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Study on correlation and path analysis in cowpea [*Vigna unguiculata* (L.) Walp.]

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Abstract
Cowpea [*Vigna unguiculata* (L.) Walp.] Also known as a black-eyed pea or Southern pea is rich in proteins, vitamins and minerals especially phosphorus. The present investigation was conducted at the Vegetable farm, RPCAU, Pusa, Samastipur during *zaid*-2017. Twenty-seven genotypes of cowpea were sown in RBD in three replications with spacing 60 cm × 45 cm and observations were recorded for eighteen quantitative traits. The result on phenotypic and genotypic correlation coefficient revealed that pod yield plant^{-1} had positive and significant correlation with plant height (0.604**), number of branches plant^{-1} (0.689**), number of nodes on main stem (0.718**), number of pods cluster^{-1} (0.461**), pod length (0.439**), average pod weight (0.521**) and number of pods plant^{-1} (0.859**) while negative and significant with pod borer infestation percentage (-0.844**). The Path Coefficient analysis of yield and yield attributing traits showed direct and positive effect of plant height, number of node on main stem, number of pod cluster^{-1}, pod length, pod weight and number of pod plant^{-1} on yield while negative and direct effect of pod borer infestation on yield. These results suggest that during the course of selection these traits may be considerable as prime trait to enhance yield of cowpea.

Keywords: Southern pea, phenotypic correlation coefficient, genotypic correlation coefficient, path coefficient analysis, yield attributing traits

Introduction
Cowpea [*Vigna unguiculata* (L.) Walp.] an annual legume (2n=22) is one of the most important food legumes of the world. Its annual production was estimated to be 4.5 million metric tons (global) providing food to millions of people (Diouf, 2014; Anonymous 2017c) [9, 5]. In India it is grown as a minor pulse in arid and semi-arid region thus recorded low in overall production and productivity. However, being a multipurpose crop used for long green pods, seeds as pulses, foliage as fodder, nitrogen fixation (Hall *et al.*, 2003; Anonymous 2017b) [4], green manuring and cover crop (Meena *et al.*, 2017) [19] it has captured the attention of researchers and breeders towards the development of improved cultivars. The present-day cultivars exhibit lower productivity, non-synchronous flowering and fruiting, non- response to high doses of inputs, lodging and shattering susceptible, long duration, complete or partial absence of genetic resistance to major insect pest and diseases like mosaic virus, rust, powdery mildew and bacterial blight which cause considerable damage and very poor harvest indices. Development of improved cultivars with early maturity, acceptable grain quality, resistance to some important diseases and pests has significantly increased the yield and cultivated area. For understanding the direction of selection and to maximize yield in the shortest period of time estimation of correlation coefficient among the yield contributing variables is a prerequisite. Yield being a complex trait is governed by a large number of genes and it depends on plant genotype and its interaction with environment (Khatab *et al.*, 2016; Jaiswal *et al*., 2019) [16]. Genotypic correlation indicates the relative importance of characters on which greater emphasis should be made in selection for yield. However, correlation alone can only reveals the direction and magnitude of the association between any two characters but the path coefficient analysis helps in partitioning the correlation into direct and indirect effects of various yield components on yield (Ahmed and Kamaluddin, 2013) [1]. Therefore, correlation studies coupled with path coefficient analysis are a powerful tool to study the character association and their final impact on yield, which helps the selection procedure accordingly. The low average yield, high year to year variation in yield and low productivity are the major challenges to cowpea improvement programmes (Singh *et al.*, 2018) [27]. Thus, there is an urgent need to make efforts for identification and evaluation of superior parent to be used in

improvement programmes aimed at increasing the cowpea production to meet the minimum requirements as well as for ensuring the food and nutritional security of fast growing population. This work is such an effort to identify superior parent and define traits of prime importance having significant positive correlation and direct effect on yield.

Materials and methods

The present investigation was carried out at Vegetable research farm, RPCAU, Pusa, Samastipur, (Bihar) during *zaid*-season 2017 in Randomized Block Design with three replication. The plot size was 378 m^2 with spacing 60 cm between rows and 45 cm between plant to plant. The experimental material was comprised of twenty-seven genotypes of cowpea collected from different sources (listed in table 1.1), including check "Kashi Unnati". The genotypes were evaluated for following traits *viz.,* Seed germination percentage, plant height (cm), number of branches plant^{-1}, days to first flowering, first flowering node, number of nodes on main stem, peduncle length (cm), number of pods cluster^{-1}, day to first picking, pod length (cm), pod diameter (cm), average pod weight (g), number of pods plant^{-1}, number of pods cluster^{-1}, test weight (g), pod yield plant^{-1} (gm), pod yield (q/ha), pod borer infestation percentage.

Statistical analysis

Data on eighteen quantitative traits were recorded on five randomly selected plants in each plot and mean values were calculated for statistical analysis as suggested by Al – Jihouri *et al*., 1958 [3] (Correlation co-efficient) and Dewey and Lu, 1959 [7] (Path analysis).

Results and Discussion

Phenotypic Correlation Coefficient Analysis

Phenotypic correlation coefficient analysis was carried out for all the traits under investigation and presented in table 1.2. Seed germination percentage do not show any significant correlation with other trait. Plant height exhibited positive and significant correlation with number of nodes on main stem (0.869**), number of branches plant^{-1} (0.8178**), number of pods plant^{-1} (0.723**) and pod yield plant^{-1} (0.604**). Similar results were reported in earlier studies on cowpea by Manggoel *et al.,* (2012) [18], Chattopadhyay *et al.,* (2014) [6] and Dinesh *et al.,* (2017) [8], while negative and significant correlation with pod borer infestation percentage (-0.463*). Number of branches plant^{-1} showed positive and significant correlation with number of nodes on main stem (0.986**), number of pod plant^{-1} (0.819**), and pod yield plant^{-1} (0.689**) similar findings were reported by Singh *et al.,* (2011) [28] and Patel *et al.,* (2016) [23], while it has shown negative and significant correlation with pod borer infestation percentage (-0.600**). Days to first flowering had shown positive and significant correlation with days to first picking (0.618**) while, it showed negative significant correlation with pod length (-0.438*). These results are in propinquity with that of Singh *et al*., (2004) [29]; Alege (2007) [2]; Rani *et al.,* (2011) [25]; Nath *et al.,* (2014) [21]. None of the character showed neither positive nor negative significant correlation with first flowering node. Number of nodes on main stem showed positive and significant correlation with number of pods per plant (0.845**), pod yield per plant (0.718**), plant height (0.896**) and number of branches plant^{-1} (0.960**) while, there was negative and significant correlation with pod borer infestation percentage (-0.611**). Peduncle length had not shown positive and significant correlation with any trait, while it had shown negative and significant correlation with pod length (-0.457*). Number of pods cluster^{-1} exhibited positive and significant correlation with number of pods plant^{-1} (0.510**) and pod yield plant^{-1} (0.461**). Days to first picking had shown positive and significant correlation with days to first flowering (0.618**), while it had shown negative and significant correlation with pod length (-0.493**) and average pod weight (-0.451*). Pod length had showed positive and significant correlation with average pod weight (0.839**), test weight (0.446*) and pod yield plant^{-1} (0.439*), while, negative and significant correlation were recorded with number of branches plant^{-1} (0.494**), days to first flowering (-0.438*), peduncle length (-0.457I*), days to first picking (-0.493**) and pod borer infestation percentage (-0.434*). The results are in consonance with those of Selvakumar and Ushakumari (2013) [26], Chattopadhyay *et al.,* (2014) [6] and Hitiksha *et al.,* (2014) [11]. Pod diameter had shown positive and significant correlation with average pod weight (0.432*). Average pod weight had shown positive and significant correlation with pod yield plant^{-1} (0.521**), test weight (0.414*), pod diameter (0.432*) and pod length (0.839**) whereas, negative and significant correlation with days to first picking (-0.451*) and pod borer infestation percentage (-0.551**). These results are in consonance with the finding of Singh *et al.,* (2004) [29] and Jogdhande *et al.,* (2017) [12]. Number of pod plant^{-1} had exhibited positive and significant correlation with plant height (0.723**), number of branches plant^{-1} (0.819**), number of nodes on main stem (0.845**) number of pods cluster^{-1} (0.510**) and pod yield per plant (0.859**), while, there was significant and negative correlation with pod borer infestation percentage (-0.681**). Number of seeds per pod had shown neither positive nor negative significant correlation with any traits. Test weight exhibited positive and significant correlation with peduncle length (0.446*) and average pod weight (0.414*). Pod borer infestation percentage had shown negative and significant correlation with plant height (-0.463*), number of branches plant^{-1} (-0.600**), number of nodes on main stem (-0.611**), pod length (-0.434*), average pod weight (-0.551**), number of pod cluster^{-1} (-0.681**) and pod yield plant^{-1} (-0.844**). Pod yield plant^{-1} had given positive and significant correlation with plant height (0.604**), number of branches plant^{-1} (0.689**), number of nodes on main stem (0.718**), number of pods cluster^{-1} (0.461**), pod length (0.439**), average pod weight (0.521**) and number of pods plant^{-1} (0.859**). The same result were reported by Vishwanath *et al.,* (2009) [30] and Khandait *et al*., (2016) [13] while negative and significant with pod borer infestation percentage (-0.844**).

Path Coefficient Analysis

From the results presented in the previous section, it is imperative that most of the character contributing to yield (green pod) studied in present investigation are inter-related and affected by each other. In the present investigation, the phenotypic correlations of pod yield with other quantitative characters were partitioned into their corresponding direct and indirect effects through path coefficient analysis. The obtained results have been furnished in Table 1.3. Plant height exhibited positive and direct effect as well as positive and indirect effect via number of branches plant^{-1} (0.071) and number pods plant^{-1} (0.063) on pod yield plant^{-1}as reported by Madhavi *et al.,* (2014) [17]. Number of branches plant^{-1} showed positive and high indirect effect via number of pods plant^{-1} (0.347) on pod yield plant^{-1}. Pod length exhibited positive and direct effect (0.046) along with positive and indirect effect via

days to first flowering (0.020), peduncle length (0.021), days to first picking (0.023) and pod borer infestation percentage (0.020) on pod yield plant^{-1}. Pod weight exhibited positive and high direct effect (0.436) along with positive indirect effect via seed germination percentage (0.107), pod diameter (0.189) and test weight (0.180) on pod yield plant^{-1}. Number of nodes on main stem showed positive and direct effect (0.027) along with positive and indirect effect via plant height (0.023), number of branches plant^{-1} (0.026) and number pods plant^{-1} (0.023) on pod yield plant^{-1}. Number of pods cluster^{-1} exhibited positive and direct effect (0.053) along with positive and indirect effect via number of pods plant^{-1} (0.227) on pod yield plant^{-1}. Number of pod plant^{-1} exhibited positive and high direct effect (0.725) as well as positive and indirect effect via plant height (0.524), number of branches plant^{-1} (0.594), number of nodes on main stem (0.613), number of pods cluster^{-1} (0.370). Similar observations were documented by Alege and Singh (2007) [2], Nehru *et al.,* (2009) [22] and Prasad *et al.,* (2013) [24]. Negative indirect effect pod borer infestation percentage (-0.493) on pod yield plant^{-1}. Pod borer infestation percentage exhibited negative and high direct effect on pod yield plant^{-1}. While, the remaining characters showed high negative indirect effect as reported by Mittal and Singh (2005) [20], Cholin *et al.,* (2012) [14] and Dinesh *et al.,* (2017) [15]. The residual was recorded too small (0.1700) i.e. 17.00 percent which indicated that 83.00 percent yield contributing characters have been accounted for yield.

Conclusion

The plant height, pod length, average pod weight and number of pods plant^{-1} exhibited positive and significant correlation with pod yield plant^{-1} comprising their positive and direct effect whereas, number of branches plant^{-1} and number of pod cluster^{-1} showed positive and significant correlation with pod yield per plant comprising positive and high indirect effect via number of pods plant^{-1}. Negative and significant correlation recorded for pod borer infestation percentage with pod yield plant^{-1} having its negative and high direct effect. Hence to enhance the yield of cowpea plant height, pod length, average pod weight and number of pods plant^{-1} may be considered as prime traits.

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Tables and Figures

Table 1.1: List of cowpea germplasm and their sources

Genotypes	Sources
Kashi Unnati (C), Kashi Gauri, EC-97738, EC-472260,EC-390216, EC-9135, EC-9739, EC-390213, EC-9736, EC-19736, EC-390210, EC-15296, EC-390223, EC-390252, EC-390268, EC-97306, EC-1738, EC-390237, Kashi Kanchan	IIVR, Varanasi
PL-2,PL-5,PL-3,P L-1,PL-4,GP-56,GP-58,GP-3	GBPUA&T, Pantnagar

Table 1.2: Phenotypic correlation coefficient between different character combinations in cowpea

Characters	SG%	PH	BPP	DFF	FFN	NMS	PEL	PPC	DFP	PL	PD	PW	PPP	SPP	TW	PBI%	YPP
SG%	1	0.024	-0.047	-0.237	0.103	-0.049	-0.092	-0.032	-0.119	0.128	0.108	0.246	-0.09	-0.044	0.196	-0.127	0.055
PH		1	0.817**	0.207	0.179	0.869**	0.205	0.166	0.379	-0.116	-0.322	-0.083	0.723**	0.143	-0.042	-0.463*	0.604**
BPP			1	0.155	0.15	0.960**	0.261	0.163	0.187	-0.018	-0.185	0.015	0.819**	0.155	-0.075	-0.600**	0.689**
DFF				1	0.187	0.181	0.305	-0.211	0.618**	-0.438*	-0.186	-0.306	0.089	0.129	-0.3	-0.016	-0.064
FFN					1	0.121	-0.041	-0.044	0.313	0.03	0.232	0.138	0.125	0.14	0.286	-0.264	0.199
NMS						1	0.295	0.175	0.210	-0.027	-0.173	0.007	0.845**	0.123	-0.023	-0.611**	0.718**
PEL							1	-0.232	0.317	-0.457*	-0.061	-0.246	0.122	0.028	-0.194	-0.074	-0.044
PPC								1	-0.089	0.124	-0.1	0.176	0.510**	-0.097	0.021	-0.272	0.461**
DFP									1	-0.493**	-0.246	-0.451*	0.155	-0.04	-0.33	0.019	-0.033
PL										1	0.347	0.839**	0.049	0.07	0.446*	-0.434*	0.439**
PD											1	0.432*	-0.12	-0.309	0.291	-0.231	0.12
PW												1	0.072	0.028	0.414*	-0.551**	0.521**
PPP													1	-0.016	0.026	-0.681**	0.859**
SPP														1	0.014	-0.004	-0.045
TW															1	-0.095	0.253
PBI%																1	-0.844**

** Significant at p = 0.01, * significant at p = 0.05

Characters:– (SG %) - Seed Germination percentage, PH - Plant Height, BPP - Number of Branches per Plant, (DFF) Days to First Flowering, (FFN) First Flowering Node, (NMS) Number of Nodes on Main Stem, (PEL) Peduncle Length, (PPC) Number of Pods per Cluster, (DFP) Days to First Picking, (PL) Pod Length, (PD) Pod Diameter, (PW) Average Pod Weight, (PPP) Number Pods per Plant, (SPP) Number of Seeds per Pod, (TW) Test Weight, (PBI %) Pod Borer Infestation %, (YPP) Pod Yield per Plant and Yield per Hectare (YQH-1)

Table 1.3: Phenotypic direct (Diagonal) and indirect effect of sixteen characters in cowpea

S. No.	Characters	SG%	PH	BPP	DFF	FFN	NMS	PEL	PPC	DFP	PL	PD	PW	PPP	SPP	TW	PBI%	Correlation with YPP
1	SG%	-0.023	-0.001	0.001	0.006	-0.002	0.001	0.002	0.001	0.003	-0.003	-0.003	-0.006	0.002	0.001	-0.005	0.003	0.054
2	PH	0.002	0.087	0.071	0.018	0.016	0.076	0.018	0.014	0.033	-0.010	-0.028	-0.007	0.063	0.012	-0.004	-0.040	0.604**
3	BPP	0.002	-0.037	-0.046	-0.007	-0.007	-0.044	-0.012	-0.007	-0.009	0.001	0.008	-0.001	0.347	-0.007	0.003	0.027	0.689**
4	DFF	0.009	-0.008	-0.006	-0.037	-0.007	-0.007	-0.011	0.008	-0.023	0.016	0.007	0.011	-0.003	-0.005	0.011	0.001	-0.064

5	FFN	-0.004	-0.006	-0.005	-0.007	-0.036	-0.004	0.001	0.002	-0.011	-0.001	-0.008	-0.005	-0.004	-0.005	-0.010	0.009	0.199
6	NMS	-0.001	0.023	0.026	0.005	0.003	0.027	0.008	0.005	0.006	-0.001	-0.005	0.000	0.023	0.003	-0.001	-0.016	0.718**
7	PEL	0.008	-0.017	-0.022	-0.025	0.003	-0.025	-0.083	0.019	-0.026	0.038	0.005	0.020	-0.010	-0.002	0.016	0.006	-0.044
8	PPC	0.002	-0.009	-0.009	0.011	0.002	-0.009	0.012	0.053	0.005	-0.007	0.005	-0.009	0.227	0.005	-0.001	0.015	0.461*
9	DFP	-0.009	0.030	0.015	0.049	0.025	0.017	0.025	-0.007	0.079	-0.039	-0.019	-0.036	0.012	-0.003	-0.026	0.002	-0.033
10	PL	-0.006	0.005	0.001	0.020	-0.001	0.001	0.021	-0.006	0.023	0.046	-0.016	-0.038	-0.002	-0.003	-0.020	0.020	0.439*
11	PD	0.001	-0.002	-0.001	-0.001	0.002	-0.001	0.000	-0.001	-0.002	0.002	0.006	0.003	-0.001	-0.002	0.002	-0.001	0.120
12	PW	0.107	-0.036	0.007	-0.133	0.060	0.003	-0.107	0.077	-0.196	0.366	0.189	0.436	0.031	0.012	0.180	-0.240	0.521**
13	PPP	-0.065	0.524	0.594	0.064	0.091	0.613	0.088	0.370	0.112	0.036	-0.087	0.052	0.725	-0.012	0.019	-0.493	0.859**
14	SPP	0.002	-0.006	-0.006	-0.005	-0.006	-0.005	-0.001	0.004	0.002	-0.003	0.013	-0.001	0.001	-0.042	-0.001	0.000	-0.045
15	TW	0.015	-0.003	-0.006	-0.023	0.022	-0.002	-0.015	0.002	-0.025	0.034	0.023	0.032	0.002	0.001	0.077	-0.007	0.254
16	PBI%	0.016	0.059	0.077	0.002	0.034	0.078	0.009	0.035	-0.002	0.055	0.030	0.070	0.087	0.001	0.012	-0.128	-0.844**

Residual Effect = 0.1700

Characters – (SG %) - Seed Germination percentage, PH - Plant Height, BPP - Number of Branches per Plant, (DFF) Days to First Flowering, (FFN) First Flowering Node, (NMS) Number of Nodes on Main Stem, (PEL) Peduncle Length, (PPC) Number of Pods per Cluster, (DFP) Days to First Picking, (PL) Pod Length, (PD) Pod Diameter, (PW) Average Pod Weight, (PPP) Number Pods per Plant, (SPP) Number of Seeds per Pod, (TW) Test Weight, (PBI %) Pod Borer Infestation %, (YPP) Pod Yield per Plant and Yield per Hectare (YQH-1)

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