.0029	0.0010	-0.0128	0.0006	0.822**
	P	0.0001	0.0000	-0.0006	0.0012	0.0009	-0.0004	**0.0019**	0.0003	0.6013	-0.1050	0.0001	0.0007	0.0052	-0.0008	0.0006	0.505**
No. Of grains per row	G	0.1019	-0.0921	-0.0072	0.0205	-0.0002	-0.0030	0.0089	**0.0129**	0.6037	-0.3417	-0.0004	0.0054	-0.0005	-0.0132	-0.0045	0.290**
	P	0.0073	-0.0042	-0.0028	0.0014	-0.0002	-0.0005	0.0002	**0.0027**	0.2449	-0.1236	0.0001	0.0014	-0.0018	-0.0007	-0.0027	0.121
Cob yield per plant	G	0.0359	-0.0325	-0.0015	0.0224	0.0010	-0.0017	0.0569	0.0065	**0.4876**	-0.5493	0.0002	0.0019	0.0012	-0.0117	0.0002	0.717**
	P	0.0021	-0.0013	-0.0003	0.0016	0.0016	-0.0003	0.0009	0.0005	**0.3391**	-0.6480	0.0001	0.0003	0.0059	-0.0007	0.0005	0.702**
Shelling %	G	-0.0483	0.0411	0.0010	0.0070	-0.0001	-0.0022	-0.0113	-0.0052	-0.7668	**0.8506**	0.0001	0.0052	-0.0011	-0.0004	-0.0012	0.069
	P	-0.0031	0.0020	0.0002	0.0004	-0.0004	-0.0004	-0.0002	-0.0003	-0.9042	**0.9597**	-0.0002	0.0016	-0.0050	-0.0001	-0.0009	0.049
100 kernel wt.	G	0.0257	-0.0233	-0.0067	0.0069	0.0006	-0.0018	0.0065	0.0009	-0.0343	-0.0154	**-0.0057**	0.0052	-0.0003	-0.0027	0.0004	-0.044
	P	0.0023	-0.0017	-0.0033	0.0010	0.0009	-0.0004	0.0000	0.0001	0.0155	-0.0488	**0.0041**	0.0020	-0.0020	-0.0002	0.0003	-0.030
Protein content	G	0.0283	-0.0231	-0.0026	0.0207	0.0029	-0.0032	0.0112	0.0034	0.1088	0.2172	-0.0015	**0.0202**	-0.0008	-0.0151	0.0004	0.367**
	P	0.0034	-0.0017	-0.0015	0.0020	0.0049	-0.0008	0.0001	0.0004	0.0479	0.1653	0.0009	**0.0094**	-0.0053	-0.0013	0.0002	0.224**
Lysine content	G	0.0062	-0.0056	-0.0001	0.0034	0.0029	-0.0018	-0.0350	0.0028	-0.6098	0.3906	-0.0009	0.0075	**-0.0023**	-0.0051	0.0005	-0.247**
	P	0.0008	-0.0004	0.0000	0.0004	0.0048	-0.0005	-0.0007	0.0003	-0.5134	0.3117	0.0005	0.0032	**-0.0153**	-0.0004	0.0005	-0.208*
Tryptophan content	G	0.0537	-0.0453	-0.0037	0.0298	0.0027	-0.0025	0.0333	0.0056	0.4568	0.0107	-0.0005	0.0101	-0.0004	**-0.0303**	-0.0026	0.517**
	P	0.0061	-0.0031	-0.0020	0.0026	0.0043	-0.0006	0.0006	0.0007	0.3497	0.0259	0.0003	0.0043	-0.0023	**-0.0027**	-0.0022	0.382**
Seed vigour index	G	-0.0060	0.0054	0.0026	-0.0049	0.0013	0.0006	0.0040	-0.0054	0.0266	-0.0905	-0.0002	0.0007	-0.0001	0.0073	**0.0109**	-0.048
	P	-0.0007	0.0007	0.0016	-0.0007	0.0015	0.0002	0.0001	-0.0006	0.0617	-0.0768	0.0001	0.0002	-0.0007	0.0005	**0.0116**	-0.001

Residual are -0.00044

Residual are 0.00386

*, ** significant at 5% and 1% level, respectively

While high indirect negative effect on grain yield was exhibited by number of grains per row *via* shelling % (-0.0868), number of grain rows per cob (-0.0368) and cob length (-0.0367); 100 kernel weight *via* shelling % (-0.0189), number of grain rows per cob (-0.0150) and plant height (-0.0188); number of grain rows per cob *via* cob diameter (-0.0096), cob yield per plant (-0.0095) and 100 kernel weight (-0.0085) in F_1 while high indirect effect on grain yield per plant was exhibited by shelling percent (0.9597) *via* protein content, lysine content, tryptophan, days to tasseling, days to silking, days to maturity and plant height in F_2 generation. Similar results were found by Suvarna *et al.* (2008) and Muneeb *et al.* (2013).

Phenotypic path coefficient. Rafiq *et al.* (2010) reported the similar results in accordance with the results from the current study at phenotypic level cob yield per plant (0.7796) followed by shelling % (0.4604), number of grains per row (0.0401), cob length (0.0400), days to tasseling (0.0400), number of grain rows per cob (0.0377), tryptophan content (0.0261), 100 kernel weight (0.0219) and lysine content (0.0064) had highest positive direct effect on grain yield per plant; while protein content (-0.0446), days to silking (-0.0452), plant height (-0.0092), cob diameter (-0.0127), seed vigor index (-0.0048) and days to maturity (-0.0223) showed negative and direct effect on grain yield per plant. Estimates of residual effect in this path was (0.06445).

High indirect positive effect on grain yield per plant was exhibited by cob yield per plant *via* number of grains per row (0.0.4642) followed by 100 kernel weight (0.3475), cob diameter (0.3346), number of grain rows per cob (0.2006), plant height (0.1794), tryptophan content (0.1467), cob length (0.1235) and days to maturity (0.0112); shelling % *via* number of grains per row (0.1916) followed by 100 kernel weight (0.1301) and cob length (0.0894); number of grains per row *via* cob yield per plant(0.0239), shelling % (0.0167) and cob diameter (0.0102) while at phenotypic level the high indirect negative effect on grain yield was exhibited by protein content *via* tryptophan content (-0.0218), cob diameter (-0.0174) and days to silking (-0.0151); days to silking *via* days to tasseling (-0.0441), days to maturity (-0.0305) and cob diameter (-0.0209); plant height *via* tryptophan content (-0.0025), days to silking (-0.0026) and cob yield per plant (-0.0021). The result observed were in accordance with the findings of Jemal *et al.* (2020) and Bekele *et al.* (2014).

Thus, on the basis of both genotypic and phenotypic path coefficient analysis, cob yield per plant, number of grains per row, 100 kernel weight, shelling and number of grain rows per cob were identified as most important positive direct contributors towards grain yield per plant.

CONCLUSIONS

In this study characters *viz.*, plant height, cob length, cob diameter, number of grain rows per cob, number of grains per row and cob yield per plant were found to be the most crucial characters in achieving high grain yield in quality protein maize as they showed significant positive correlation at genotypic and phenotypic correlation along with high positive direct effects at both genotypic and phenotypic level on grain yield per plant in both the generations. Therefore, we need to consider using these traits as the selection criterion to improve grain yield in QPM.

FUTURE SCOPE

Through the studies of correlation and path coefficient analyses for grain yield and its contributing traits in Quality Protein Maize. Genotypic correlation coefficients showed that all the traits considered in our study have positive correlation with grain yield per plant except days to tasseling, days to silking, lysine content, days to maturity, protein content and seed vigor index. Genotypic correlations among traits affecting grain yield explain the true association as they exclude any environmental influences. Hence, it can be concluded that plant height, cob length, cob diameter are the best traits for selection to improve grain yield per plant of the maize genotypes tested in our study.

Acknowledgements. This work was done by author for the Doctoral program thesis at C. S. Azad University of Agriculture and Technology, Kanpur, U.P. The author is highly grateful for the research facilities provided by the university and sincerely acknowledge the support of Dr. R. K. Yadav, Professor and advisor for the support during whole research work.

Conflict of interest. None.

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How to cite this article: Harshit Tripathi, R.K. Yadav, Lokendra Singh, H.C. Singh, Shweta, Pawan Kumar Saini, Swapnil Dwivedi and Pratyksh Pandey (2023). Correlation and path coefficient analyses for grain yield and its contributing traits in Quality Protein Maize (*Zea mays* L.). *Biological Forum – An International Journal*, *15*(10): 47-54.