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Effects of Various Morphological Traits on Yield Attributes of Cowpea

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A B S T R A C T

Cowpea **(***Vigna unguiculata*) is an important grain legume of the tropics and subtropics, covering Asia, Africa, and Central and South America, as well as parts of southern Europe and the United States of America. The present investigation was carried out at Vegetable Research Farm, Department of Horticulture, SHUATS, Allahabad during the year 2017-2018. The experiment was laid out in Randomized Block Design with three replications having twenty genotypes. The path coefficient analysis is the standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effect of independent variables on the dependent variable. Genotypic and Phenotypic Path Coefficient Analysis revealed that seed yield (2.28, 1.27) had greatest positive direct effect on pod yield/plant.

Introduction

Cowpea, *Vigna unguiculata* (L.) Walp, Leguminosae (2n= 2x = 22), is an essential food crop in less-developed countries of the tropics and subtropics, especially in sub-Saharan Africa, Asia, and Central and South America (Singh *et al.*, 1997). The wild forms are endemic to Africa (Pasquet, 1999; Coulibaly *et al.*, 2002). It is the second most important grain legume crop after groundnut as well as second only to cereals (Blade *et al.*, 1997). As cowpea is native to West Africa where wild and weedy forms exist in many parts of the region (Ng and Marechal, 1985), it is one of the most variable species and genetic variability is the basis of genetic enhancement.

Materials and Methods

The experiment was conducted at Vegetable Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higg in bottom University of Agriculture, Technology and Sciences, Allahabad (UP) during 2017-2018. The experiment comprised of 20 genotypes of cowpea collected from IIVR, Varanasi. Parameters under study were Plant height at first flowering (cm), Plant height at maturity (cm), Number of nodes on the main stem, Days to first flower formation, Days to first pod formation, Days to 50 % flowering, Days to 50 % maturity, Number of pods per peduncle, Number of pods per plant, Number of peduncle per plant, Dry Pod weight (g),

Pod length (cm), Pod yield (kg/ha), Test weight (g), Seed yield (kg/ha), Number of seeds per pod, Number of seeds per plant, Seed weight per plant (g), Protein content (%), TSS content (^{0}brix). Path coefficient analysis suggested by Wright (1921) and illustrated by Dewey and Lu (1959) was carried out separately to know the direct and indirect effects of the important component traits on fruit yield per plant.

Standard path coefficients which are the standardised partial regression coefficient were obtained by solving the following set of 'P' simultaneous equations through the use of Doolittle technique as given by Goulden (1959).

Results and Discussion

Path coefficient analysis

Correlation coefficient values do not reveal the real association pattern of the independent variables with the dependent one. This approach is more important to comprehend genetic makeup of independent trait when the determining component characters are correlated.

Genotypic path coefficient analysis

Path coefficients which are worked out from genotypic correlation coefficient are referred to as genotypic path coefficient analysis. It splits the genotypic correlation coefficient into the measures of direct and indirect effect. In other words, it measures the direct and indirect contribution of various independent characters towards a dependent character, say yield in plant breeding experiments.

Phenotypic path coefficient analysis

Path coefficients which are worked out from phenotypic correlation coefficient are referred to as phenotypic path coefficient analysis. All possible phenotypic correlation coefficients among various characters under study are used for the estimation of phenotypic path. It splits the phenotypic correlation coefficient into the measures of direct and indirect effects.

Seed yield

Genotypic path coefficient

At genotypic level, plant height at flowering (0.6761), nodes on main stem (0.2386), days to first pod formation (0.3931), pods per peduncle (0.0132), pods per plant (0.3658), dry pod weight (0.1536), seeds per pod (0.4887), seeds per plant (0.0126), Test weight (0.3608), TSS (0.0576), protein content (0.0392), pod yield (0.4497) had direct positive effect on seed yield per hectare. Similar findings were reported by Kwon *and Kwala* (2017) for pods per plant, seeds per pod, plant height.

However, the negative direct effect on seed yield per plant was exerted by plant height at maturity (-0.7028), days to first flowering (-0.1165), days to 50 % flowering (-0.2075), days to 50 % maturity (-0.1249), peduncles per plant (-0.0843), pod length (-0.0432), seed weight per plant (-0.0325) at genotypic level. Results are represented in table 1a and 1b.

Phenotypic path coefficient

At phenotypic level, plant height at flowering (0.0711), nodes on main stem (0.0652), days to first flowering (0.0132), days to 50 % flowering (0.0953), days to 50 % maturity (0.0149), dry pod weight (0.1946), seeds per pod (0.3176), seeds per plant (0.3493), seed weight per plant(0.0458), Test weight (0.3663), TSS (0.0331), protein content % (0.0003), pod yield (0.6049) had direct positive effect on seed yield per plant. Results are represented in table 2a and 2b.

Table.1a Genotypic path matrix of seed yield

No.	Character	Plant Height At Flowering (cm)	Plant Height At Maturity (cm)	Nodes On Main Stem	Days to First Pod Formation	Days to First Flowering	Days to 50 % Flowering	Days to 50 % Maturity	Peduncles/ Plant	Pods/ Peduncle	Pods / Plant
1	Plant Height at Flowering (cm)	**0.6761**	0.6745	0.0994	0.0548	0.0404	0.0799	0.1403	-0.2770	0.0902	-0.3254
2	Plant Height at Maturity (cm)	-0.7012	**-0.7028**	-0.1199	-0.0642	-0.0524	-0.0968	-0.1460	0.2776	-0.0900	0.3097
3	Nodes On Main Stem	0.0351	0.0407	**0.2386**	0.1151	0.1232	0.1570	0.1315	-0.0149	0.0472	0.0705
4	Days to First Pod Formation	0.0318	0.0359	0.1896	**0.3931**	0.3912	0.3713	0.3271	-0.0256	0.1391	0.0901
5	Days to First Flowering	-0.0070	-0.0087	-0.0602	-0.1160	**-0.1165**	-0.1113	-0.0930	0.0006	-0.0439	-0.0363
6	Days to 50 % Flowering	-0.0245	-0.0286	-0.1366	-0.1960	-0.1982	**-0.2075**	-0.1806	0.0216	-0.0838	-0.0693
7	Days to 50 % Maturity	-0.0259	-0.0260	-0.0688	-0.1040	-0.0997	-0.1087	**-0.1249**	0.0390	-0.0489	-0.0029
8	Peduncles/ Plant	0.0345	0.0333	0.0053	0.0055	0.0004	0.0088	0.0263	**-0.0843**	0.0343	-0.0427
9	Pods/ Peduncle	0.0018	0.0017	0.0026	0.0047	0.0050	0.0053	0.0051	-0.0054	**0.0132**	0.0010
10	Pods / Plant	-0.1761	-0.1612	0.1080	0.0838	0.1139	0.1222	0.0084	0.1853	0.0267	**0.3658**
11	Dry Pod Weight (g)	0.0207	0.0250	0.0713	0.0695	0.0764	0.0606	0.0266	0.0480	0.0159	0.0493
12	Pod Length (cm)	-0.0062	-0.0053	0.0021	-0.0095	-0.0088	-0.0096	-0.0162	0.0058	-0.0213	0.0093
13	Seeds/ Pod	0.0303	0.0234	-0.0151	-0.1494	-0.1391	-0.1310	-0.0621	-0.0010	0.0124	0.0081
14	Seeds/ Plant	-0.0051	-0.0048	0.0035	0.0013	0.0024	0.0027	-0.0001	0.0061	0.0006	0.0113
15	Seed Weight/ Plant (g)	0.0104	0.0101	-0.0093	0.0064	0.0043	0.0007	0.0075	-0.0089	-0.0037	-0.0213
16	Test Weight (g)	0.1655	0.1571	0.0052	-0.0659	-0.0790	-0.0570	-0.0419	-0.1118	-0.0379	-0.1607
17	TSS (^{0}brix)	0.0116	0.0135	0.0183	0.0052	0.0090	0.0156	0.0093	0.0111	-0.0041	0.0193
18	Protein Content (%)	-0.0118	-0.0110	0.0135	0.0064	0.0086	0.0100	0.0064	0.0118	-0.0019	0.0143
19	Pod Yield (kg/ha)	-0.1435	-0.1250	0.2136	0.1783	0.2059	0.1911	0.0610	0.1779	0.0761	0.3812
20	**Seed Yield (kg/ha)**	**-0.0835**	**-0.0583**	**0.5610**	**0.2192**	**0.2870**	**0.3033**	**0.0849**	**0.2560**	**0.1202**	**0.6711**
	Partial R^2	-0.0564	0.0410	0.1339	0.0862	-0.0335	-0.0629	-0.0106	-0.0216	0.0016	0.2455

R SQUARE =1.0003 , RESIDUAL EFFECT =SQRT(1- 1.0003)

Table.1b Genotypic Path Matrix of seed yield (cont.)

No.	Character	Dry Pod Weight (g)	Pod Length (cm)	Seeds/ Pod	Seeds/ Plant	Seed Weight/ Plant (g)	Test Weight (g)	TSS (^{0}brix)	Protein Content (%)	Pod Yield (kg/ha)
1	Plant Height at Flowering (cm)	0.0911	0.0966	0.0419	-0.2751	-0.2165	0.3100	0.1365	-0.2033	-0.2157
2	Plant Height at Maturity (cm)	-0.1142	-0.0862	-0.0336	0.2665	0.2183	-0.3059	-0.1642	0.1963	0.1954
3	Nodes On Main Stem	0.1107	-0.0114	-0.0074	0.0668	0.0682	0.0034	0.0757	0.0822	0.1133
4	Days to First Pod Formation	0.1779	0.0860	-0.1202	0.0413	-0.0772	-0.0718	0.0356	0.0640	0.1559
5	Days to First Flowering	-0.0580	-0.0236	0.0332	-0.0223	0.0152	0.0255	-0.0182	-0.0256	-0.0534
6	Days to 50 % Flowering	-0.0819	-0.0462	0.0556	-0.0451	0.0044	0.0328	-0.0561	-0.0528	-0.0882
7	Days to 50 % Maturity	-0.0217	-0.0468	0.0159	0.0007	0.0287	0.0145	-0.0202	-0.0205	-0.0169
8	Peduncles/ Plant	-0.0264	0.0113	0.0002	-0.0412	-0.0229	0.0261	-0.0163	-0.0253	-0.0333
9	Pods/ Peduncle	0.0014	0.0065	0.0003	0.0007	0.0015	-0.0014	-0.0009	-0.0006	0.0022
10	Pods / Plant	0.1174	-0.0789	0.0060	0.3282	0.2400	-0.1628	0.1227	0.1331	0.3100
11	Dry Pod Weight (g)	**0.1536**	0.0183	0.0044	0.0463	0.0050	-0.0215	0.0397	0.0160	0.1022
12	Pod Length (cm)	-0.0051	**-0.0432**	-0.0173	0.0005	0.0002	0.0039	-0.0053	0.0177	0.0082
13	Seeds/ Pod	0.0139	0.1957	**0.4887**	0.2167	0.2302	-0.0163	-0.0022	-0.1548	-0.0009
14	Seeds/ Plant	0.0038	-0.0002	0.0056	**0.0126**	0.0099	-0.0051	0.0041	0.0029	0.0094
15	Seed Weight/ Plant (g)	-0.0011	0.0001	-0.0153	-0.0256	**-0.0325**	0.0027	-0.0045	0.0020	-0.0151
16	Test Weight (g)	-0.0505	-0.0323	-0.0120	-0.1463	-0.0294	**0.3608**	-0.0695	-0.0563	-0.1499
17	TSS (^{0}brix)	0.0149	0.0070	-0.0003	0.0189	0.0080	-0.0111	**0.0576**	0.0189	0.0145
18	Protein Content (%)	0.0041	-0.0160	-0.0124	0.0090	-0.0024	-0.0061	0.0129	**0.0392**	0.0141
19	Pod Yield (kg/ha)	0.2993	-0.0851	-0.0008	0.3354	0.2088	-0.1869	0.1133	0.1617	**0.4497**
20	**Seed Yield (kg/ha)**	**0.6292**	**-0.0485**	**0.4325**	**0.7879**	**0.6573**	**-0.0092**	**0.2406**	**0.1948**	**0.8015**
	Partial R^2	0.0967	0.0021	0.2113	0.0099	-0.0214	-0.0033	0.0139	0.0076	0.3604

R SQUARE =1.0003, RESIDUAL EFFECT =SQRT(1- 1.0003)

Table.2a Phenotypic path matrix of seed yield

No.	Character	Plant Height At Flowering (cm)	Plant Height At Maturity (cm)	Nodes On Main Stem	Days to First Pod Formation	Days to First Flowering	Days to 50 % Flowering	Days to 50 % Maturity	Peduncles/ Plant	Pods/ Peduncle	Pods / Plant
1	Plant Height at Flowering (cm)	**0.0711**	0.0709	0.0100	0.0057	0.0042	0.0084	0.0148	-0.0281	0.0086	-0.0340
2	Plant Height at Maturity (cm)	-0.1262	**-0.1266**	-0.0209	-0.0113	-0.0093	-0.0171	-0.0263	0.0479	-0.0144	0.0554
3	Nodes On Main Stem	0.0091	0.0108	**0.0652**	0.0292	0.0324	0.0397	0.0340	-0.0021	0.0132	0.0181
4	Days to First Pod Formation	-0.0048	-0.0053	-0.0268	**-0.0596**	-0.0583	-0.0549	-0.0486	0.0039	-0.0195	-0.0132
5	Days to First Flowering	0.0008	0.0010	0.0065	0.0129	**0.0132**	0.0123	0.0104	0.0000	0.0045	0.0040
6	Days to 50 % Flowering	0.0112	0.0129	0.0582	0.0878	0.0892	**0.0953**	0.0822	-0.0089	0.0348	0.0313
7	Days to 50 % Maturity	0.0031	0.0031	0.0078	0.0121	0.0118	0.0129	**0.0149**	-0.0045	0.0053	0.0004
8	Peduncles/ Plant	0.0247	0.0237	0.0021	0.0041	0.0001	0.0058	0.0187	**-0.0625**	0.0249	-0.0304
9	Pods/ Peduncle	-0.0003	-0.0003	-0.0005	-0.0007	-0.0008	-0.0008	-0.0008	0.0009	**-0.0022**	-0.0001
10	Pods / Plant	0.0721	0.0660	-0.0418	-0.0335	-0.0461	-0.0496	-0.0036	-0.0734	-0.0096	**-0.1508**
11	Dry Pod Weight (g)	0.0244	0.0299	0.0812	0.0857	0.0937	0.0738	0.0312	0.0556	0.0165	0.0609
12	Pod Length (cm)	-0.0134	-0.0115	0.0045	-0.0196	-0.0186	-0.0209	-0.0351	0.0125	-0.0425	0.0187
13	Seeds/ Pod	0.0195	0.0148	-0.0095	-0.0942	-0.0880	-0.0826	-0.0398	0.0005	0.0100	0.0057
14	Seeds/ Plant	-0.1419	-0.1323	0.0938	0.0359	0.0664	0.0748	-0.0018	0.1656	0.0166	0.3117
15	Seed Weight/ Plant (g)	-0.0146	-0.0142	0.0123	-0.0089	-0.0060	-0.0008	-0.0105	0.0121	0.0047	0.0301
16	Test Weight (g)	0.1678	0.1592	0.0050	-0.0654	-0.0797	-0.0570	-0.0424	-0.1099	-0.0354	-0.1621
17	TSS (^{0}brix)	0.0062	0.0073	0.0101	0.0023	0.0047	0.0077	0.0049	0.0067	-0.0025	0.0100
18	Protein Content (%)	-0.0001	-0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001	0.0000	0.0001
19	Pod Yield (kg/ha)	-0.1925	-0.1677	0.2736	0.2374	0.2749	0.2535	0.0815	0.2316	0.0933	0.5096
20	**Seed Yield (kg/ha)**	**-0.0840**	**-0.0583**	**0.5309**	**0.2200**	**0.2837**	**0.3005**	**0.0838**	**0.2481**	**0.1064**	**0.6654**
	Partial R^2	-0.0060	0.0074	0.0346	-0.0131	0.0037	0.0286	0.0012	-0.0155	-0.0002	-0.1003

R SQUARE = 1.0003, RESIDUAL EFFECT =SQRT(1- 1.0003)

Table.2b Phenotypic path matrix of seed yield (cont.)

No.	Character	Dry Pod Weight (g)	Pod Length (cm)	Seeds/ Pod	Seeds/ Plant	Seed Weight/ Plant (g)	Test Weight (g)	TSS (^{0}brix)	Protein Content (%)	Pod Yield (kg/ha)
1	Plant Height at Flowering (cm)	0.0089	0.0100	0.0044	-0.0289	-0.0227	0.0326	0.0132	-0.0195	-0.0226
2	Plant Height at Maturity (cm)	-0.0195	-0.0153	-0.0059	0.0479	0.0393	-0.0550	-0.0279	0.0323	0.0351
3	Nodes On Main Stem	0.0272	-0.0031	-0.0019	0.0175	0.0175	0.0009	0.0198	0.0227	0.0295
4	Days to First Pod Formation	-0.0263	-0.0123	0.0177	-0.0061	0.0116	0.0107	-0.0042	-0.0095	-0.0234
5	Days to First Flowering	0.0063	0.0026	-0.0036	0.0025	-0.0017	-0.0029	0.0019	0.0027	0.0060
6	Days to 50 % Flowering	0.0361	0.0209	-0.0248	0.0204	-0.0017	-0.0148	0.0221	0.0221	0.0400
7	Days to 50 % Maturity	0.0024	0.0055	-0.0019	-0.0001	-0.0034	-0.0017	0.0022	0.0022	0.0020
8	Peduncles/ Plant	-0.0178	0.0082	-0.0001	-0.0296	-0.0165	0.0187	-0.0127	-0.0194	-0.0239
9	Pods/ Peduncle	-0.0002	-0.0010	-0.0001	-0.0001	-0.0002	0.0002	0.0002	0.0000	-0.0003
10	Pods / Plant	-0.0472	0.0296	-0.0027	-0.1346	-0.0990	0.0667	-0.0458	-0.0486	-0.1270
11	Dry Pod Weight (g)	**0.1946**	0.0233	0.0049	0.0566	0.0069	-0.0263	0.0435	0.0122	0.1265
12	Pod Length (cm)	-0.0114	**-0.0953**	-0.0375	0.0011	-0.0004	0.0084	-0.0094	0.0369	0.0177
13	Seeds/ Pod	0.0080	0.1251	**0.3176**	0.1398	0.1492	-0.0106	-0.0019	-0.0902	-0.0005
14	Seeds/ Plant	0.1016	-0.0042	0.1537	**0.3493**	0.2744	-0.1416	0.1075	0.0739	0.2601
15	Seed Weight/ Plant (g)	0.0016	0.0002	0.0215	0.0360	**0.0458**	-0.0037	0.0057	-0.0028	0.0212
16	Test Weight (g)	-0.0496	-0.0322	-0.0122	-0.1485	-0.0298	**0.3663**	-0.0661	-0.0526	-0.1520
17	TSS (^{0}brix)	0.0074	0.0033	-0.0002	0.0102	0.0041	-0.0060	**0.0331**	0.0115	0.0077
18	Protein Content (%)	0.0000	-0.0001	-0.0001	0.0001	0.0000	0.0000	0.0001	**0.0003**	0.0001
19	Pod Yield (kg/ha)	0.3931	-0.1121	-0.0009	0.4505	0.2800	-0.2510	0.1407	0.1972	**0.6049**
20	**Seed Yield (kg/ha)**	**0.6153**	**-0.0469**	**0.4279**	**0.7841**	**0.6534**	**-0.0092**	**0.2222**	**0.1712**	**0.8009**
	Partial R^2	0.1197	0.0045	0.1359	0.2739	0.0300	-0.0034	0.0074	0.0000	0.4845

R SQUARE = 1.0003, RESIDUAL EFFECT =SQRT(1- 1.000)

Table.3 Genotypic path matrix of pod yield

No.	Character	Plant Height At Flowering (cm)	Plant Height At Maturity (cm)	Nodes On Main Stem	Days to First Pod Formation	Days to First Flowering	Days to 50 % Flowering	Days to 50 % Maturity	Peduncles/ Plant	Pods/ Peduncle	Pods / Plant
1	Plant Height at Flowering (cm)	**-1.5359**	-1.5324	-0.2259	-0.1244	-0.0917	-0.1816	-0.3188	0.6294	-0.2049	0.7393
2	Plant Height at Maturity (cm)	1.6023	**1.6060**	0.2740	0.1467	0.1197	0.2211	0.3336	-0.6342	0.2057	-0.7078
3	Nodes On Main Stem	-0.0790	-0.0916	**-0.5368**	-0.2589	-0.2772	-0.3533	-0.2958	0.0335	-0.1062	-0.1585
4	Days to First Pod Formation	-0.0721	-0.0814	-0.4296	**-0.8908**	-0.8864	-0.8413	-0.7411	0.0580	-0.3153	-0.2041
5	Days to First Flowering	0.0148	0.0184	0.1277	0.2462	**0.2474**	0.2363	0.1973	-0.0013	0.0932	0.0770
6	Days to 50 % Flowering	0.0564	0.0657	0.3140	0.4506	0.4557	**0.4771**	0.4153	-0.0498	0.1927	0.1594
7	Days to 50 % Maturity	0.0562	0.0562	0.1492	0.2252	0.2159	0.2356	**0.2707**	-0.0844	0.1059	0.0062
8	Peduncles/ Plant	-0.0758	-0.0730	-0.0116	-0.0120	-0.0009	-0.0193	-0.0577	**0.1849**	-0.0753	0.0937
9	Pods/ Peduncle	-0.0047	-0.0045	-0.0070	-0.0126	-0.0134	-0.0143	-0.0139	0.0145	**-0.0355**	-0.0026
10	Pods / Plant	0.4466	0.4089	-0.2740	-0.2126	-0.2889	-0.3100	-0.0213	-0.4699	-0.0678	**-0.9278**
11	Dry Pod Weight (g)	-0.0496	-0.0599	-0.1710	-0.1668	-0.1833	-0.1455	-0.0639	-0.1153	-0.0381	-0.1183
12	Pod Length (cm)	0.0167	0.0143	-0.0056	0.0255	0.0237	0.0260	0.0437	-0.0157	0.0574	-0.0252
13	Seeds/ Pod	-0.0726	-0.0559	0.0361	0.3579	0.3332	0.3138	0.1487	0.0023	-0.0297	-0.0193
14	Seeds/ Plant	-0.0348	-0.0324	0.0239	0.0090	0.0164	0.0186	-0.0005	0.0418	0.0044	0.0767
15	Seed Weight/ Plant (g)	-0.0178	-0.0173	0.0159	-0.0109	-0.0073	-0.0012	-0.0128	0.0151	0.0064	0.0365
16	Test Weight (g)	-0.3784	-0.3592	-0.0119	0.1507	0.1806	0.1304	0.0957	0.2557	0.0866	0.3674
17	TSS (^{0}brix)	-0.0282	-0.0327	-0.0444	-0.0127	-0.0218	-0.0378	-0.0226	-0.0270	0.0101	-0.0469
18	Protein Content (%)	0.0280	0.0260	-0.0320	-0.0151	-0.0204	-0.0236	-0.0153	-0.0279	0.0045	-0.0338
19	Seed Yield (kg/ha)	-0.1910	-0.1334	1.2837	0.5015	0.6567	0.6940	0.1942	0.5859	0.2751	1.5357
20	**Pod Yield (kg/ha)**	**-0.3191**	**-0.2780**	**0.4749**	**0.3965**	**0.4579**	**0.4250**	**0.1356**	**0.3957**	**0.1692**	**0.8476**
	Partial R^2	0.4901	-0.4465	-0.2549	-0.3532	0.1133	0.2028	0.0367	0.0732	-0.0060	-0.7864

R SQUARE = 1.0003, RESIDUAL EFFECT =SQRT(1- 1.0003)

Table.4 Genotypic path matrix of pod yield (cont.)

No.	Character	Dry Pod Weight (g)	Pod Length cm	Seeds/ Pod	Seeds/ Plant	Seed Weight/ Plant (g)	Test Weight (g)	TSS (^{0}brix)	Protein Content (%)	Seed Yield (kg/ha)
1	Plant Height at Flowering (cm)	-0.2069	-0.2194	-0.0953	0.6249	0.4918	-0.7043	-0.3102	0.4618	0.1282
2	Plant Height at Maturity (cm)	0.2609	0.1970	0.0768	-0.6089	-0.4988	0.6990	0.3753	-0.4485	-0.0936
3	Nodes On Main Stem	-0.2490	0.0256	0.0166	-0.1502	-0.1535	-0.0077	-0.1703	-0.1850	-0.3012
4	Days to First Pod Formation	-0.4032	-0.1948	0.2724	-0.0935	0.1749	0.1627	-0.0807	-0.1450	-0.1952
5	Days to First Flowering	0.1230	0.0502	-0.0704	0.0474	-0.0323	-0.0541	0.0387	0.0543	0.0710
6	Days to 50 % Flowering	0.1883	0.1062	-0.1279	0.1037	-0.0101	-0.0754	0.1291	0.1213	0.1447
7	Days to 50 % Maturity	0.0469	0.1013	-0.0344	-0.0014	-0.0622	-0.0314	0.0438	0.0444	0.0230
8	Peduncles/ Plant	0.0578	-0.0249	-0.0004	0.0905	0.0504	-0.0573	0.0357	0.0555	0.0473
9	Pods/ Peduncle	-0.0037	-0.0175	-0.0009	-0.0018	-0.0041	0.0037	0.0026	0.0017	-0.0043
10	Pods / Plant	-0.2978	0.2002	-0.0153	-0.8325	-0.6087	0.4131	-0.3111	-0.3376	-0.6227
11	Dry Pod Weight (g)	**-0.3686**	-0.0438	-0.0104	-0.1110	-0.0120	0.0516	-0.0953	-0.0385	-0.2319
12	Pod Length (cm)	0.0139	**0.1167**	0.0467	-0.0014	-0.0005	-0.0104	0.0142	-0.0476	-0.0057
13	Seeds/ Pod	-0.0332	-0.4686	**-1.1703**	-0.5190	-0.5512	0.0389	0.0052	0.3707	-0.5061
14	Seeds/ Plant	0.0257	-0.0011	0.0379	**0.0855**	0.0673	-0.0346	0.0281	0.0196	0.0673
15	Seed Weight/ Plant (g)	0.0018	-0.0002	0.0262	0.0438	**0.0556**	-0.0045	0.0077	-0.0034	0.0365
16	Test Weight (g)	0.1156	0.0738	0.0274	0.3345	0.0673	**-0.8251**	0.1590	0.1287	0.0076
17	TSS (^{0}brix)	-0.0361	-0.0170	0.0006	-0.0460	-0.0193	0.0269	**-0.1398**	-0.0458	-0.0336
18	Protein Content (%)	-0.0097	0.0380	0.0295	-0.0214	0.0057	0.0145	-0.0305	**-0.0930**	-0.0181
19	Seed Yield (kg/ha)	1.4397	-0.1109	0.9896	1.8028	1.5041	-0.0210	0.5505	0.4458	**2.2881**
20	**Pod Yield (kg/ha)**	**0.6655**	**-0.1893**	**-0.0018**	**0.7459**	**0.4643**	**-0.4155**	**0.2519**	**0.3596**	**0.8015**
	Partial R^2	-0.2453	-0.0221	0.0021	0.0637	0.0258	0.3429	-0.0352	-0.0334	1.8338

R SQUARE = 1.0003, RESIDUAL EFFECT =SQRT(1- 1.0003)

Table.5 Phenotypic path matrix of pod yield

No	Character	Plant Height At Flowering (cm)	Plant Height At Maturity (cm)	Nodes On Main Stem	Days to First Pod Formation	Days to First Flowering	Days to 50 % Flowering	Days to 50 % Maturity	Peduncles/ Plant	Pods/ Peduncle	Pods / Plant
1	Plant Height at Flowering (cm)	**-0.3892**	-0.3881	-0.0545	-0.0312	-0.0227	-0.0457	-0.0808	0.1537	-0.0473	0.1860
2	Plant Height at Maturity (cm)	0.4478	**0.4490**	0.0743	0.0402	0.0331	0.0608	0.0931	-0.1701	0.0510	-0.1966
3	Nodes On Main Stem	-0.0126	-0.0149	**-0.0902**	-0.0405	-0.0448	-0.0550	-0.0471	0.0030	-0.0183	-0.0250
4	Days to First Pod Formation	0.0135	0.0151	0.0758	**0.1689**	0.1652	0.1555	0.1376	-0.0110	0.0554	0.0375
5	Days to First Flowering	-0.0045	-0.0057	-0.0385	-0.0758	**-0.0775**	-0.0725	-0.0613	0.0002	-0.0264	-0.0237
6	Days to 50 % Flowering	-0.0233	-0.0269	-0.1212	-0.1828	-0.1859	**-0.1986**	-0.1713	0.0185	-0.0725	-0.0653
7	Days to 50 % Maturity	0.0099	0.0099	0.0250	0.0389	0.0378	0.0412	**0.0478**	-0.0143	0.0169	0.0011
8	Peduncles/ Plant	-0.0285	-0.0273	-0.0024	-0.0047	-0.0002	-0.0067	-0.0216	**0.0722**	-0.0288	0.0351
9	Pods/ Peduncle	0.0041	0.0039	0.0069	0.0112	0.0116	0.0124	0.0121	-0.0136	**0.0340**	0.0022
10	Pods / Plant	-0.1388	-0.1272	0.0805	0.0645	0.0888	0.0955	0.0070	0.1415	0.0185	**0.2906**
11	Dry Pod Weight (g)	-0.0163	-0.0200	-0.0542	-0.0573	-0.0626	-0.0493	-0.0209	-0.0372	-0.0111	-0.0407
12	Pod Length (cm)	0.0098	0.0084	-0.0033	0.0143	0.0136	0.0152	0.0257	-0.0091	0.0310	-0.0137
13	Seeds/ Pod	-0.0254	-0.0192	0.0123	0.1224	0.1144	0.1074	0.0518	-0.0006	-0.0131	-0.0074
14	Seeds/ Plant	0.1739	0.1621	-0.1149	-0.0440	-0.0813	-0.0916	0.0023	-0.2029	-0.0203	-0.3818
15	Seed Weight/ Plant (g)	0.0041	0.0040	-0.0035	0.0025	0.0017	0.0002	0.0029	-0.0034	-0.0013	-0.0085
16	Test Weight (g)	-0.2219	-0.2106	-0.0066	0.0865	0.1054	0.0754	0.0560	0.1453	0.0468	0.2143
17	TSS (^{0}brix)	-0.0096	-0.0114	-0.0157	-0.0036	-0.0074	-0.0120	-0.0077	-0.0105	0.0039	-0.0157
18	Protein Content (%)	-0.0040	-0.0037	0.0050	0.0023	0.0030	0.0033	0.0022	0.0045	-0.0002	0.0046
19	Seed Yield (kg/ha)	-0.1072	-0.0745	0.6776	0.2808	0.3621	0.3835	0.1070	0.3167	0.1358	0.8493
20	**Pod Yield (kg/ha)**	**-0.3182**	**-0.2772**	**0.4522**	**0.3925**	**0.4544**	**0.4191**	**0.1348**	**0.3828**	**0.1542**	**0.8424**
	Partial R^2	0.1239	-0.1245	-0.0408	0.0663	-0.0352	-0.0832	0.0064	0.0276	0.0053	0.2448

R SQUARE = 1.0003, RESIDUAL EFFECT =SQRT(1- 1.0003)

Table.6 Phenotypic path matrix of pod yield (cont.)

No	Character	Dry Pod Weight (g)	Pod Length (cm)	Seeds/ Pod	Seeds/ Plant	Seed Weight/ Plant (g)	Test Weight (g)	TSS (^{0}brix)	Protein Content (%)	Seed Yield (kg/ha)
1	Plant Height at Flowering (cm)	-0.0489	-0.0547	-0.0239	0.1582	0.1243	-0.1783	-0.0724	0.1070	0.0327
2	Plant Height at Maturity (cm)	0.0691	0.0543	0.0209	-0.1701	-0.1393	0.1952	0.0990	-0.1144	-0.0262
3	Nodes On Main Stem	-0.0376	0.0043	0.0027	-0.0242	-0.0242	-0.0012	-0.0275	-0.0314	-0.0479
4	Days to First Pod Formation	0.0744	0.0347	-0.0501	0.0174	-0.0327	-0.0302	0.0119	0.0269	0.0371
5	Days to First Flowering	-0.0373	-0.0151	0.0215	-0.0147	0.0101	0.0169	-0.0110	-0.0159	-0.0220
6	Days to 50 % Flowering	-0.0753	-0.0435	0.0516	-0.0425	0.0036	0.0309	-0.0461	-0.0460	-0.0597
7	Days to 50 % Maturity	0.0077	0.0176	-0.0060	-0.0003	-0.0109	-0.0055	0.0071	0.0072	0.0040
8	Peduncles/ Plant	0.0206	-0.0095	0.0001	0.0342	0.0190	-0.0217	0.0147	0.0224	0.0179
9	Pods/ Peduncle	0.0029	0.0152	0.0011	0.0016	0.0035	-0.0033	-0.0026	-0.0005	0.0036
10	Pods / Plant	0.0909	-0.0571	0.0052	0.2593	0.1908	-0.1286	0.0882	0.0937	0.1933
11	Dry Pod Weight (g)	**-0.1300**	-0.0156	-0.0033	-0.0378	-0.0046	0.0176	-0.0291	-0.0081	-0.0800
12	Pod Length (cm)	0.0084	**0.0696**	0.0274	-0.0008	0.0003	-0.0061	0.0069	-0.0270	-0.0033
13	Seeds/ Pod	-0.0103	-0.1627	**-0.4129**	-0.1817	-0.1940	0.0138	0.0024	0.1173	-0.1767
14	Seeds/ Plant	-0.1245	0.0051	-0.1883	**-0.4279**	-0.3361	0.1734	-0.1317	-0.0905	-0.3355
15	Seed Weight/ Plant (g)	-0.0005	-0.0001	-0.0060	-0.0101	**-0.0129**	0.0010	-0.0016	0.0008	-0.0084
16	Test Weight (g)	0.0655	0.0425	0.0162	0.1963	0.0394	**-0.4843**	0.0874	0.0696	0.0045
17	TSS (^{0}brix)	-0.0116	-0.0051	0.0003	-0.0159	-0.0065	0.0093	**-0.0517**	-0.0180	-0.0115
18	Protein Content (%)	0.0009	-0.0056	-0.0041	0.0030	-0.0009	-0.0021	0.0050	**0.0144**	0.0025
19	Seed Yield (kg/ha)	0.7853	-0.0598	0.5461	1.0008	0.8340	-0.0118	0.2836	0.2186	**1.2764**
20	**Pod Yield (kg/ha)**	**0.6498**	**-0.1853**	**-0.0015**	**0.7447**	**0.4629**	**-0.4149**	**0.2326**	**0.3260**	**0.8009**
	Partial R^2	-0.0845	-0.0129	0.0006	-0.3187	-0.0060	0.2009	-0.0120	0.0047	1.0223

R SQUARE = 1.0003, RESIDUAL EFFECT =SQRT(1- 1.0003)

However, the negative direct effect on seed yield per plant was exerted by plant height at maturity (-0.1266), days to first pod formation (-0.0596), peduncles per plant (-0.0625), pods per peduncle (-0.0022), pod length (-0.0953) at phenotypic level.

Pod yield

Genotypic path coefficient

At genotypic level, plant height at maturity (1.6060), days to first flowering (0.2474), days to 50 % flowering (0.4771), days to 50 % maturity (0.2707), peduncles per plant (0.1849), pods per peduncle (0.1692), pod length (0.1167), seeds per plant (0.0855), seed weight per plant (0.0556), seed yield (2.2881) had positive direct effect on pod yield per plant.

The present findings are in conformity with Patel *et al.*, (2016) for days to 50 % flowering, pod length and seeds per plant.

However the negative direct effect on pod yield per plant was exerted by plant height at flowering (-1.5359), nodes on main stem (-0.5368), days to first pod formation (-0.8908), pods per peduncle (-0.0355), pods per plant (-0.9278), dry pod weight (-0.3686), seeds per pod (-1.1703), test weight (-0.8251), TSS ^{0}(-0.1398), protein content % (-0.0930) at genotypic level. Results are represented in table 3 and 4.

Phenotypic path coefficient

At phenotypic level, plant height at maturity (0.4490), days to first pod formation (0.1689), days to 50 % maturity (0.0478), peduncles per plant (0.0722), pods per peduncle (0.0340), pods per plant (0.2906), pod length (0.0696), protein content % (0.0144), seed yield (1.2764) had positive direct effect on pod yield per plant (Table 5 and 6).

It is concluded as at genotypic and phenotypic level, Nodes on main stem, Days to first Pod Formation, Days to First Flowering, Days to 50 % Flowering, Days to 50 % Maturity, Peduncles per Plant, Pods per Peduncle, Pods per Plant, Dry Pod Weight, Seeds per Plant, Seed Weight per Plant, TSS, Protein Content, Seed Yield had direct positive effect on Pod Yield per Plant. The study reveals significant direct and indirect effects of various morphological traits on the total fruit yield of the crop and helps in estimating those helpful traits which should be considered while undertaking any breeding improvement program in the related crop.

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