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Research Article

Characterization of pigeonpea germplasm using DUS descriptors

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Abstract
The present study was carried out on sixty-eight early duration pigeonpea genotypes during *rabi,* 2021-22. Twenty traits were recorded as per the descriptors provided by PPV & FRA and several genotypes possessed unique traits that aid in genotype identification and varietal purification. The traits *viz.,* branching pattern, growth habit, stem colour, colour of base of petal, pattern of streaks on petal (standard), pod colour, pod surface stickiness, pod size, the number of seeds per pod, seed colour, seed shape, seed pattern and seed size showed significant variation among genotypes. Characters such as leaf shape, leaf pubescence, days to 50% flowering and pod constriction showed no variation. Sixty-eight genotypes were subjected to cluster analysis and the genotypes were grouped into eight major clusters, where cluster II was the largest one followed by clusters VI, I, IV, V, VII, VIII and III. The genotypes present in different clusters showed high variation for different traits and will be utilized for crop improvement programs.

Keywords: Pigeonpea, Distinctiveness, Uniformity, Stability, qualitative, clustering

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp. is an important pulse crop, tolerant to drought grown in most tropics and sub-tropics. India is considered to be a place of origin due to the presence of a wide range of diversity. Pigeonpea ranks sixth in global grain legume production, with an annual production of 5.96 million tonnes with mean productivity of 852 kg per hectare. (FAOSTAT, 2019). India is the world's leading producer of pigeonpea grown in an area of around 48.24 lakh hectares with yearly production and productivity of 38.8 lakh tonnes and 804 kg per hectare, respectively (DES, 2020-2021). Inspite of the benefits, it is viewed as an orphan crop. Lately, a study of the national agricultural program described that it was one of the nineteen neglected and underutilized priority crops that deserves attention and support. The need of increasing the utilization of genetic resources to enhance the productivity of the crop has long been well recognized. The concept of DUS was fundamental to the characterization of variety as a unique creation (Sahu *et al*., 2018). The foremost objective of this study was a phenotypic characterization of pigeonpea genotypes based on the DUS descriptors for various morphological characters.

MATERIALS AND METHODS

The experiment was conducted at the Department of Pulses, Tamil Nadu Agricultural University, Coimbatore during *rabi,* 2021-22. The experimental material comprised of sixty-eight early duration pigeonpea genotypes (**Table 1**). Genotypes were grown in Augmented Block Design II for evaluation. Each genotype was raised in 4 m length with a spacing of 60 x 30 cm. Observations were recorded for twenty traits at various stages of plant growth. It includes growth characters *viz.,* plant branching

Table 1. List of pigeonpea genotypes used in the study

S. No.	Genotypes	Source of origin
1	CRG 16-12	TNAU, Coimbatore
2	CRG 16-07	TNAU, Coimbatore
3	ICPL 20325	ICRISAT, Telangana
4	ICPL 90047	ICRISAT, Telangana
5	ICPL 11301	ICRISAT, Telangana
6	ICP 9808	ICRISAT, Telangana
7	ICP 91	ICRISAT, Telangana
8	ICP 3215	ICRISAT, Telangana
9	ICP 10697	ICRISAT, Telangana
10	ICP 13271	ICRISAT, Telangana
11	ICP 2387	ICRISAT, Telangana
12	ICP 2391	ICRISAT, Telangana
13	ICP 245507	ICRISAT, Telangana
14	ICP 7919	ICRISAT, Telangana
15	ICP 92047	ICRISAT, Telangana
16	IC 525443	ICRISAT, Telangana
17	IC 525520	ICRISAT, Telangana
18	IC 525454	ICRISAT, Telangana
19	IC 342747	ICRISAT, Telangana
20	IC 73895	ICRISAT, Telangana
21	IC 74016	ICRISAT, Telangana
22	ACP 1225	IIPR, Kanpur
23	AL 1685	PAU, Ludhiana
24	AL 1692	PAU, Ludhiana
25	AL 1727	PAU, Ludhiana
26	C 2542	IIPR, Kanpur
27	CO 5	TNAU, Coimbatore
28	DPP 2-52	IIPR, Kanpurv
29	DPP 3-81	IIPR, Kanpur
30	DPP-2-183	IIPR, Kanpur
31	DPP-2-188	IIPR, Kanpur
32	DPP-2-89	IIPR, Kanpur
33	DPP-3-2	IIPR, Kanpur
34	PA 509	GBPAU&T, Pantnagar
35	RVKT 333	IIPR, Kanpur
36	AL 2184	PAU, Ludhiana
37	IPAE 15-05	IIPR, Kanpur
38	IPAE 18-04	IIPR, Kanpur
39	AL 2250	PAU, Ludhiana
40	AL 2276-1	PAU, Ludhiana
41	PA 669	GBPAU&T, Pantnagar
42	PusaArhar 21-45	Pusa, New Delhi
43	CRG 16-01	TNAU, Coimbatore
44	PusaArhar 21-14	Pusa, New Delhi
45	PusaArhar 21-27	Pusa, New Delhi
46	PusaArhar 21-24	Pusa, New Delhi
47	PusaArhar 21-29	Pusa, New Delhi
48	PAU 881	PAU, Ludhiana
49	PusaArhar 291	Pusa, New Delhi
50	IPAE 15-08	IIPR, Kanpur
51	PusaArhar 21-61	Pusa, New Delhi
52	PusaArhar 21-57	Pusa, New Delhi
53	AL 2324	PAU, Ludhiana
54	TJT 501	BARC & Khargone
55	PT 0012	IIPR, Kanpur
56	BDN 711	ARS, Badnapur
57	BWR 243	IIPR, Kanpur
58	BWR 853	IIPR, Kanpur
59	BSMR 26	IIPR, Kanpur
60	BWR 253	IIPR, Kanpur
61	BWR 553	IIPR, Kanpur
62	BWR 316	IIPR, Kanpur
63	BSMR 65	IIPR, Kanpur
64	BSMR 399	IIPR, Kanpur
65	BWR 23	IIPR, Kanpur
66	BWR 164	IIPR, Kanpur
67	BWR 153	IIPR, Kanpur
68	BWR 134	IIPR, Kanpur

pattern, plant growth habit, plant height and stem colour; leaf characters *viz.,* leaf shape and leaf pubescence on the lower surface of the leaf; flower characters *viz*., days to 50% flowering, colour of base of petal and pattern of streaks on petal(standard); pod characters *viz.,* pod colour, pod pubescence, pod waxiness, pod surface stickiness, pod constriction, pod size and the number of seeds per pod and seed characters *viz.,* seed colour, seed colour pattern, seed shape and seed size (hundred seed weight) as per the guidelines given by PPV&FRA. The morphological data were subjected to cluster analysis using GGT 2.0 software.

RESULTS AND DISCUSSION

Relative and absolute frequency were observed for each trait (**Table 2**). Sixty-eight genotypes were grouped based on 20 morphological traits (**Table 3**). In order to find distinctiveness among genotypes both qualitative and quantitative characters were used for evaluation. Qualitative traits were considered as morphological markers in the identification of genotypes because they are less influenced by the environment. Morphological traits were important for varietal description.

Erect as well as semi-spreading nature of the branching pattern was distributed equal among genotypes (**Fig. 1**). Nearly 89.71 per cent genotypes showed indeterminate growth and remaining 10.29 per cent genotypes showed determinate growth habit *viz.,* ICPL 20325, ACP 1225, AL 2184, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24 and PusaArhar 21-29 (**Fig. 2**). Green stem was found in 64.71 per cent of genotypes, whereas purple stem was found in 35.29 per cent of genotypes (**Table 3**). Muniswamy *et al.* (2014) showed similar results for 196 pigeonpea genotypes for features including stem colour and growth habit.

All sixty-eight genotypes showed oblong leaf shape with 100 per cent relative frequency. Leaf pubescence was absent in all sixty-eight genotypes (**Table 3**). Concurrent results were reported by Sahu *et al*. (2018) in sixty pigeonpea genotypes, for characters such as leaf shape and leaf pubescence.

Light yellow flowers were observed in 63.24 per cent of genotypes, yellow flowers in 27.94 per cent of genotypes and red flowers were observed in 8.82 per cent of genotypes *viz.,* PusaArhar 21-27, Pusa Arhar 21-24, PusaArhar 21-29, BSMR 26, BSMR 65 and BWR 134 (**Fig. 3**). Medium floral streaks on the base petal were found in 45.59 per cent of genotypes, absent in 17.65 per cent, sparse and dense streaks in 13.24 per cent and 23.53 per cent of genotypes, respectively (**Fig. 4**). Comparable results for flower colour were reported by Metkar *et al*. (2014) and Sahu *et al*. (2018) during characterizing twenty-five and sixty pigeonpea genotypes, respectively.

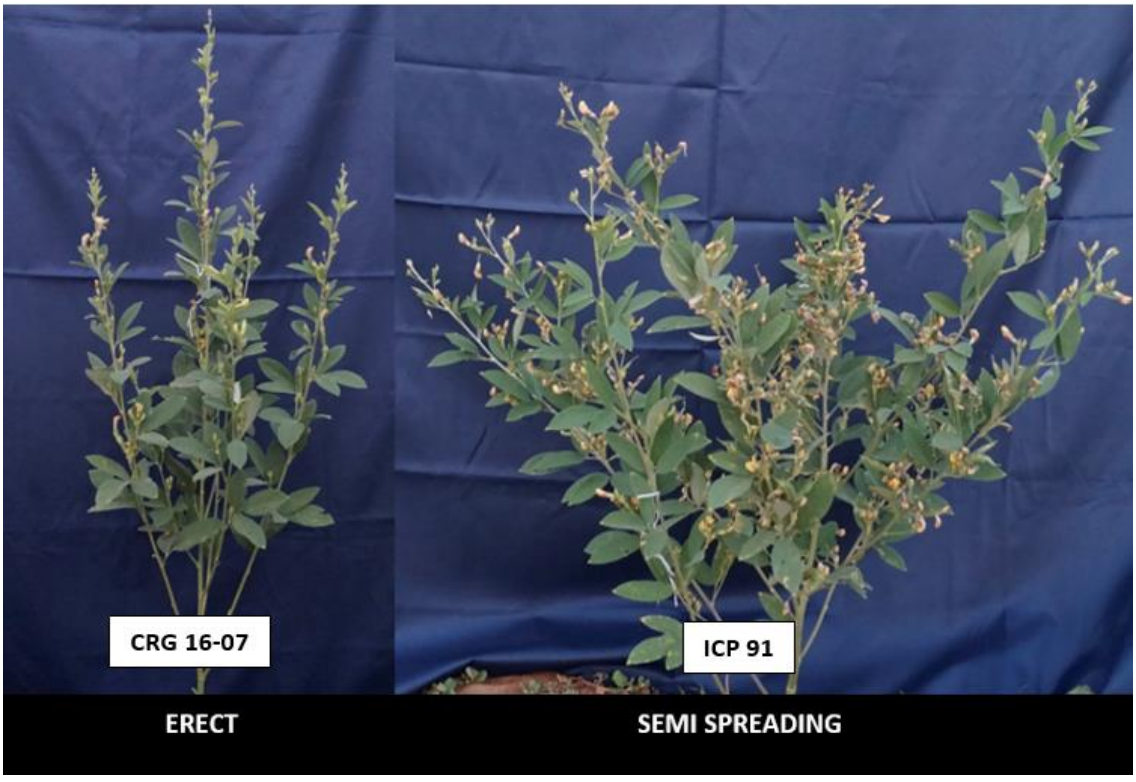

Fig. 1. Variation for branching pattern

Table 2. Characterization of 68 pigeonpea genotypes based on morphological traits

S. No.	Morphological characters	States	Code	Absolute Frequency	Relative Frequency (%)
1	Plant: branching pattern	Erect (<30°)	3	34	50.00
		Semi-spreading (30°-60°)	5	34	50.00
		Spreading (>60°)	7	0	0.00
2	Plant: growth habit	Determinate	1	7	10.29
		Indeterminate	3	61	89.71
3	Stem: colour	Green	1	44	64.71
		Purple	2	24	35.29
4	Leaf: shape	Oblong	1	68	100.00
		Obovate	3	0	0.00
		Narrowly Oblong	5	0	0.00
5	Leaf: pubescence on lower surface of the leaf	Absent	1	68	100.00
		Present	9	0	0.00
6	Time of flowering (50% of the plants with at least one open flower)	Very early (<60)	1	0	0.00
		Early (61-90 days)	3	68	100.00
		Medium(90-130days)	5	0	0.00
		Late (131-160days)	7	0	0.00
		Very late (>160days)	9	0	0.00
7	Flower: colour of base of petal	Light yellow	1	43	63.24
		Yellow	2	19	27.94
		Orange yellow	3	0	0.00
		Purple	4	0	0.00
		Red	5	6	8.82
8	Flower: pattern of streaks on petal (standard)	Absent	1	12	17.65
		Sparse	3	9	13.24
		Medium	5	31	45.59
		Dense	7	16	23.53
		Mosaic	9	0	0.00
9	Pod: colour	Green	1	1	1.47
		Green with brown streaks	2	63	92.64
		Green with purple streaks	3	4	5.88
		Purple	4	0	0.00
		Dark purple	5	0	0.00
10	Pod: pubescence	Absent	1	0	0.00
		Present	9	68	100.00
11	Pod: waxiness	Absent	1	68	100.00
		Present	9	0	0.00
12	Pod: surface stickiness	Absent	1	49	72.00
		Present	9	19	27.94
13	Pod: constriction	Slight	3	0	0.00
		Prominent	7	68	100.00
14	Pod: size (cm)	<4cm	3	6	8.82
		4-5cm	5	54	79.41
		>5cm	7	8	11.76
15	Pod: number of seeds	2	3	0	0.00
		3	5	37	54.41
		4	7	31	45.59
16	Plant: height	Short(<100cm)	3	59	86.76
		Medium(100-150cm)	5	9	13.23
		Tall(>150cm)	7	0	0.00
17	Seed: colour	Cream	1	8	11.76
		Brown	2	52	76.47
		Dark brown	3	7	10.29
		Grey	4	0	0.00
		Purple	5	1	1.47
18	Seed: colour pattern	Uniform	1	59	86.76
		Mottled	2	9	13.24
19	Seed: shape	Oval	1	51	75.00
		Globular	2	16	23.52
		Elongate	3	1	1.47
20	Seed: size (100 seed weight)	Small(<7g)	3	14	20.58
		Medium(7-9g)	5	48	70.58
		Large(>9-11g)	9	6	8.82

Table 3. Grouping of pigeonpea genotypes based on various morphological characters

S. No.	Morphological characters	States	Genotypes
1	Plant: branching pattern	Erect (<30°)	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 11301, ICP 3215, ICP 10697, ICP 2387, ICP 2391, ICP 92047, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, PA 509, AL 2184, IPAE 15-05, IPAE 18-04, AL 2276-1, PA 669, PusaArhar 21-45, PusaArhar 21-14, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, AL 2324, BWR 253, BWR 553, BWR 316, BSMR 399, BWR 164.
		Semi-spreading (30°-60°)	ICPL 90047, ICP 9808, ICP 91 ICP 13271, ICP 7919, ICP 245507, IC 525443, IC 525520 IC 342747, CO 5, DPP 2-52, DPP 3-81, IC 525454, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, RVKT 333, AL 2250, CRG 16-01, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-61, PusaArhar 21-57, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 65, BWR 23, BSMR 26, BWR 153, BWR 134.
		Spreading (>60°)	-
2	Plant: growth habit	Determinate	ICPL 20325, ACP 1225, AL 2184, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29.
		Indeterminate	CRG 16-12, CRG 16-07, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
3	Stem: colour	Green	CRG 16-12, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 245507, ICP 7919, ICP 92047, IC 525520, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, CO 5, DPP 2-52, DPP-2-183, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, PT 0012, BDN 711, BSMR 26, BWR 316, BSMR 65.
		Purple	CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 2387, ICP 2391, IC 525443, IC 525454, C 2542, DPP 3-81, DPP-2-188, CRG 16-01, PAU 881, TJT 501, BWR 243, BWR 853, BWR 253, BWR 553, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
4	Leaf: shape	Oblong	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		Obovate	-
		Narrowly Oblong	-
5	Leaf: pubescence on lower surface of the leaf	Absent	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		Present	-

6	Time of flowering (50% of the plants with at least one open flower)	Very early (<60)	-
		Early (61-90 days)	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		Medium (90-130days)	-
		Late (131-160days)	-
		Very late (>160days)	-
7	Flower: colour of base of petal	Light yellow	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 3215, ICP 13271, ICP 245507, ICP 7919, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PAU 881, IPAE 15-08, PusaArhar 21-57, TJT 501, PT 0012, BDN 711, BWR 243, BWR 253, BWR 553, BWR 316, BWR 164, BWR 153.
		Yellow	ICP 9808, ICP 91, ICP 10697, ICP 2387, ICP 2391, ICP 92047, IC 525443, IC 525520, AL 1692, DPP-2-89, DPP-3-2, AL 2250, PusaArhar 21-14, PusaArhar 291, PusaArhar 21-61, AL 2324, BWR 853, BSMR 399, BWR 23.
		Orange yellow	-
		Purple	-
		Red	PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, BSMR 26, BSMR 65, BWR 134.
8	Flower: pattern of streaks on petal (standard)	Absent	ICP 13271, IC 342747, AL 1692, AL 1727, C 2542, PusaArhar 21-24, PAU 881, PusaArhar 291, BDN 711, BWR 316, BWR 164, BWR 153.
		Sparse	ICPL 11301, ICP 10697, ICP 92047, IC 74016, ACP 1225, DPP-2-188, PusaArhar 21-61, BWR 243, BWR 253.
		Medium	CRG 16-12, ICPL 20325, ICPL 90047, ICP 3215, ICP 245507, ICP 7919, IC 525443, IC 525520, IC 73895, AL 1685, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-89, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, IPAE 15-08, PusaArhar 21-57, TJT 501, PT 0012, BSMR 26, BSMR 65.
		Dense	CRG 16-07, ICP 9808, ICP 91, ICP 2387, ICP 2391, IC 525454, DPP-3-2, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-29, AL 2324, BWR 853, BWR 553, BSMR 399, BWR 23, BWR 134.
		Mosaic	-
9	Pod: colour	Green	CRG 16-07.
		Green with brown streaks	CRG 16-12, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		Green with purple streaks	CO 5, PusaArhar 21-24, BDN 711, BWR 316.
		Purple	-
		Dark purple	-

10	Pod: pubescence	Absent	-
		Present	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
11	Pod: waxiness	Absent	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		Present	-
12	Pod: surface stickiness	Absent	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525520, IC 525454, IC 342747, IC 74016, ACP 1225, AL 1685, AL 1692, C 2542, DPP-2-188, DPP-3-2, PA 509, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, PusaArhar 21-57, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 553, BWR 316, BWR 164, BWR 153.
		Present	IC 525443, IC 73895, AL 1727, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-89, RVKT 333, IPAE 15-08, AL 2324, PusaArhar 21-61, TJT 501, PT 0012, BWR 253, BSMR 65, BSMR 399, BWR 23, BWR 134.
13	Pod: constriction	Slight	-
		Prominent	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
14	Pod: size (cm)	<4cm	ICP 91, ICP 13271, ICP 7919, ICPL 90047, IC 525454, AL 2184.
		4-5cm	CRG 16-07, ICPL 20325, ICPL 11301, ICP 9808, ICP 3215, ICP 10697, ICP 245507, ICP 92047, IC 525443, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		>5cm	CRG 16-12, ICP 2387, ICP 2391, IC 525520, DPP 2-52, PusaArhar 21-14, BWR 243, BSMR 65.
15	Pod: number of seeds	2	-
		3	CRG 16-12, ICPL 20325, ICPL 90047, ICP 9808, ICP 91, ICP 13271, ICP 2387, ICP 245507, IC 525443, IC 525520, IC 525454, IC 73895, ACP 1225, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-89, PA 509, RVKT 333, AL 2184, AL 2250, CRG 16-01, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PusaArhar 291, IPAE 15-08, PusaArhar 21-57, BWR 853, BWR 253, BSMR 65, BSMR 399, BWR 164, BWR 153.
		4	CRG 16-07, ICPL 11301, ICP 3215, ICP 10697, ICP 2391, ICP 7919, ICP 92047, IC 342747, IC 74016, AL 1685, AL 1692, DPP-2-188, DPP-3-2, IPAE 15-05, IPAE 18-04, AL 2276-1, PA 669, PusaArhar 21-45, PusaArhar 21-14, PAU 881, PusaArhar 21-61, AL 2324, TJT 501, PT 0012, BDN 711, BWR 243, BSMR 26, BWR 553, BWR 316, BWR 23, BWR 134.

16	Plant: height	Short (<100cm)	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 92047, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, BDN 711, BWR 243, BSMR 26, BWR 553, BSMR 65, BWR 23, BWR 164, BWR 134.
		Medium(100-150cm)	ICP 7919, IC 525443, IC 525520, PT 0012, BWR 853, BWR 253, BWR 316, BSMR 399, BWR 153.
		Tall(>150cm)	-
17	Seed: colour	Cream	RVKT 333, BDN 711, BSMR 26, BSMR 65, BWR 23, BWR 164, BWR 153, BWR 134.
		Brown	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 90047, ICPL 11301, ICP 9808, ICP 91, ICP 10697, ICP 13271, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1692, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, PA 509, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-27, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BWR 853, , BWR 253, BWR 553, BWR 316, BSMR 399.
		Dark brown	ICP 3215, ICP 2387, IC 525454, AL 1685, PusaArhar 21-14, PusaArhar 21-24, BWR 243.
		Grey	-
		Purple	DPP-3-2.
18	Seed: colour pattern	Uniform	ICPL 90047, ICPL 11301, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1685, AL 1727, C 2542, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, RVKT 333, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, PA 669, PusaArhar 21-45, CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-24, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316, BSMR 65, BSMR 399, BWR 23, BWR 164, BWR 153, BWR 134.
		Mottled	CRG 16-12, CRG 16-07, ICPL 20325, ICP 9808, ICP 245507, AL 1692, CO 5, AL 2276-1, TJT 501.
19	Seed: shape	Oval	ICPL 90047, ICPL 11301, ICP 91, ICP 3215, ICP 10697, ICP 13271, ICP 2387, ICP 2391, ICP 245507, ICP 7919, ICP 92047, IC 525443, IC 525520, IC 525454, IC 342747, IC 73895, IC 74016, AL 1685, AL 1727, C 2542, CO 5, DPP 2-52, DPP 3-81, DPP-2-183, DPP-2-188, PA 509, AL 2184, IPAE 15-05, IPAE 18-04, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-24, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-57, TJT 501, PT 0012, BDN 711, BWR 243, BWR 853, BSMR 26, BWR 253, BWR 553, BWR 316,BSMR 399,BWR 164, BWR 153, BWR 134.
		Globular	CRG 16-12, CRG 16-07, ICPL 20325, ICP 9808, ACP 1225, AL 1692, DPP-2-89, DPP-3-2, RVKT 333, AL 2276-1, PusaArhar 21-27, PusaArhar 21-29, PusaArhar 21-61, AL 2324, BSMR 65, BWR 23.
		Elongate	IC 73895.
20	Seed: size (100 seed weight)	Small(<7g)	ICPL 90047, ICP 91, ICP 2387, ICP 2391, ICP 245507, IC 525520, IC 525454, AL 1685, PusaArhar 21-24, BWR 243, BWR 253, BWR 153, RVKT 333, IPAE 18-04.
		Medium (7-9g)	CRG 16-12, CRG 16-07, ICPL 20325, ICPL 11301, ICP 9808, ICP 3215, ICP 10697, ICP 13271, ICP 7919, ICP 92047, IC 525443, IC 342747, IC 73895, IC 74016, ACP 1225, AL 1692, AL 1727, C 2542, CO 5, DPP-2-183, DPP-2-188, DPP-2-89, DPP-3-2, PA 509, AL 2184, IPAE 15-05, AL 2250, AL 2276-1, PA 669, PusaArhar 21-45,CRG 16-01, PusaArhar 21-14, PusaArhar 21-27, PusaArhar 21-29, PAU 881, PusaArhar 291, IPAE 15-08, PusaArhar 21-61, PusaArhar 21-57, AL 2324, TJT 501, PT 0012, BDN 711, BWR 853,BWR 553, BWR 316, BSMR 399, BWR 164.
		Large (>9-11g)	DPP 2-52, DPP 3-81, BSMR 26, BSMR 65, BWR 23, BWR 134.

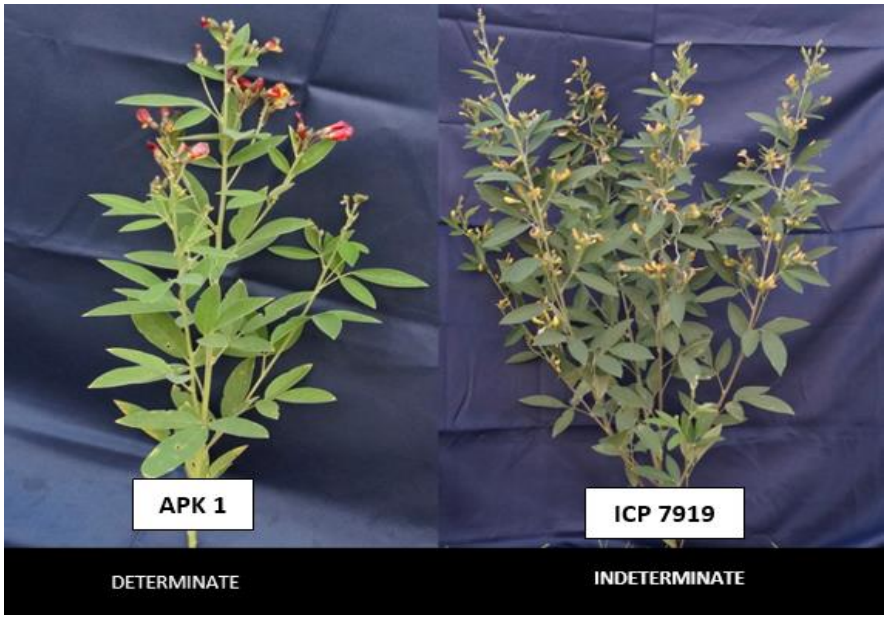

Fig. 2. Variation for plant growth habit

Fig. 3. Variation for flower colour of base petal

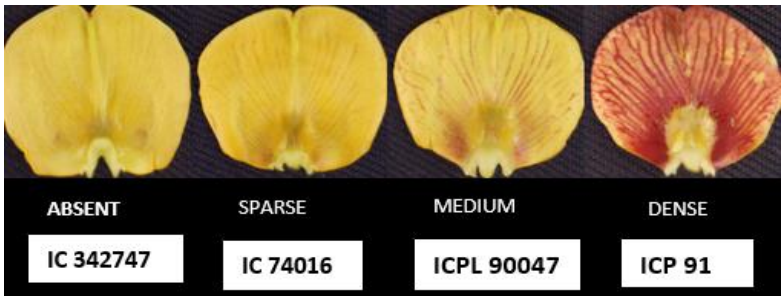

Fig. 4. Variation for flower streaks pattern on base petal

With respect to pod colour, genotypes were divided into green, green with brown streaks, green with purple streaks, dark purple and purple. Only 1.47 per cent of genotypes contain green pods. CRG 16-07 is an example of genotype with green pod. Green pods with brown streaks were found in 92.64 per cent of genotypes, while green pods with purple streaks were found in 5.88 per cent of genotypes. The genotypes CO 5, PusaArhar 21-24, BDN 711 and BWR 31 had purple streaks on their pods. Pod surface stickiness was present in 70.59 per cent of genotypes, but absent in the remaining 29.41 per cent. Based on the length of pod, it was cleaved into three classes. Nearly 79.41 per cent of genotypes had a pod length of 4-5 cm, 11.76 per cent had a pod length

greater than 5 cm and 8.82 per cent with pod length less than 4 cm. Eight genotypes *viz*., CRG 16-12, ICP 2387, ICP 2391, IC 525520, DPP 2-52, PusaArhar 21-14, BWR 243 and BSMR 65 had greater pod length of more than 5 cm. The maximum number of genotypes with 54.41 per cent had three seeds per pod, whereas 45.59 per cent of genotypes had four seeds per pod. Muniswamy *et al.* (2014) reported similar results for features including characters such as pod waxiness and pod pubescence. In the case of pod length, most of the genotypes had 4 to 5 cm length and it was in accordance with results are shown by Sahu *et al*. (2018) during characterization of sixty pigeonpea genotypes.

Creamy seed colour was reported in 11.76 per cent of genotypes which include RVKT 333, BDN 711, BSMR 26, BSMR 65, BWR 23, BWR 164, BWR 153 and BWR 134. Brown seed colour was found in 76.47 per cent of genotypes, 10.29 per cent showed dark brown seed colour *viz.,* ICP 3215, ICP 2387, IC 525454, AL 1685, PusaArhar 21-14, PusaArhar 21-24 and BWR 243. Only the genotype DPP-3-2 showed purple seed colour with relative frequency of 1.47 per cent (**Fig. 5**). Uniform seed pattern was noticed in 86.76 per cent genotypes, whereas the remaining 13.24 per cent had mottled seed patterns (**Fig. 6**). Oval seeds were found in 75 per cent genotypes, globular seeds in 23.52 per cent and elongate seed shape were found in IC 73895 with a relative frequency of 1.47 per cent. The maximum of 70.58 per cent of genotypes recorded hundred seed weight of 7 to 9 g and was grouped in medium seed size, 20.58 per cent of genotypes were categorized under small seed size and large seed size was found in 8.82 per cent of genotypes. Large seeds were mostly found in creamy seeded genotypes *viz.,* DPP 2-52, DPP 3-81, BSMR 26, BSMR 65, BWR 23 and BWR 134. Similar results were found by Geofroy *et al*. (2020) and Metkar *et al*. (2014) for seed patterns, while characterizing fifty and twenty-five pigeonpea genotypes, respectively.

Fig. 5. Variation for seed colour

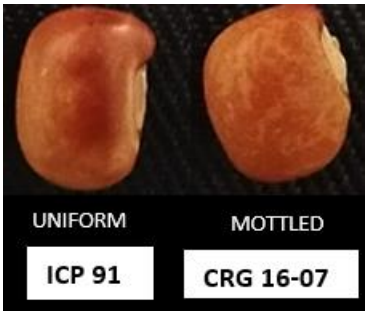

Fig. 6. Variation for seed pattern

Sixty-eight genotypes were grouped into eight major clusters by cluster analysis using GGT 2.0 software (**Fig.7**). The similarity coefficient ranged between 0.42 and 0.87. Cluster I was split into two subgroups, where subgroup I had three genotypes and subgroup II with four genotypes. Cluster II had more genotypes (25), making it as the largest cluster. It was divided into two subgroups. Twenty-three genotypes were present in subgroup I and two genotypes in subgroup II. Cluster III was also divided into two subgroups *viz*., I and II and had two genotypes and it was found to be the smallest. There were five genotypes in cluster IV and was divided into two subgroups. Cluster V was divided into two subgroups which contain four genotypes, cluster VI contains nineteen genotypes making it the second largest cluster after cluster II. Both clusters VII and VIII

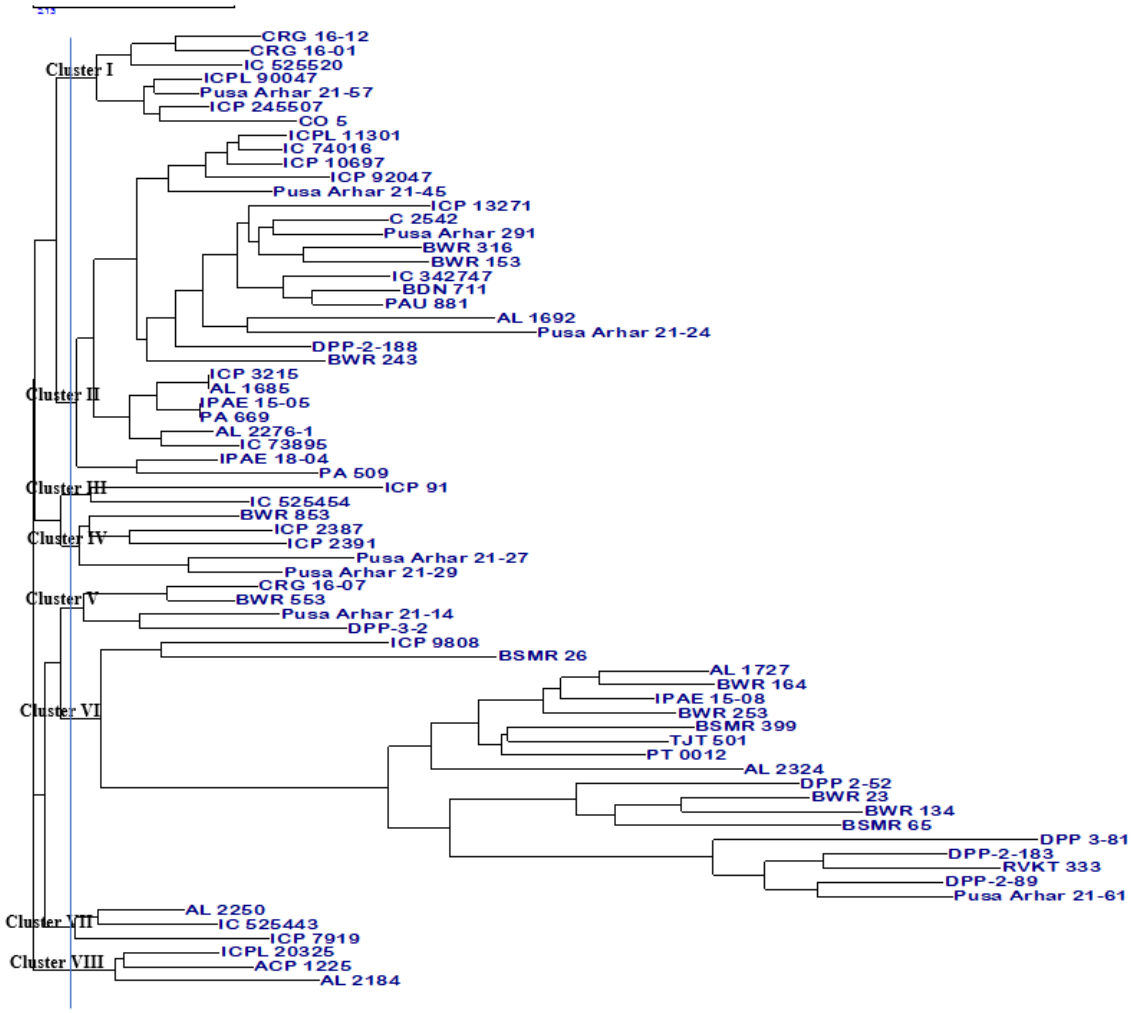

Fig. 7. Dendrogram constructed by cluster analysis of 68 pigeonpea genotypes

consisted of only three genotypes. Genotypes present in different clusters showed high variation among them than those present in the same cluster. The clustering pattern reveals that pigeonpea accessions from different origins were frequently found in the same cluster with high morphological similarities. Genotypes *viz*., ICP 3215 and AL 1685 exhibited 100 per cent similarity located in cluster II. Similarly, the genotypes IPAE 15-05 and PA 669 were highly comparable in cluster II. Rupika and Bapu (2014) grouped ninety pigeonpea genotypes into six major clusters. According to Chaudhary *et al*. (2021), 243 pigeonpea genotypes were grouped into six primary clusters. Ranjani *et al*. (2021) classified sixty-eight pigeonpea genotypes into four different clusters.

Out of the twenty morphological characters studied, three characters *viz.,* leaf pubescence, pod pubescence and pod waxiness were monomorphic, noticed in all sixty-eight genotypes. Seven characters *viz.,* growth habit, branching pattern, stem colour, pod surface stickiness, the number of seeds per pod, plant height and seed pattern were dimorphic, five characters *viz.,* flower colour, pod size, pod colour, seed shape and hundred seed weight were trimorphic, two characters *viz.,* flower pattern and seed colour were tetramorphic. Both high seed weight and pod length were observed in genotypes DPP 2-52 and BSMR 65. These genotypes can be effectively utilized in hybridization programs for improving yield traits. Sixty-eight genotypes were grouped into eight major clusters and genotypes from different clusters can be effectively utilized in a breeding program.

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