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Morphological diversity and identification of early-maturing cowpea (Vigna unguiculata L. Walp) accessions for crop improvement

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Abstract **Original Research**

One hundred cowpea (Vigna unguiculata L. Walp) accessions comprising 21 improved varieties and 79 landraces obtained from the Genetic Resources Center of the International Institute of Tropical Agriculture (IITA), Ibadan, were evaluated to assess morphological diversity and identify early-maturing, high-yielding accessions based on seedling emergence, flower and pod appearance, number of pods harvested and the number of seeds harvested per plant for crop improvement. The experiment was conducted in a screenhouse using a completely randomized design with three replications. Qualitative traits were analyzed using frequency distribution while quantitative traits were subjected to analysis of variance (ANOVA) followed by mean separation using least significant difference (LSD, $\alpha = 0.05$). Cluster analysis was performed based on seedling emergence, morphological and reproductive traits. Results showed substantial variability among accessions with predominance of brown seed coat colour (45%), globular seed shape (63%), smooth seed coat texture (73%), white flowers (48%), erect growth habit (83%), and non-twining type (93%). Significant differences were recorded for days to emergence, flowering, and podding. Accessions TVu-1497, TVu-10303, and TVu-11545 emerged earliest; TVu-1702, TVu-1544, and TVu-3000 flowered earliest; while TVu-3657, TVu-3000, and TVu-2252 reached podding earliest. TVu-3658, TVu-1387, and TVu-1707 combined earliness with superior yield performance, whereas TVNu-1963, TVu-14040, and IT98K-205-8 failed to flower. Cluster analysis grouped the accessions into three major clusters, revealing useful genetic diversity for breeding programmes. Twelve accessions combining desirable morphological traits, early maturity, and yield potential were identified as promising parental lines for the development of improved cowpea varieties.

Keywords: Genetic diversity, morphological traits, earliness, cluster analysis, breeding programme.

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is an economically important grain legume widely cultivated in the semi-arid and semi-humid regions of Sub-Saharan Africa. It is a rich dietary source for humans, containing high levels of protein and vitamins with higher nutritional qualities than soybeans (*Glycine max*), dry beans (*Phaseolus vulgaris*) and mung beans (*Vigna radiata*) and is more tolerant of high temperatures and moisture deficit conditions due to its tendency to form a deep tap root system (Masvodza *et al*., 2014). Although cowpea is rich in protein and contains high levels of amino acids, lysine, tryptophan and some amount of vitamins and minerals when compared to cereal grains (Huaqian *et al.*, 2012), its productivity is usually low under field conditions due to insect pest (bean leaf beetles, aphids, flower thrips, pod-borer) and disease (mosaic virus, *cercospora* leaf spot, *fusarium* wilt, to mention a few) infestations (Singh 1997, Rivas-Vega *et al*., 2006, Jayathilake *et al*., 2018, Mahesha *et al.*, 2022). Earlier studies (Singh *et al*., 1997, Mahesha *et al*., 2017, Owusu *et al.*, 2022) have shown that approximately 70-80 percent losses in cowpea yield annually can be attributed to severe biotic, abiotic and physiological constraints. This underscores the need to develop varieties that combine high productivity with tolerance to prevalent biotic and/or abiotic stress factors including drought. A preliminary step to achieving this objective is to assess the existing cowpea accessions for their diversity for traits that can be used to evolve new genotypes that combine high yield potential with resistance/tolerance to biotic and abiotic stress factors.

Cowpea exhibits a considerable level of morphological variation which can be used to distinguish and characterize one accession from another for yield improvement purposes. These attributes include plant type (dwarf, creeping and climbing), leaf size and shape, flower colour as well as pod and seed characteristics including number, size, colour, shape and length (Alemu *et al.*, 2016; Herniter *et al.*, 2018). Cowpea characterization has been extensively done using plant-related morphological descriptors such as growth habit, leaf type, floral colour, shape and colour of seed. Yield attributes have also been characterized using yield components such as number of pods per plant, number of seeds per pod and weight of seeds per accession (Adediran *et al.*, 2018, Owusu *et al.*, 2022). In a study which assessed genetic diversity in cowpea germplasm using morphological and molecular characterization, Mafakheri *et al*. (2017) reported a wide diversity among the different cowpea varieties, even when cultivated under the same environmental conditions such as soil and climate. Masvodza *et al.* (2014) also opined that despite the narrow genetic diversity in some cowpea species, both morphological characterization and molecular studies can help in the description, classification and establishment of the relationships among germplasm collections.

The preliminary step in the development of improved varieties is to screen available germplasm materials for their potential in respect of grain yield and other yield related traits as well as establish the extent of relatedness among them for improvement purposes. The cowpea genetic resource centre of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria has several improved and landraces of cowpea from which those with desirable agronomic attributes, including yield can be identified and selected for a cowpea breeding programme. The objectives of the study reported herein were therefore to assess performances of 100 cowpea accessions for their yield potential and determine the extent of their diversity based on morphological attributes and yield attributes.

MATERIALS AND METHODS

Sources of Genetic Materials

One hundred (100) cowpea accessions, consisting of improved varieties and landraces (Table 1) from the Genetic Resources Center (GRC) of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria were used for this study which involved screenhouse and laboratory studies.

Experiment

The experiment was conducted in the screenhouse of IITA, Ibadan during 2016 cropping season. A completely randomized design consisting of 100 cowpea accessions with three (3) replications was used for the study. The screenhouse environment was adequately covered with net having tiny mesh to prevent insect pests and other pollutants from causing diseases and/or physiological disorders to the plants. The plants were also protected from direct sunlight and rainfall, using a transparent roof cover. Each of the polythene pots was filled with sandy-loam soil and planted with four (4) seeds per hole and later thinned twice (2) to three (3) seedlings per hole at two (2) and five (5) weeks after planting to prevent overcrowding. No insecticide or fertilizer was applied throughout the duration of the study.

Data Collection

Data were collected from the genetic materials on both qualitative and quantitative traits with the qualitative traits scored using two (2) randomly selected plants per pot. These included flower colour, growth habit, seed coat colour, seed shape, seed texture and twining tendency. Growth habit (Plant type) was scored on the basis of erect, semi-erect, prostrate or climbing at 6 weeks after sowing (WAS) while flower colour was scored on the basis of white, yellow or purple colour at number of days from sowing to first flower emergence. Seed coat colour was scored as white, cream, brown, purple or reddish while seed shape was based on either kidney-shaped or globular. Seed coat texture was scored as either smooth or wrinkled while pod colour was scored as either green or purple. The accessions were also scored for twining tendency as moderate, pronounced or erect.

The quantitative parameters assessed for each accession included days to seedling emergence which was as the number of days from sowing to the day when seedling(s) emerged and flowering, estimated as number of days from sowing to flower emergence. Others included days to podding which was recorded as the number of days from sowing to the day of first pod formation, total number of pods harvested/pod and total number of seeds/pod. Harvesting of matured pods was done at 106 days after planting. The pods were plucked by hand when almost 90% of the leaves and the pods have turned brownish. Ripe pods for each accession were kept in big brown envelopes to ensure complete dryness, and the seeds per pod were counted by hand.

Statistical Analysis

Data collected on qualitative traits were analyzed by frequency distribution while data collected on the quantitative traits were subjected to analysis of variance (ANOVA) and pertinent means were separated using the Least Significant Difference (LSD), according to Steel and Torrie (1982). Cluster analysis was performed using Unweighted paired group method using arithmetic mean (UPGMA) method.

RESULTS AND DISCUSSION

Morphological traits

Distribution of the cowpea accessions for morphological characteristics is as presented in Table 2. Growth habit is a very important character in cowpea production in terms of increased yield production, ease of weed control and harvesting. The accessions clustered into four (4) classes with respect to growth habit with erect plant type predominating (83%) followed by prostrate and semi-erect while the climbing type was the least (Table 2). Earlier studies conducted by Alemu *et al*. (2016) and Saka *et al*. (2018) have shown that erect and semi-erect cowpea types have reproductive efficiency, good returns for high intercrop situation and also in terms of higher total pod quality since they do not require staking and their pods do not touch the ground. This implies that majority of these accessions (i.e. erect/semi-erect types) will be good sources of genes for breeding improved cowpea varieties for high yield and intercropping purposes. Conversely, harvesting is highly laborious in prostrate varieties and the period for pod maturity is unnecessarily elongated. This eliminates the advantage of their capacity to suppress weeds which reduces the frequency and cost of weeding (Woghiren *et al*., 2021). Furthermore, total pod yield in the climbing forms is also lower compared with the other types, and apart from the additional cost incurred for staking, the erect and prostrate types are still the most desirable accessions in terms of cost effectiveness and weed control (Alemu *et al.*, 2016). Saka *et al*. (2018) however opined that the prostrate type improves soil nitrogen concentration, which inadvertently improves the growth of cereals as a follow up crop. With respect to twining tendency, majority of the accessions (93%) are not the trailing type (Table 2) which implies that most of the accessions would not require staking.

Reproductive traits

Flower colour is an important trait as it attracts insects to suck the nectar thus, aiding the process of pollination (Stoddard 2017, Dingha *et al.*, 2021). The accessions varied in flower colour with 48% having white flower followed by purple (38%) and yellow (11%) in that order (Figure 3). Three (3) accessions (TVNu-1963, TVu-14040 and IT98K-205-8) did not flower at >70 days after sowing implying that they cannot be useful for breeding unless they are first subjected to mutation to induce flowering. Eighty-four (84%) of the accessions had green pods while 16% had purple pods (Table 2).

Seed coat colour is an important trait in cowpea because it determines consumers' preference either for consumption or other uses. The accessions were grouped into six (6) classes on the basis of seed coat colour, with the brown coat colour having the highest (approximately 50%) while black colour was the least (Table 2). In terms of consumer preferences, the brown large-seeded beans are preferred by most consumers in South-western Nigeria for processing into bean cakes (locally called moin-moin) or into powdered form for future consumption (Boukar *et al.* (2018). Saka *et al*. (2018) also reported that farmers and even consumers showed a higher preference for brown seed coat colour and making it attract higher market prices compared to other seed coat colours. Conversely, white and cream seeded ones like Sokoto white are widely consumed in the northern region of Nigeria due to its swelling and short cooking time (Boukar *et al*., 2018). Cowpea seeds that are purple, black or reddish seed coats are basically for research purposes, and the genes underlying these desirable traits can be introgressed into commercially acceptable ones through targeted breeding and marker-assisted selection (Herniter *et al.*, 2018). The percentage distribution of the cowpea accessions for morphological attributes are as shown in Table 2.

Seedling emergence and reproductive traits

Means, ranges in the means and coefficient of variation (%) for seedling emergence, flowering and yield parameters in 100 cowpea accessions are presented in Table 3. Mean days to seedling emergence was three (3) with similar range in interval for this trait among the accessions. Accession TVu-10303 was the earliest to emerge while accessions TVu-13913 and TVu-15447 were the latest to emerge. Days to flowering ranged from approximately 39 days in TVu-1544 to 70 days in TVu-13003 and IT98K-506-1 with a mean of 52 days. Three (3) accessions (TVNu-1963, TVu-14040 and IT98K-205-8) did not flower 70 days after sowing (DAS) when data collection for this trait was terminated. The mean period for pod formation among the accessions was approximately 73 days with a range of 29 days between the earliest accession to pod (TVu-3657) and the latest (IT89KD-288), The result further showed that pod formation did not occur in 12 accessions which flowered. Notable among these are TVu-1496, TVu-10199 and TVu-18486, which implies they are unsuitable for developing improved cowpea varieties for the rainforest ecologies of southwestern Nigeria. However, Saka *et al*. (2018) and Owusu *et al.* (2022) in separate studies noted that research efforts are being geared towards ensuring development of cowpea varieties that are of different maturity periods which can equally adapt to diverse agro-ecologies of Southwestern Nigeria.

Yield attributes

Increased seed yield is one of the major aims of plant breeding (Adediran *et al.,* 2018). Consequently, a good knowledge of a plant's morphological and agronomic characteristics helps the plant breeder in the selection of varieties with desirable traits. The mean number of pods was 3.09 with a range of 23 pods between TVu-11600 with the highest number of pods and other varieties (for example, IT86D-721, IT89KD-349) which had the lowest (Table 3). The mean total number of seeds harvested was 75 with a range of 431 seeds between the accession with the highest number of seeds (TVu-11600) and those with the lowest (Tvu-11567, TVu-15007 and TVu-11474). Other traits like the number of pods per plant and the total number of seeds harvested per plant measured are directly related to the total amount of yield per time and season. Therefore, accessions including TVu-11600, IT89KD-288, TV-1480 and Tvu-1387, possessing higher yields, in terms of the number of pods and the number of seeds produced per plant can be recommended for hybridization in the cowpea breeding programmes.

Grouping of accessions for seedling emergence and reproductive traits

The summary distribution of the accessions with respect to the morphological and reproductive traits is shown in Table 4. Generally, the accessions fall into three (3) major groups for seedling emergence with Group I which emerged within 2 to 3 days after sowing (DAS) and which was below the mean germination time, comprising 47 accessions. The remaining 53 accessions had emerged seedlings between 3-4 DAS (in 34 accessions) and >4 DAS (in 19 accessions). The accessions were grouped into four (4) major classes for days to flowering with 54 exhibiting flowering between 39 and 53 DAS and so could be classified as early-maturing genotypes. Days to flowering which is an indication of maturity has been used to group crop genotypes with respect to maturity (Owusu *et al.*, 2022). Group I with 48 accessions flowered in less than 53 DAS while 43 accessions which flowered after 53 days were categorized in Group III. Similar to days to seedling emergence, eight (8) out of the 21 improved lines used for the study were early-maturing having flowered within the mean (53) days. Sousa *et al*. (2015) postulated that short flowering periods is required to produce good yield since post-flowering energy is diverted into pod and seed development. Therefore, a cross between the six (6) accessions in Group II with the 48 in Group I can be utilized to transfer genes for earliness to obtain early-maturing types in cowpea and also to breed varieties with higher yields that are equally resistant to insect pests and diseases.

Extra-early and early-maturing cowpea varieties are capable of flowering within the first four to five weeks after planting, after which they begin to set pods and fill their seeds. Accessions that attained earliness in pod development are expected to have sufficient time for seed maturity and consequently high yield because the number of days to podding appeared to be directly related to flowering period (Owusu *et al.,* 2022). In this study, the accessions that flowered early also attained podding stage within the mean days to podding (73 days) which implies that earliness in flower appearance in cowpea is directly related to pod development. Podding among the accessions occurred in 87 of the 100 accessions between 59 and 102 DAS (Table 4) with 48 accessions producing pods within the mean (73) days to podding while the remaining accessions produced pods between 74 and 106 days. The accessions were grouped into four (4) classes with respect to podding, as shown in Table 4. Thirty-seven (37) other accessions attained podding after 73 DAS (see Group 3) while twelve (12) accessions prominent among which are TVu-13728, TVu-13486 and TVu-16451 did not pod at all while one (1) accession (IT98K-506-1) produced only one (1) pod which was seedless. Twenty-seven (27) accessions produced an average of 3 pods and above with TVu-11600 and TVu-801 having 24 (the highest number of pods); 61 accessions produced less than 3 pods while 12 accessions did not pod at all at 106 DAS. The total number of seeds harvested varied among the accessions. The mean number of seeds harvested was 75 and only thirteen (13) of the accessions produced between 75 and 501 seeds. The accessions were grouped into four (4) for this attribute with 12 accessions (including TVu-11600 (501 seeds), TVu-13003 and TVu-801) producing ≥75 seeds. There was a correlation between the total number of pods harvested and the total number of seeds harvested because all 12 accessions that produced ≥3 pods also had ≥75 seeds.

Twelve (12) accessions including TVu-801, TVu-1192, TVu-1480, TVu-1695, TVu-1387, TVu-3658, TVu-1890, TVu-12496, TVu-16690, IT84S-2246-4, TVu-10370 and TVu-1707 exhibited highly desirable characteristics combining earliness in seedling emergence with days to flowering and podding, and yield potentials such as the number of pods harvested and the number of seeds per pod. These accessions can be intercrossed in order to transfer genes for earliness from the accessions in Group II into those in Group I as well as those in Group III into those in Group II.

Table 5 shows a summary of the accessions that combined earliness in seedling emergence, days to flowering, days to podding, number of pods and the total number of seeds harvested, with mean values of 2-3 days, 53 days, 73 days, 3 pods and 75 seeds, respectively. The 12 outstanding cowpea accessions were based on yield and yield-related attributes which captured earliness, reproductive efficiency and yield potential. Seedling emergence (which indicated strong seed vigour and better establishment) ranged from 2.67 and 4.33 days with the fastest (2.67 days) in TVu-1480 and IT84S-2246-4 while the slowest to emerge (4.33 days) was observed in TVu-10370. Accessions TVu-1480 and IT84S-2246-4 were found desirable for stress-prone or rain-fed systems.

The earliest (43.00 and 44.30) number of days to flowering was observed in TVu-1480 and TVu-1192. These were recorded for short-growing seasons and climate resilience in drought-prone areas but the latest (54.33 and 53.66 days) occurred in TVu-801 and TVu-3658, respectively. For days to podding, TVu-1480 (in 60.67 days) and TVu-1890 (in 60.33 days) had the earliest while the latest was in TVu-16690 (79.67 days). Early podding was observed to align with early flowering. Also, found notable in TVu-1480 and TVu-1890 was early-maturity and their early podding is critical for rapid crop turnover and drought avoidance.

The number of pods per plant varied widely from 2.67 to 24.00. However, the highest pod-bearing accessions were TVu-801, TVu-1480, and TVu-1695 with 16.33 to 24.00 pods per plant. High podding ability is a primary yield determinant in cowpea and other legumes whereby it often compensates for moderate seed size. Outstanding seed yield was recorded for TVu-801, TVu-1480, TVu-3658, TVu-12496 and TVu-10370 which has led to the total number of seeds per plant being considered as the most decisive yield indicator, thereby integrating pod number and seed set efficiency. Conclusively, TVu-801 and TVu-1480 still stand out clearly as elite yield accessions with 432.00 and 272.00 seeds per plant, respectively.

Degree of relatedness among 100 cowpea accessions using morphological traits

Using the morphological and reproductive attributes exhibited by 100 cowpea accessions, a dendrogram of similarity among the accessions grouped them into two major classes for seedling emergence and three major classes for flowering. However, there were also minor classes within each of the major classes which could also be utilized for development of cowpea varieties for different maturity groups. A study by Mishili *et al*. (2007) has shown that consumers' preference for cowpea consumption is governed by seed characters such as shape, size, texture and colour. Saka *et al*., (2018) also identified cowpea traits preferred among farmers for cultivation in Southwestern Nigeria to include seed characteristics such as coat colour, texture and grain size; growth pattern, days to maturity, pod length and yield. The seed size is majorly considered as a primary determinant of yield in cowpea production; it differs according to the varieties and the agro-ecological zone(s) where it is cultivated (Agyeman *et al.,* 2015).

Previous studies (Nwofia, 2004, Shanko *et al.*, 2014, Mafakheri *et al*., 2017, and Gerrano *et al.,* 2019) have shown that the highest contributors to seed yield are number of branches per plant, number of pods per plant and number of seeds per plant. In other words, characterization of germplasm accessions based on these attributes can facilitate breeding programmes aimed at the development of new and improved varieties with desirable characters. The major clusters (1 and 7) consisted of seventeen (17) accessions: IT81D-994, IT97K-499-35, TVu-1387, TVu-14464, IT89KD-288, TVu-14040, IT98K-506-1, TVu-13003, TVu-13913, TVu-14855, TVu-13486, TVu-14379, TVu-1192, TVu-1208, IT82E-60, and TVu-14388 while the minor clusters (2 to

6) contained twelve (12) accessions TVu-1496, IT90K-59, TVu-12345, TVu-1480, IT86D-364, IT90K-277-2, TVu-1170, IT97K-569-9, IT86D-721, IT86D-719, IT97K-837-8, IT95K-222-3, and IT89KD-349. These accessions reflected underlying genetic similarities for morphological and reproductive attributes including seed size and colour, pod length and number of seeds per pod, flower colour and plant growth habit, days to flowering/maturity, plant height and leaf shape.

CONCLUSION AND RECOMMENDATIONS

The observed variability and clustering patterns provide opportunities for strategic parental selection in breeding programmes targeting early maturity and yield improvement. Therefore, for breeding purpose, cowpea accessions TVu-1480 can serve as a donor for earliness and yield stability while TVu-801 can be a high-yielding parent in hybridization programmes. Also, early types including TVu-1480 and TVu-1192 can be crossed with TVu-801 (high podding varieties) for desirable trait combination. However, IT84S-2246-4 should not be prioritized for yield improvement despite its early seedling emergence without significant genetic improvement.

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Table 1: List of cowpea genetic materials used for the study

S/N	Accession	S/N	Accession	S/N	Accession	S/N	Accession
1.	TVu-801	26.	TVu-2377	51.	IT89KD-288	76.	IT93K-452-1
2.	TVu-10110	27.	TVu-2381	52.	TVu-1496	77.	TVu-16191
3.	TVu-1192	28.	IT90K-59	53.	TVu-1387	78.	TVu-15447
4.	TVu-10199	29.	TVu-1890	54.	IT-88D-867-11	79.	TVu-15555
5.	TVu-11545	30.	IT97K-499-35	55.	TVu-13913	80.	TVu-10479
6.	TVu-13728	31.	TVu-1880	56.	IT90K-76	81.	TVu-10370
7.	IT97K-569-9	32.	TVu-2267	57.	IT90K-277-2	82.	TVu-10204
8.	TVu-13486	33.	TVu-1882	58.	TVu-15883	83.	TVu-14464
9.	TVu-15141	34.	TVu-1707	59.	TVu-16040	84.	TVu-12496
10.	TVu-1170	35.	TVu-1978	60.	TVu-16563	85.	TVu-15007
11.	IT86D-1010	36.	TVu-2027	61.	TVu-14040	86.	TVu-14855
12.	IT98K-506-1	37.	IT84S-2246-4	62.	TVu-14379	87.	TVu-14519
13.	IT86D-721	38.	TVu-2260	63.	TVu-16162	88.	TVu-15185
14.	IT86D-364	39.	TVu-1702	64.	TVu-14388	89.	TVu-15245
15.	TVu-15567	40.	IT98K-205-8	65.	TVu-2555	90.	TVu-15423
16.	IT86D-719	41.	TVu-13003	66.	TVu-10303	91.	TVu-15455
17.	TVu-16451	42.	IT97K-837-8	67.	TVu-16690	92.	TVX3236
18.	IT81D-994	43.	IT95K-222-3	68.	TVu-11600	93.	TVu-12527
19.	TVu-11574	44.	TVu-3661	69.	TVu-12345	94.	TVu-3000
20.	TVu-2398	45.	TVu-2273	70.	TVu-3439	95.	TVu-11527
21.	TVu-2417	46.	IT84S-2246-4	71.	TVu-3656	96.	TVu-11474
22.	TVu-1208	47.	TVu-1576	72.	TVu-3658	97.	TVu-10708
23.	TVu-1480	48.	TVu-1544	73.	TVu-3657	98.	TVu-11986
24.	IT97K-499-38	49.	TVu-1497	74.	TVu-2252	99.	TVu-15575
25.	TVu-1695	50.	IT89KD-349	75.	IT82E-60	100.	TVNu-1963

Table 2: Percentage distribution of 100 cowpea accessions for morphological characters under screenhouse conditions (Ibadan, Southwestern Nigeria)

S/N	Trait	Percentage	S/N	Trait	Percentage
1.	**Growth Habit/Plant Type**		**5.**	**Seed Coat Colour**	
	Erect	83%		White	15%
	Semi-Erect	6%		Cream	19%
	Prostrate	9%		Brown	45%
	Climbing	2%		Purple	10%
2.	**Twining Tendency**			Black	3%
	None	93%		Red	8%
	Moderate	3%	**6.**	**Seed Shape**	
	Pronounced	4%		Kidney shaped	37%
3.	**Flower Colour**			Globular	63%
	Purple	38%	**7.**	**Seed Coat Texture**	
	White	48%		Smooth	73%
	Yellow	11%		Wrinkled	27%
	Colourless	3%			
4.	**Pod Colour**				
	Green	84%			
	Purple	16%			

Table 3: Means, ranges in the means and coefficient of variation (%) for seedling emergence, flowering and yield parameters in 100 cowpea accessions

Character	Mean	Minimum	Maximum	Range	Coefficient of variation (%)
Days to seedling emergence	3.27	2.00	4.67	2.67	13.96
Days to first flower appearance	53.8	38.7	70.33	31.63	12.51
Days to first pod appearance	73	58.53	101.94	43.41	46.26
Number of pods/plant	3.09	0.33	24.67	24.34	118.85
Total number of seeds harvested	75	0.30	501.33	501.03	151.8

Table 4: Grouping of 100 cowpea accessions based on morphological and yield attributes

Group	**No of accessions**	**Days/Trait**	**Prominent accessions (10)**
	Days to seedling emergence		
I	47	≤3	TVu-1497, TVu-10303, TVu-10708, TVu-2555, TVu-14519, TVu-12527, TVu-15575, TVu-1480, TVu-2377, TVu-11545.
II	34	3>; <4	TVu-10110, TVu-10199, TVu-15141, TVu-3657, IT98K-506-1, IT93K-452-1, IT86D-721, TVu-2417, TVu-1695, TVu-15007, TVu-2381.
III	19	>4	IT86D-1010, TVu-1702, TVu-1576, IT90K-76, TVu-14379, TVu-14855, IT86D-364, TVu-15567, IT90K-277-2, TVu-16563.
	Days to flowering		
I	48	<53	TVu-1192, TVu-10199, IT97K-569-9, TVu-13486, TVu-1170, IT86D-1010, TVu-15567, TVu-16451, TVu-2398, TVu-2417.
II	6	53 days	TVu-1978, TVu-3658, TVu-12496, TVu-14855, TVu-15423, TVu-1387.
III	43	>53 days	IT89KD-288, IT90K-227-2, TVu-16040, TVu-16162, TVu-11600, TVu-12345, TVu-3439, TVu-16191, TVu-15447, TVu-15555.
IV	3	+	TVu-14040, IT98K-205-8, TVNu-1963.
	Days to Podding		
I	42	< 73 days	TVu-1192, IT97K-569-9, TVu-1170 TVu-2377 TVu-11574, TVu-2398, TVu-1480, TVu-1695 IT86D-719, TVu-2381.

II	5	73 days	IT86D-721, TVu-15245, TVu-2273, TVu-16563, TVu-1707
III	40	> 73days	TVu-801, TVu-10110, TVu-11545, TVu-15141, TVu-1497, TVu-3439, TVu-15567, IT81D-994, TVu-1880, TVu-13003.
IV	13	++	TVu-13728, TVu-13486, TVu-16451, TVu-2417, TVu-11986, TVu-10199, TVu-1496, TVu-2027, TVu-15447, TVu-11527.
	Number of pods harvested/plant		
I	61	< 3 pods	IT97K-569-9, IT97K-499-35, TVu-1170, TVu-2377, TVu-11574, TVu-2398, IT86D-719 TVu-2381, IT90K-59, TVu-1707.
II	4	3 pods	IT88D-867-11, TVu-15455, TVu-16162, TVu-14464.
III	23	> 3pods	TVu-801, TVu-10110, TVu-11545, TVu-13003, TVu-1387, TVu-16690, IT90K-277-2, IT84S-2246-4, TVu-1480, IT89KD-288.
IV	13	No pod	TVu-13728, TVu-13486, TVu-2417, IT97K-499-38, TVu-10199, IT86D-1010, TVu-16451, TVu-15447, TVu-2027, TVu-1496.
	Total number of seeds harvested/plant		
I	73	< 75 seeds	IT97K-569-9, IT97K-499-35, TVu-1170, TVu-2377, TVu-11574, TVu-2398, IT86D-719, TVu-2381, IT90K-59, TVu-1707.
II	1	75 seeds	TVu-13003.
III	12	>75 seeds	TVu-801, TVu-1387, TVu-16690, TVu-1480, TVu-1695, TVu-3658, IT90K-277-2, IT89KD-288, TVu-1890, TVu-10370.
IV	14	No seed	TVu-13728, TVu-13486, TVu-1496, IT97K-499-38, *IT98K-506-1, TVu-16451, IT86D-1010, TVu-2417, TVu-15447, TVu-11527.

+; No flower >70 DAS; ++; No pod >106 DAS; * Seedless pod formed.

Table 5: Cowpea accessions with desirable yield and yield attributes

	Mean Days to				
Accession name	**Seedling emergence (3 Days)**	**Flowering (53 Days)**	**Podding (73 Days)**	**No. Pods/plant (3 Days)**	**No. Seeds/plant (75 Days)**
TVu-801	3.00	54.33	77.33	24.00	432.00
TVu-1192	3.00	44.30	61.00	4.33	60.67
TVu-1480	2.67	43.00	60.67	16.00	272.00
TVu-1695	3.33	48.33	65.00	16.33	147.00
TVu-1890	3.00	52.67	60.33	9.70	154.67
TVu-1707	3.00	50.67	72.67	2.67	10.67
IT84S-2246-4	2.67	51.67	69.33	4.67	42.00
TVu-1387	3.00	53.33	75.33	9.33	130.67
TVu-16690	3.33	51.67	79.67	8.67	168.00
TVu-3658	3.00	53.66	71.33	14.44	223.67
TVu-10370	4.33	50.67	66.33	10.67	192.00
Tvu-12496	3.33	53.00	60.66	12.33	214.00

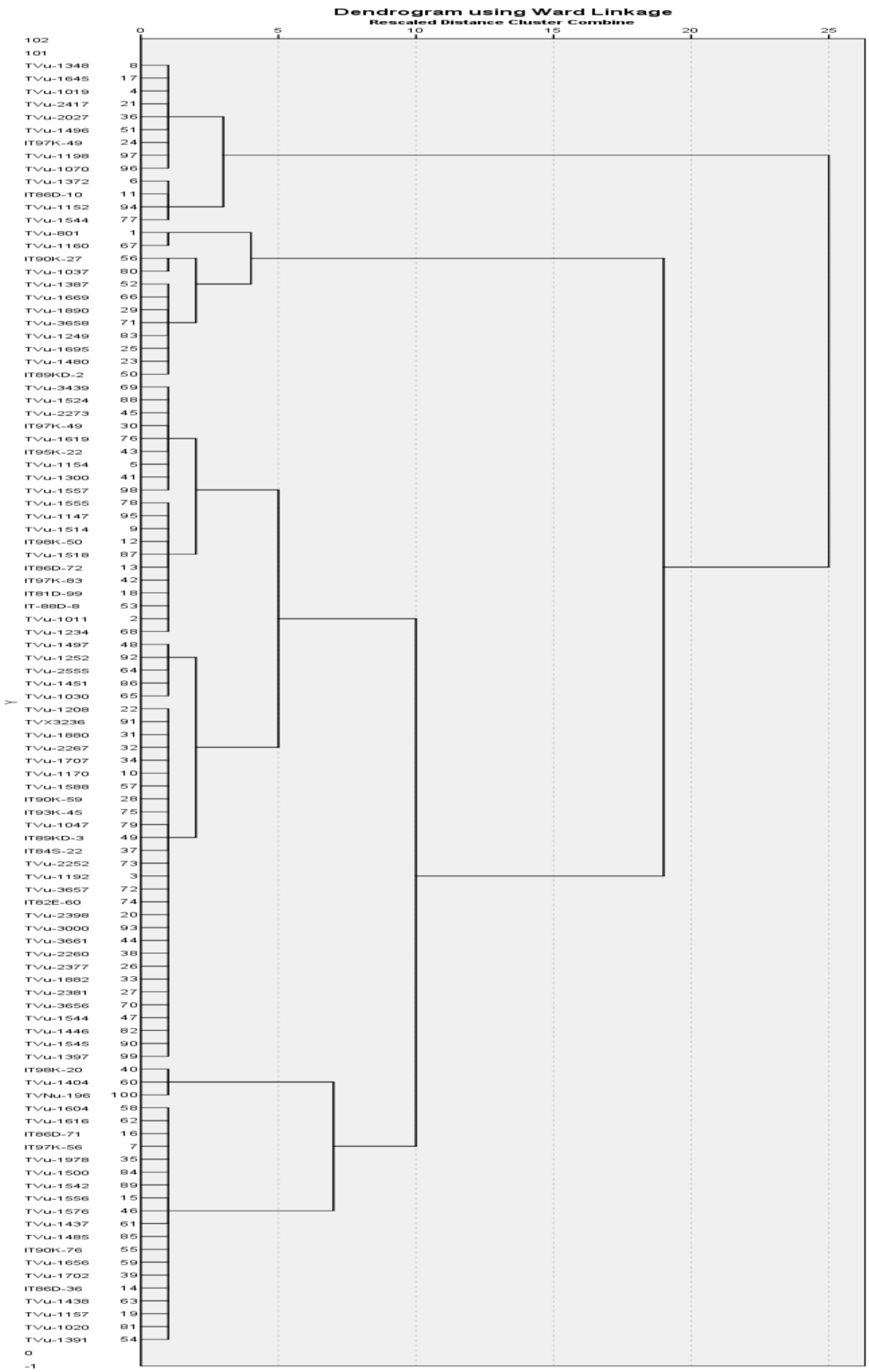

Figure 1: Dendrogram showing the degree of relatedness for morphological and reproductive traits in 100 selected accessions