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Character association and path coefficient analysis in vegetable cowpea [*Vigna unguiculata* (L.) Walp]

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Abstract
A field experiment was conducted during *Kharif* season 2021 to determine correlation coefficient and path analysis among 69 genotypes for sixteen characters comprised of pod yield and its contributing characters. These genotypes were planted in Randomized Block Design with three replications during *Kharif*, 2021 at Vegetable Research Centre, GBPUA& T, Pantnagar. The result revealed that at genotypic and phenotypic level maximum significant and positive correlation was shown by green pod yield per plot, per plant, green pod weight, number of pods per plant and pods per plot, pod length, 100 seed weight and number of seeds per pod with green pod yield per hectare. The results of path coefficient analysis indicated that at phenotypic and genotypic level, the effect was significant and high positive on green pod yield per hectare of characters pod length, number of pods per plant, number of pods per plot, green pod weight, green pod yield per plant and per plot and significant negative effects shown by number of pods per cluster. Maximum direct effect was shown by green pod yield per plot. Hence, these characters may be simultaneously selected for developing better quality high yielding varieties of vegetable cowpea.

Keywords: Cowpea, correlation, pod yield, path analysis, phenotypic and genotypic

Introduction
Cowpea [*Vigna unguiculata* (L.) Walp.] is an annual, autogamous leguminous vegetable crop of India belongs to family leguminosae with a chromosome number of 2n=2x=22. It is native to India but tropical and central Africa is also considered as secondary centre of origin where wild races are found. Its young leaves, pods and grains contain vitamins and minerals which have fuelled its usage for human consumption and animal feeding (Nielson *et al*., 1997) [12]. It is considered as one of the oldest legumes and referred as “Poor man’s meat” because of its high protein (20-25%) source for human and livestock (Steele, 1972) [19]. In different parts of the world it is known as Lobia, Southern pea, Blackeye pea, Chawalie and Mulatto-Gelato. It has multipurpose use such as green pods for vegetable, seed as pulse and leaves and foliage for fodder purpose, that’s why it is an important crop of the arid and humid tropics. It is a drought tolerant crop and thrives in warm weather (21- 35 ºC) and well adapted to the drier regions of the tropics, where other food legumes do not perform well. In India, vegetable cowpea is mainly grown in Uttar Pradesh, Punjab, Haryana, Rajasthan and Madhya Pradesh. In Rajasthan, cowpea is one of the importance vegetable legume crop because of its short duration, high yield potential and quick growing habit along with high protein content and as cover crop which help in conservation of soil. Yield improvement is one of the primary objectives of plant breeding in cowpea (Santos *et al*., 2014a) [15]. Yield is a multifaceted quantitative trait which is governed by polygenes, highly influenced by various yield attributing traits and environment (Navaselvakkumaran *et al.*, 2019; Priyanka *et al.*, 2019) [11, 14]. Correlation among the various traits should be well studied to develop a high yielding cowpea ideotype (Kumawat and Raje 2005) [7]. Linkage, heterozygosity and pleiotropy are the evolutionary reason behind correlation between two traits (Zhang *et al*., 2011) [21]. Positive correlation between two desirable traits helps in simultaneous improvement of both, whereas negative correlation between a desirable and undesirable trait is of great advantage during stress resistance breeding (Navaselvakkumaran *et al.*, 2019) [11]. However, linear correlation studies between and yield and its contributing traits is puzzling due to the inter correlation among its attributing characters. Hence, study of direct and indirect effects of yield and its attributing traits in the form of path coefficient analysis is very crucial (Meena *et al.*, 2015) [10]. The success of path analysis is mainly based on breeder’s preceding knowledge to formulate the cause and effect relationship (Silva *et al*., 2005) [17].

Knowledge on correlation and path analysis will help the cowpea breeders in selection of desirable traits and superior genotypes which could be utilized in crop improvement program (Shanko *et al.,* 2014) [16]. Hence the present study is designed to study the intra and inter relationship between the twelve quantitative characters in cowpea germplasm.

Materials and Method

The present investigation was carried out at Vegetable Research Centre, GBPUA& T, Pantnagar, Uttarakhand, during the *Kharif* season of the year 2021. The experimental material for the present study consisted of 69 promising genotypes of vegetable cowpea collected from different State Agricultural Universities, ICAR Research Institutes and the collection was maintained. The experiment was laid out in Randomized Block Design with three replications of each genotype. Two rows of each genotype were sown at spacing of 45x 10 cm in a plot of size is 4.0 x 0.9 m^2.

Correlation coefficient analysis

Phenotypic and genotypic correlations were worked out by using formula suggested by Falconer (1964) [5].

Phenotypic coefficient of correlation (r_p)

$$r(x_i.x_j)_p = \frac{COV\ (x_i.x_j)_p}{\sqrt{V\ (x_i)_p.\ V\ (x_j)_p}}$$

Where

$r(x_i.x_j)_p$ = Phenotypic correlation between i^{th} and j^{th} character.
COV $(x_i.x_j)_p$ = Phenotypic covariance between i^{th} and j^{th} character.
V $(x_i)_p$ = Phenotypic variance of i^{th} character.
V $(x_j)_p$ = Phenotypic variance of j^{th} character.

Genotypic coefficient of correlation (r_g)

$$r(x_i.x_j)_g = \frac{COV\ (x_i.x_j)_g}{V\ (x_i)_g.\ V\ (x_j)_g}$$

Where

$r(x_i.x_j)_g$ = Genotypic correlation between i^{th} and j^{th} character.
COV $(x_i.x_j)_g$ = Genotypic covariance between i^{th} and j^{th} character.
V $(x_i)_g$ = genotypic variance of i^{th} character.
V $(x_j)_g$ = genotypic variance of j^{th} character.

Path coefficient analysis

Path coefficient analysis was carried out as suggested by Dewey and Lu (1959) [4] by partitioning the simple correlation coefficients into direct and indirect effects. The direct and indirect effects were ranked based on the scales of Lenka and Misra (1973) [9] as given below

Negligible: 0.00 to 0.09
Low: 0.10 to 0.19
Moderate: 0.20 to 0.29
High: 0.30 to 0.99
Very high: > 1.00

Result and Discussion

Correlation coefficient

Phenotypic and genotypic correlation coefficients among fifteen quantitative and qualitative characters are presented in Table 1. At genotypic and phenotypic level maximum significant and positive correlation with green pod yield per hectare shown by green pod yield per plot (p=0.938, g=0.955), green pod yield per plant (p=0.904, g=0.945), green pod weight (p=0.675, g=0.810), number of pods per plot (p=0.625, g=0.710), number of pods per plot (p=0.667, g=0.672), number of seeds per pod (p=0.193, g=0.210), 100 seed weight (p=0.164, g=0.175) and pod length (p=0.621, g=0.662). Similar findings are also reported by Kalaiyarasi and Palanismy (2000) [6] and Belhekar *et al*. (2003) [3] for number of pods per plant. Kutty *et al*. (2003) [8] and Singh *et al*. (2004) [18] for pod length and number of pods per plant and by Xiao *et al.* (2004) [20] for pod length. These results were parallel with the findings of Alle *et al.,* (2016), Meena *et al.*, (2015) and Paliwal *et al*., (2005) [1, 10, 13].

These characters are also showing significant correlation with each other. Plant height at phenotypic and genotypic correlation was significantly positive correlated with days to first flowering (0.385 P, 0.454 G), days to 50% flowering (0.360 P, 0.441 G), days to first pod emergence, maturity (0.347, 0.340 P, 0.411, 0.397 G), number of pods per cluster (0.176 P, 0.302 G), number of pods per plant (0.432 P, 0.446 G), number of pods per plot (0.443 P, 0.476 G), green pod yield per hectare (0.136 P, 0.140 G). Negative significant correlation was noticed with green pod weight (-0.219 P, -0.225 G), 100 seed weight (-0.158 P, -0.179 G). The character days to first flowering was significantly positive correlated with days to 50% flowering (0.915 P, 0.915 G), days to first pod emergence (0.936 P, 0.946 G), maturity (0.912 P, 0.918 G), number of primary branches (0.243 P, 0.267 G), number of pods per cluster (0.259 P, 0.489 G), number of seeds per pod (0.236 P, 0.292 G), number of pods per plant (0.229 P, 0.284 G) and number of pods per plot (0.235 P, 0.289 G). Days to 50% flowering was significantly positive correlated with days to first pod emergence (0.943 P, 0.958 G), maturity (0.919 P, 0.924 G), number of primary branches (0.223 P, 0.249 G), number of pods per cluster (0.282 P, 0.526 G), number of seeds per pod (0.238 P, 0.300 G), number of pods per plant (0.225 P, 0.279 G) and number of pods per plot (0.237 P, 0.282 G). Days to first pod emergence was significantly positive correlated with days to first pod maturity (0.915 P, 0.915 G), number of primary branches (0.235 P, 0.258 G), number of pods per cluster (0.295 P, 0.481 G), number of seeds per pod (0.248 P, 0.310 G), number of pods per plant (0.186 P, 0.214 G) and number of pods per plot (0.198 P, 0.217 G). Days to first pod maturity was significantly positive correlated with number of primary branches (0.206 P, 0.227 G), number of pods per cluster (0.216 P, 0.463 G), number of seeds per pod (0.250 P, 0.294 G), number of pods per plant (0.186 P, 0.214 G) and number of pods per plot (0.202 P, 0.230 G).

Pod length was highly significant and positively correlated with number of seeds per pod (0.573 P, 0.674 G), green pod weight (0.767 P, 0.812 G), green pod yield per plant (0.638 P, 0.698 G), green pod yield per hectare (0.621 P, 0.662 G), 100 seed weight (0.384 P, 0.458 G) and number of pods per plant (0.221 P, 0.243 G). Number of seeds per pod was significantly positive correlated with100 seed weight (0.273 P, 0.356 G), green pod weight (0.440 P, 0.507 G), green pod yield per hectare (0.193 P, 0.210 G) and green pod yield per plant (0.214 P, 0.238 G). 100 seed weight is having significant positive correlation with green pod weight (0.399 P, 0.471 G), green pod yield per plant (0.175 P, 0.189 G) and green pod yield per hectare (0.164 P, 0.175 G). Negatively significant with number of pods per plant and per plot (-0.212 P, -0.204 P, -0.254 G, -0.251 G). Number of pods per plant is having significant positive correlation with number of pods per plot (0.963 P, 0.936 G), green pod yield per plant (0.656 P, 0.670 G) and green pod yield per hectare (0.667 P, 0.672 G).

Number of pods per plot is having significant positive correlation with green pod yield per plant (0.637 P, 0.668 G), green pod yield per plot (0.642 P, 0.692 G) and green pod yield per hectare (0.675 P, 0.710 G). Green pod weight is having significant positive correlation with green pod yield per plant (0.683 P, 0.712 G), green pod yield per plot (0.685 P, 0.728 G) and green pod yield per hectare (0.675 P, 0.810 G).

Table 1: Phenotypic (P) and Genotypic (G) correlation coefficients of yield and yield attributes in sixty nine genotypes of Cowpea

Characters		PH	DFF	D50F	DPE	DPM	NPB	NPPC	PL	NSPP	100SW	NPPPLA	NPPPLOT	GPW	GPYPPLA	Gpypplo	GPYPH
Plant height(cm)	P	1.00	0.385**	0.360**	0.347**	0.340**	0.093NS	0.176*	-0.068N	0.090NS	-0.158*	0.432**	0.443**	-0.219**	0.124NS	0.118NS	0.136*
	G	1.00	0.454**	0.441**	0.411**	0.397**	0.104NS	0.302**	-0.071N	0.089NS	-0.179**	0.446**	0.476**	-0.225**	0.130NS	0.123NS	0.140*
Days to first flowering	P		1.00	0.915**	0.936**	0.912**	0.243**	0.259**	0.028NS	0.236**	-0.112N	0.229**	0.235**	-0.140*	0.053NS	0.049NS	0.038NS
	G		1.00	0.915**	0.946**	0.918**	0.267**	0.489**	0.085NS	0.292**	-0.162*	0.284**	0.289**	-0.155*	0.057NS	0.051NS	0.044NS
Days to 50% flowering	P			1.00	0.943**	0.919**	0.223**	0.282**	0.044NS	0.238**	-0.091N	0.225**	0.237**	-0.127N	0.064NS	0.058NS	0.040NS
	G			1.00	0.948**	0.924**	0.249**	0.526**	0.096NS	0.300**	-0.149*	0.279**	0.282**	-0.141*	0.068NS	0.061NS	0.045NS
Days to first pod emergence	P				1.00	0.915**	0.235**	0.295**	0.058NS	0.248**	-0.054N	0.186**	0.198**	-0.120N	0.045NS	0.037NS	0.015NS
	G				1.00	0.915**	0.258**	0.481**	0.096NS	0.310**	-0.118N	0.214**	0.217**	-0.132N	0.038NS	0.032NS	0.013NS
Days to first pod maturity	P					1.00	0.206**	0.216**	0.059NS	0.250**	-0.062N	0.186**	0.202**	-0.098N	0.078NS	0.071NS	0.052NS
	G					1.00	0.227**	0.463**	0.096NS	0.294**	-0.100N	0.214**	0.230**	-0.101N	0.078NS	0.072NS	0.057NS
Number of primary branches	P						1.00	-0.006N	-0.068N	-0.090N	-0.201**	0.120NS	0.099NS	-0.110N	0.034NS	0.031NS	0.020NS
	G						1.00	-0.049N	-0.089N	-0.087N	-0.297**	0.130N	0.106NS	-0.130N	0.029NS	0.026NS	0.016NS
Number of pods per cluster	P							1.00	-0.129N	0.122NS	-0.039N	0.006NS	0.003NS	-0.251**	-0.167*	-0.174*	-0.191**
	G							1.00	-0.161*	0.143*	0.063NS	-0.005N	-0.059N	-0.408**	-0.306**	-0.316**	-0.320**
Pod length(cm	P								1.00	0.573**	0.384**	0.221**	0.223**	0.767**	0.638**	0.637**	0.621**
	G								1.00	0.674**	0.458**	0.243**	0.251**	0.812**	0.698**	0.667**	0.662**
Number of Seeds per Pod	P									1.00	0.273**	0.029NS	0.063NS	0.440**	0.214**	0.215**	0.193**
	G									1.00	0.356**	0.032N	0.069NS	0.507**	0.238**	0.237**	0.210**
100 Seed weight (g)	P										1.00	-0.212**	-0.204**	0.399**	0.175*	0.173*	0.164*
	G										1.00	-0.254**	-0.251**	0.471**	0.189**	0.187**	0.175*
Number of pods per plant	P											1.00	0.963**	0.084N	0.656**	0.655**	0.667**
	G											1.00	0.936**	0.086NS	0.670**	0.667**	0.672**
Number of pods per plot	P												1.00	0.081N	0.637**	0.642**	0.625**
	G												1.00	0.087NS	0.668**	0.692**	0.710**
Green pod weight (g)	P													1.00	0.683**	0.685**	0.675**
	G													1.00	0.712**	0.728**	0.810**
Green pod yield per plant(g)	P														1.00	0.922**	0.904**
	G														1.00	0.938**	0.945**
Green pod yield per plot (kg)	P															1.00	0.938**
	G															1.00	0.955**
Green pod yield per ha (q)	P																1.00
	G																1.00

*Significant at 5 per cent level; **Significant at 1 percent level

Path analysis

The results of path coefficient analysis in table 2 indicated that at the phenotypic and genotypic level, the significant and positive effect on green pod yield per hectare through pod length (p=0.620, g=0.676), number of seeds per pod (p=0.192, g=0.209), 100 seed weight (p=0.164, g=0.175), number of pods per plant (p=0.656, g=0.671), number of pods per plot (p=0.625, g=0.676), green pod weight (p=0.674, g=0.703), green pod yield per plant (p=0.987, g=0.994) and), green pod yield per plot (p=0.988, g=0.995). Maximum direct effect shown by plant height at phenotypic and genotypic level because, it was most important character as it was having maximum direct effect on green pod yield per hectare (p=0.033, g=0.0457).

Table 2: Phenotypic (P) and Genotypic (G) path coefficient analysis indicating direct and indirect effects of component characters on pod yield in sixty nine genotypes of cowpea

Characters		PH	DFF	D50F	DPE	DPM	NPB	NPPC	PL	NSPP	100SW	NPPPLA	NPPPLOT	GPW	GPYPPLA	GPYPPLO
PH	P	0.0335	0.0129	0.012	0.0116	0.0114	0.0031	0.0059	-0.0023	0.003	-0.0053	0.0145	0.0148	-0.0073	0.0042	0.0039
	G	0.0457	0.0207	0.0201	0.0188	0.0181	0.0048	0.0138	-0.0032	0.0041	-0.0082	0.0204	0.0217	-0.0103	0.0059	0.0056
DFF	P	0.0479	0.1245	0.1214	0.1166	0.1135	0.0302	0.0322	0.0035	0.0294	-0.0139	0.0285	0.0293	-0.0174	0.0066	0.0061
	G	-0.1758	-0.3872	-0.3869	-0.3774	-0.3710	-0.1034	-0.1893	-0.0331	-0.1129	0.0627	-0.1100	-0.1119	0.0602	-0.0221	-0.0199
D50F	P	-0.0285	-0.0772	-0.0792	-0.0747	-0.0728	-0.0176	-0.0223	-0.0035	-0.0189	0.0072	-0.0178	-0.0188	0.01	-0.0051	-0.0046

	G	0.3927	0.8903	0.8910	0.8799	0.8707	0.2220	0.4684	0.0857	0.2671	-0.1323	0.2486	0.2512	-0.1255	0.0603	0.0542
DPE	P	-0.0389	-0.105	-0.1057	-0.1122	-0.109	-0.0264	-0.0331	-0.0065	-0.0279	0.0061	-0.0209	-0.0222	0.0134	-0.005	-0.0041
	G	-0.2513	-0.5959	-0.6038	-0.6114	-0.6054	-0.1580	-0.2942	-0.0588	-0.1894	0.0721	-0.1309	-0.1329	0.0809	-0.0232	-0.0195
DPM	P	0.0188	0.0503	0.0507	0.0536	0.0552	0.0114	0.0156	0.0032	0.0138	-0.0034	0.0102	0.0111	-0.0054	0.0043	0.0039
	G	0.0469	0.1132	0.1155	0.1170	0.1182	0.0268	0.0548	0.0113	0.0347	-0.0118	0.0253	0.0272	-0.0120	0.0092	0.0086
NPB	P	-0.0013	-0.0034	-0.0032	-0.0033	-0.0029	-0.0142	0.0001	0.001	0.0013	0.0029	-0.0017	-0.0014	0.0016	-0.0005	-0.0004
	G	0.0006	0.0016	0.0014	0.0015	0.0013	0.0058	-0.0003	-0.0005	-0.0005	-0.0017	0.0008	0.0006	-0.0008	0.0002	0.0001
NPPC	P	-0.0027	-0.0040	-0.0043	-0.0045	-0.0043	0.0001	-0.0154	0.0020	-0.0019	0.0006	-0.0001	0.0000	0.0039	0.0026	0.0027
	G	-0.0194	-0.0314	-0.0338	-0.0309	-0.0298	0.0031	-0.0642	0.0103	-0.0092	-0.0040	0.0003	0.0038	0.0262	0.0196	0.0203
PL	P	-0.0003	0.0001	0.0002	0.0002	0.0002	-0.0003	-0.0005	0.004	0.0023	0.0015	0.0009	0.0009	0.0031	0.0026	0.0026
	G	-0.0014	0.0017	0.0020	0.0020	0.0019	-0.0018	-0.0033	0.0204	0.0137	0.0093	0.0049	0.0051	0.0100	0.0142	0.0142
NSPP	P	-0.0017	-0.0046	-0.0046	-0.0048	-0.0048	0.0017	-0.0024	-0.0111	-0.0194	-0.0053	-0.0006	-0.0012	-0.0085	-0.0041	-0.0042
	G	-0.0028	-0.0092	-0.0094	-0.0097	-0.0092	0.0028	-0.0045	-0.0212	-0.0314	-0.0112	-0.0010	-0.0022	-0.0159	-0.0075	-0.0075
100SW	P	-0.0002	-0.0002	-0.0001	-0.0001	-0.0001	-0.0003	-0.0001	0.0006	0.0004	0.0016	-0.0003	-0.0003	0.0006	0.0003	0.0003
	G	-0.0042	-0.0038	-0.0035	-0.0028	-0.0024	-0.0070	0.0015	0.0108	0.0084	0.0236	-0.0060	-0.0059	0.0111	0.0045	0.0044
NPPPLA	P	0.0787	0.0418	0.0411	0.034	0.0339	0.0219	0.0011	0.0403	0.0052	-0.0387	0.1823	0.1755	0.0153	0.1196	0.1194
	G	-0.0096	-0.0061	-0.0060	-0.0046	-0.0046	-0.0028	0.0001	-0.0052	-0.0007	0.0054	-0.0214	-0.0214	-0.0018	-0.0144	-0.0143
Nppplot	P	-0.0773	-0.041	-0.0413	-0.0346	-0.0352	-0.0174	-0.0005	-0.0389	-0.0109	0.0356	-0.1679	-0.1744	-0.014	-0.1112	-0.111
	G	0.0114	0.0069	0.0067	0.0052	0.0055	0.0025	-0.0014	0.0060	0.0016	-0.0060	0.0238	0.0239	0.0021	0.0159	0.0159
GPW	P	-0.0052	-0.0033	-0.003	-0.0028	-0.0023	-0.0026	-0.0059	0.0182	0.0104	0.0095	0.002	0.0019	0.0237	0.0162	0.0162
	G	-0.0024	-0.0017	-0.0015	-0.0014	-0.0011	-0.0014	-0.0043	0.0086	0.0054	0.0050	0.0009	0.0009	0.0106	0.0076	0.0076
Gpyppla	P	0.0191	0.0082	0.0099	0.0069	0.012	0.0052	-0.0256	0.098	0.0329	0.0269	0.1008	0.0979	0.1049	0.1536	0.1533
	G	-0.0588	-0.0258	-0.0306	-0.0172	-0.0353	-0.0132	0.1386	-0.3162	-0.1078	-0.0857	-0.3035	-0.3027	-0.3225	-0.4531	-0.4528
Gpypplo	P	0.0946	0.0391	0.0465	0.0297	0.0575	0.0249	-0.1398	0.5122	0.1728	0.139	0.5269	0.512	0.5508	0.8031	0.8043
	G	0.1689	0.0707	0.0838	0.0439	0.0998	0.0354	-0.4359	0.9613	0.3266	0.2581	0.9196	0.9190	0.9842	1.3776	1.3785
Gpyph	P	0.1365	0.0382	0.0403	0.0155	0.0522	0.0198	-0.1907	0.6207	0.1927	0.1642	0.6567	0.625	0.6746	0.9871	0.9884
	G	0.1403	0.0441	0.045	0.0128	0.0569	0.0156	-0.3201	0.6763	0.2097	0.1754	0.6718	0.6764	0.7031	0.9947	0.9955

Phenotypic residual effect = 0.1335; Genotypic residual effect = 0.0943

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