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Principal component analysis and correlation for characterization and evaluation of germplasm in cowpea (*Vigna unguiculata* L. Walp.)

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Abstract
The present study was carried out to study the genetic diversity and correlation in 79 genotypes of cowpea for various quantitative characters. All the seventy nine genotypes were laid out in augmented block design with nine blocks and four checks. A total of nine principal components contributed for cent percent of variability in the present study. Principal component 1 contributed for 42.96% of total variation for which pod number, peduncle number, number of primary branches/plant, pod yield/plant and peduncle length contributed for variability. Total variability contribution by component 2 was 21.84% by 10 pod weight, pod length, seed number and plant height. 12.14% of total variability was contributed by principal component 3 for which yield per plant, pod weight, pod number and pod length contributed. The component 4, component 5 and component 6 contributed 7.74%, 6.48% and 4.27% of total variability. The first six principal components contributed a cumulative total of 95.43% by nine quantitative characters. Out of nine characters studied the characters that contributed maximum towards divergence were pod number, peduncle number, number of primary branches per plant and yield per plant. Highly significant posititve correlation for the dependant variable pod yield (kg/plant) was observed with pod number (0.7489) followed by peduncle number (0.6725), peduncle length (cm) (0.5185) and number of primary branches/plant (0.4533).

Keywords: Genetic diversity, correlation, quantitative characters, principal components, variability

1. Introduction

Cowpea is grown primarily in the third world for its cheap source of dietary protein, lysine and as a supplement for meat. Vegetable cowpea refers to varieties of cowpea (*Vigna unguiculata* L.) grown for their immature succulent pods, popularly known as long bean, bodi, bora, sitao, snake pea and aspargus bean in different parts of the world. In India, *Vigna unguiculata* ssp. *unguiculata* and *Vigna unguiculata* ssp. *biflora* types are predominantly cultivated for pulse purpose. However, *Vigna unguiculata* ssp. *sesqupedalis* (yard long bean) is grown for its immature pods in almost all the regions except high hilly areas and widely cultivated in India, Bangladesh, Indonesia, Philippines and Sri Lanka. The indigenous varieties of vegetable cowpea were climbing types. In recent times, many erect bushy varieties with increased yields have been developed. The cowpea crop is used in a variety of ways. Tender pods are used in the same way as snap beans while the green cowpea seeds are boiled as fresh vegetable, can be canned or frozen. Dry mature seeds used as pulse suitable for boiling and canning.

2. Materials and Methods

Seventy nine genotypes of cowpea (Table 1) were laid out in augmented block design with nine blocks and four checks. The checks that were used were Kashi Kanchan, Kashi Nidhi, Kashi Unnati and Kashi Gauri. The experiment was conducted at research farm of ICAR-Indian Institute of Vegetable Research, Varanasi for two consecutive years. The seeds were sown at the spacing of 60 cm × 15 cm. All the package of practices for growing a good crop was done timely. In the experiment, the following characteristics were studied: Plant height (cm), number of primary branches/plant, peduncle length, pod length, peduncle number, pod number, seed number, pod weight (g) and yield (kg/plant). The data was recorded on 10 random plants for all the characters except yield which is recorded on a whole plot basis.

The results underwent introductory analysis by building a correlation matrix between the primary variables and by verifying the null hypothesis that correlation matrix is the identity matrix (H0: [R] = [I]).

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The number of principal components that underwent interpretation was set on the basis of Kaiser's criterion, according to which those variables are chosen whose eigenvalues are greater than 1 (Stanisz, 2007) [5]. For the assessment of the degree of carrying the information supplies contained in the input variables (their variation) by components chosen for interpretation, the factor loads and eigenvectors of the variables were used. The analysis was done using SAS software 3.0.

3. Results and Discussion
The Mean data for the nine yield and yield related traits of 79 genotypes of cowpea used in the study was presented in Table 2. A total of nine principal components contributed for cent percent of variability in the present study (Table 3). Principal component 1 contributed for 42.96% of total variation for which pod number, peduncle number, number of primary branches/plant, pod yield/plant and peduncle length contributed for variability. Total variability contribution by component 2 was 21.84% by 10 pod weight, pod length, seed number and plant height. 12.14% of total variability was contributed by principal component 3 for which yield per plant, pod weight, pod number and pod length contributed. The component 4, component 5 and component 6 contributed 7.74%, 6.48% and 4.27% of total variability. The first six principal components contributed a cumulative total of 95.43% by nine quantitative characters (Table 4). The characters that had high correlation with pod yield/plant were pod number, peduncle number, peduncle length and number of primary branches per plant.

Out of nine characters studied the characters that contributed maximum towards divergence were pod number, peduncle number, number of primary branches per plant and yield per plant. The results are in accordance with the findings of Ahamed *et al.* (2014) [1], Sousa *et al.* (2015) [4], Vural *et al.* (2007) [7].

Highly significant posititve correlation (Table 5) for the dependant variable pod yield (kg/plant) was observed with pod number (0.7489) followed by peduncle number (0.6725), peduncle length (cm) (0.5185) and number of primary branches/plant (0.4533). Whereas, the highly significant correlation between yield related traits was observed between peduncle number and pod number (0.9049), pod length (cm) and pod weight (g) (0.8029), number of primary branches/plant and peduncle number (0.6679), number of primary branches/plant and pod number, peduncle length (cm) and pod number (0.5213), peduncle length (cm) and peduncle number (0.4953), number of primary branches/plant and peduncle length (cm) (0.4917), plant height and number of primary branches/plant (0.3691). Highly significant negative correlation was observed between pod length (cm) and pod number (-0.4414), pod number and pod weight (g) (-0.4014), pod length (cm) and peduncle number (-0.3636), peduncle number and pod weight (g) (-0.3296), peduncle length (cm) and pod length (cm) (-0.3016). The results are in accordance with the findings of Patel *et al.* (2016) [3], Walle *et al.* (2018) [8], Ugale *et al.* (2020) [6], Owusu *et al.* (2021) [2].

Table 1: List of cowpea genotypes used to study the principal component analysis and correlation

Kashi Kanchan (C)	HACP-3	EC572715	EC9135-B
Kashi Nidhi (C)	Pusa Komal	EC390242	EC30950
Kashi Unnati (C)	DR-214	EC528382	EC37588
Kashi Gauri (C)	RCCP-1	EC19736	EC9736
Vyjayanthi	Ujjain AC	EC528398	EC9738
Arya Vaibhav Laxmi	Kashyang AC-2	EC472272	EC160493/20
Assam AC	Ankur Gomati	EC1738	EC390216
Jaipur AC-2	Ajeet-1	EC390213	EC528412
RCV-395	Swarn Harita	EC390252	EC390223
Sel.2-2	Shahjahanpur AC	EC390220	EC399251
Indira Lal	Red Seeded	EC390210	EC9739
IRD-30	BS-5	EC394756	EC390240
Sel 103 (USA)	Sweta	EC390241	EC390237
Almora LC	Kashi Sudha	EC390226	EC390257
LC-03-1	Vanita	EC390225	EC390268
NDCP-13	Sel. 2-1	EC472261	EC15296
ACP-1	Jaipur AC-1	EC37587	EC472260
LC-2013	Lobiya Banarasi	EC390224	EC390287
BCKV-1	LC-03-2	EC367702	EC97738
Kalimpong AC	AP-1	EC91171-A	

Table 2: Mean data of the 79 genotypes of cowpea used for the study for the two consecutive years

S. No.	Genotype	Plant height (cm)	Number of primary branches/plant	Peduncle length (cm)	Pod length (cm)	Peduncle number	Pod number	Seed number	10 pod weight (g)	Yield/Plant (g)
1)	Kashi Kanchan (C)	34.83	3.17	23.25	29.33	13.83	20.17	13.75	93.33	184.00
2)	Kashi Nidhi (C)	34.25	3.75	28.88	31.00	17.75	26.25	14.63	96.25	240.63
3)	Kashi Unnati (C)	29.67	3.33	14.42	24.67	12.17	15.67	11.33	70.83	110.67
4)	Kashi Gauri (C)	35.33	3.67	31.50	26.00	18.67	28.00	12.83	75.00	232.67
5)	Vyjayanthi	206.50	7.00	28.50	39.00	22.00	17.00	16.50	125.00	212.50
6)	Arya Vaibhav Laxmi	382.00	4.00	13.50	35.50	10.00	4.00	15.00	125.00	50.00
7)	Assam AC	59.50	5.50	38.00	20.00	41.00	74.00	12.00	70.00	518.00
8)	Jaipur AC-2	52.50	4.50	33.50	23.50	23.00	41.00	16.00	50.00	205.00
9)	RCV-395	45.00	5.50	38.00	18.00	44.00	80.00	17.00	70.00	560.00
10)	Sel.2-2	36.50	4.00	25.50	25.00	15.00	20.00	14.00	85.00	170.00
11)	Indira Lal	33.00	4.00	21.00	23.50	7.00	7.00	12.00	70.00	49.00
12)	IRD-30	68.00	1.00	29.50	11.00	19.00	59.00	12.00	25.00	147.50
13)	Sel 103 (USA)	32.00	4.00	20.50	25.50	18.00	29.00	15.50	65.00	188.50
14)	Almora LC	42.00	2.00	28.50	15.00	18.00	46.00	14.00	30.00	138.00
15)	LC-03-1	38.00	3.00	25.50	23.50	22.00	27.00	14.50	60.00	162.00
16)	NDCP-13	45.00	5.00	31.00	26.00	30.00	42.00	13.00	90.00	378.00
17)	ACP-1	50.00	8.00	28.50	16.50	64.00	111.00	14.00	20.00	222.00
18)	LC-2013	82.00	5.00	6.00	23.00	5.00	4.00	9.00	40.00	16.00
19)	BCKV-1	42.00	3.00	17.00	16.00	30.00	55.00	11.00	35.00	192.50
20)	Kalimpong AC	254.50	4.50	30.50	22.00	55.00	76.00	17.50	80.00	608.00
21)	HACP-3	310.00	4.00	17.50	33.00	15.00	10.00	14.00	150.00	150.00
22)	Pusa Komal	41.50	3.00	28.50	18.50	19.00	33.00	10.00	84.00	277.20
23)	DR-214	250.00	6.00	32.00	18.00	34.00	64.00	15.00	45.00	288.00
24)	RCCP-1	250.00	5.00	37.00	16.00	24.00	48.00	12.50	45.00	216.00
25)	Ujjain AC	32.00	3.00	19.50	34.50	13.00	19.00	15.00	165.00	313.50
26)	Kashyang AC-2	33.00	4.00	17.00	16.00	9.00	6.00	10.50	90.00	54.00
27)	Ankur Gomati	123.00	2.00	20.50	26.50	9.00	16.00	15.00	95.00	152.00
28)	Ajeet-1	40.00	1.00	22.50	18.50	5.00	13.00	10.50	30.00	39.00
29)	Swarn Harita	35.00	5.00	18.50	21.50	19.00	24.00	13.50	45.00	108.00
30)	Shahjahanpur AC	80.00	4.00	21.50	18.00	20.00	30.00	16.00	60.00	180.00
31)	Red Seeded	45.00	2.00	32.00	22.50	18.00	32.00	10.50	125.00	400.00
32)	BS-5	48.00	3.00	28.00	23.50	16.00	21.00	14.00	65.00	136.50
33)	Sweta	324.00	3.00	13.50	34.00	14.00	16.00	15.50	95.00	152.00
34)	Kashi Sudha	42.00	3.00	28.50	30.50	14.00	16.00	11.50	90.00	144.00
35)	Vanita	22.00	2.00	12.00	18.00	7.00	8.00	9.50	80.00	64.00
36)	Sel. 2-1	38.00	6.00	27.50	21.00	33.00	87.00	11.50	55.00	478.50
37)	Jaipur AC-1	38.00	3.00	26.00	12.50	23.00	45.00	8.50	20.00	90.00
38)	Lobiya Banarasi	31.00	3.00	20.00	17.50	18.00	32.00	14.50	85.00	272.00
39)	LC-03-2	35.00	5.00	15.50	18.00	25.00	36.00	10.00	30.00	108.00
40)	AP-1	45.00	4.00	24.50	15.00	20.00	43.00	14.50	30.00	129.00
41)	EC572715	75.00	8.00	28.50	15.00	76.00	115.00	10.00	20.00	230.00
42)	EC390242	145.00	7.00	25.00	12.50	47.00	51.00	11.50	40.00	204.00
43)	EC528382	59.00	6.00	32.00	18.50	37.00	87.00	14.00	60.00	522.00
44)	EC19736	150.00	6.00	44.00	17.50	25.00	44.00	14.50	40.00	176.00
45)	EC528398	62.00	6.00	34.50	21.00	37.00	67.00	11.00	60.00	402.00
46)	EC472272	175.00	5.00	33.00	16.50	41.00	32.00	14.50	50.00	160.00
47)	EC1738	177.00	7.00	37.00	16.50	38.00	66.00	15.00	50.00	330.00
48)	EC390213	60.00	9.00	33.00	12.50	55.00	120.00	15.50	40.00	480.00
49)	EC390252	78.00	5.00	24.50	16.50	49.00	67.00	15.50	35.00	234.50
50)	EC390220	167.00	9.00	40.50	16.00	21.00	28.00	15.00	60.00	168.00
51)	EC390210	235.00	7.00	30.50	18.50	12.00	19.00	17.50	60.00	114.00
52)	EC394756	388.00	11.00	29.00	15.50	40.00	69.00	12.00	65.00	448.50
53)	EC390241	105.00	7.00	35.50	18.50	21.00	62.00	13.50	60.00	372.00
54)	EC390226	62.00	5.00	28.50	14.00	18.00	40.00	14.00	40.00	160.00
55)	EC390225	378.00	5.00	25.00	19.50	21.00	27.00	18.50	45.00	121.50
56)	EC472261	33.00	1.00	21.00	18.00	4.00	5.00	8.50	50.00	25.00
57)	EC37587	34.00	2.00	11.50	12.50	7.00	14.00	13.50	35.00	49.00
58)	EC390224	37.00	4.00	22.00	24.50	12.00	17.00	16.00	58.00	98.60
59)	EC367702	66.00	3.00	28.50	16.00	12.00	14.00	15.00	45.00	63.00
60)	EC91171-A	71.00	6.00	30.50	12.00	29.00	52.00	12.00	25.00	130.00
61)	EC9135-B	45.00	4.00	18.50	15.00	15.00	19.00	15.50	65.00	123.50
62)	EC30950	32.00	5.00	27.00	19.50	7.00	12.00	14.50	60.00	72.00
63)	EC37588	46.00	7.00	25.50	15.50	42.00	94.00	15.50	40.00	376.00
64)	EC9736	127.00	9.00	36.50	14.50	56.00	79.00	14.00	50.00	395.00

65)	EC9738	300.00	7.00	41.00	13.50	30.00	53.00	11.50	50.00	265.00
66)	EC160493/20	166.00	4.00	28.00	13.50	33.00	52.00	14.50	40.00	208.00
67)	EC390216	225.00	8.00	42.00	12.50	41.00	65.00	14.50	30.00	195.00
68)	EC528412	45.00	7.00	34.50	17.50	30.00	31.00	14.00	40.00	124.00
69)	EC390223	200.00	5.00	33.50	16.50	39.00	54.00	14.00	50.00	270.00
70)	EC399251	170.00	8.00	25.00	18.00	39.00	57.00	14.50	60.00	342.00
71)	EC9739	275.00	7.00	34.00	15.50	29.00	38.00	13.00	50.00	190.00
72)	EC390240	309.00	6.00	26.00	17.50	18.00	25.00	16.00	50.00	125.00
73)	EC390237	130.00	6.00	33.00	19.50	29.00	44.00	14.50	50.00	220.00
74)	EC390257	60.00	7.00	29.00	12.50	45.00	81.00	11.00	50.00	405.00
75)	EC390268	47.00	5.00	27.50	18.50	20.00	27.00	18.50	50.00	135.00
76)	EC15296	100.00	5.00	34.50	14.50	46.00	59.00	16.50	60.00	354.00
77)	EC472260	171.00	9.00	29.50	16.50	72.00	98.00	16.50	40.00	392.00
78)	EC390287	35.00	2.00	19.50	12.00	6.00	3.00	6.00	30.00	9.00
79)	EC97738	40.00	9.00	25.00	15.50	24.00	41.00	13.50	40.00	164.00
80)	CD Between two check mean	9.19	0.96	8.75	6.31	6.62	13.51	2.39	36.72	113.72
81)	CD Between two genotypes in same block	20.54	2.14	19.56	14.10	14.81	30.22	5.34	82.11	254.29
82)	CD Between two genotypes not in same block	22.86	2.38	21.76	15.69	16.48	33.62	5.94	91.36	282.95
83)	CD Between genotype and check	17.71	1.85	16.86	12.15	12.76	26.04	4.60	70.77	219.17

Table 3: Eigen vectors showing variation contributed by different cowpea traits towards each principal component

Character	Principal component 1	Principal component 2	Principal component 3	Principal component 4	Principal component 5	Principal component 6	Principal component 7	Principal component 8	Principal component 9
Plant height	0.11244	0.36805	-0.634	0.48575	0.09566	-0.4389	0.05832	-0.0922	0.01756
Number of primary branches/plant	0.39566	0.12497	-0.2343	0.25016	-0.1207	0.77417	-0.2978	-0.0882	0.00068
Peduncle length (cm)	0.36036	0.08579	-0.0418	-0.2792	0.83413	0.11721	0.2572	0.0767	0.03953
Pod length (cm)	-0.263	0.52397	0.21531	0.0662	-0.0947	0.27069	0.61046	-0.3782	-0.0872
Peduncle number	0.4616	0.02641	0.13078	0.12217	-0.3065	-0.0646	0.40603	0.58592	-0.3847
Pod number	0.46926	-0.048	0.23867	0.04954	-0.2202	-0.1632	0.18085	-0.1927	0.75704
Seed number	0.12251	0.43182	-0.3179	-0.7559	-0.3241	-0.0758	-0.1163	0.03282	0.02666
Pod weight (g)	-0.2224	0.55459	0.31427	0.16936	0.13734	0.02885	-0.309	0.54496	0.32154
Yield (kg/plant)	0.36611	0.26452	0.47025	0.04108	0.07254	-0.2892	-0.4032	-0.3954	-0.4067

Table 4: Proportionate contribution of each principal component towards divergence

Principal component	Eigen value	Difference	Proportion	Cumulative
Principal component 1	3.8663	1.9007	0.4296	0.4296
Principal component 2	1.9656	0.8730	0.2184	0.6480
Principal component 3	1.0926	0.3957	0.1214	0.7694
Principal component 4	0.6970	0.1140	0.0774	0.8468
Principal component 5	0.5830	0.1989	0.0648	0.9116
Principal component 6	0.3841	0.1494	0.0427	0.9543
Principal component 7	0.2347	0.1090	0.0261	0.9804
Principal component 8	0.1257	0.0746	0.0140	0.9943
Principal component 9	0.0511		0.0057	1.0000

Table 5: Correlation between various yield and yield related traits in cowpea

Character	Plant height (cm)	Number of primary branches/plant	Peduncle length (cm)	Pod length (cm)	Peduncle number	Pod number	Seed number	Pod weight (g)	Pod Yield (kg/plant)
Plant height	1.0000	0.3691**	0.1826	0.0997	0.1628	0.0413	0.3227**	0.1367	0.0902
Number of primary branches/plant	0.3691**	1.0000	0.4917**	-0.2685*	0.6679**	0.6101**	0.2511	-0.2404*	0.4533**
Peduncle length (cm)	0.1826	0.4917*	1.0000	-0.3016**	0.4953**	0.5213**	0.2375	-0.2083*	0.5185**
Pod length (cm)	0.0997	-0.2685*	-0.3016	1.0000	-0.3636	-0.4414	0.2022	0.8029**	-0.0585
Peduncle number	0.1628	0.6679**	0.4953**	-0.3636**	1.0000	0.9049**	0.1819	-0.3296**	0.6725**
Pod number	0.0413	0.6101**	0.5213**	-0.4414**	0.9049**	1.0000	0.1142	-0.4014**	0.7489**
Seed number	0.3227**	0.2511*	0.2375*	0.2022	0.1819	0.1142	1.0000	0.1513	0.2165*
Pod weight (g)	0.1367	-0.2404*	-0.2083	0.8029**	-0.3296**	-0.4014**	0.1513	1.0000	0.1380
Yield (kg/plant)	0.0902	0.4533**	0.5185**	-0.0585	0.6725**	0.7489**	0.2165*	0.1380	1.0000

4. Conclusion

The maximum variability in the 79 genotypes was observed in the first six principal components that contributed a cumulative total of 95.43% by nine quantitative characters. Out of nine characters studied the characters that contributed maximum towards divergence were pod number, peduncle number, number of primary branches per plant and yield per plant. Highly significant posititve correlation for the

dependant variable pod yield (kg/plant) was observed with pod number followed by peduncle number, peduncle length (cm) and number of primary branches/plant.

5. Acknowledgement

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