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(RESEARCH ARTICLE)

Assessment of variation in the agronomic traits of wild cowpea (*Vigna unguiculata* (L.) Walp.) subspecies under a rainforest agro-ecology in Nigeria

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Abstract

Wild relatives of crop species are often sources of genes for diseases and insect pest resistance, increased yield, improved quality, earliness and wide adaptation. Wild subspecies of cowpea that are cross-compatible with cultivated varieties have great potential as an additional source of useful germplasm for cowpea improvement. In this study, the variations in the growth and agronomic traits of 20 cowpea accessions from the subspecies: *stenophylla, dekindtiana* and *tenuis* were evaluated in a randomized complete block design with four replications. Highly significant variations were observed among accessions for all traits measured. There were variations for same traits among the accessions from the subsp. *dekindtiana* whereas, the accessions from the subspecies *stenophylla* and *tenuis* showed similar performance. Accession TVNu1839 from the subsp. *dekindtiana* showed an outstanding performance in number of days to flowering and pod ripening, number of main branches at flowering, number of seeds per pod, 100 - seed weight and total seed weight which implies that the accession has a high yield potential. Therefore, the subsp. *dekindtiana* may be a useful source of genetic variation needed for the development of improved cowpea varieties for resource poor farmers at a relatively low expense, since it has been established that they are cross-compatible with the cultivated varieties. Highly significant ($P < 0.001$) and very strong correlation coefficient among traits, may be useful as selection index and can be exploited in cowpea improvement programmes. These results confirm that wild cowpea subspecies have the potential to enhance cowpea gene pool.

Keywords: Accession; Cowpea improvement; Subsp. *dekindtiana*; Subsp. *stenophylla*; Subsp. *tenuis*; Variability

1. Introduction

Cowpea (*Vigna unguiculata* (L.) Walpers), is a leguminous plant grown throughout the African countries as well as in Southeast Asia, North and South America, though the centre of diversity is West Africa [1-2]. The grain legume contribute significantly to household food security in West and Central Africa [3] and also represents a valuable commodity for income generation by farmers and traders [4]. Cowpea is a multipurpose grain legume useful as food and fodder without anti-nutritive factors, a very important source of carbohydrates (63%), a major source of dietary protein (25% - rich in lysine and tryptophan), fat (1.5%), minerals (calcium, phosphorus, iron), vitamins (A, C, folic acid, thiamine, riboflavin) [5-6]. This pulse crop is drought tolerant, shade-tolerant cover crop, may be used as green manure, a nitrogen-fixing or soil erosion controlling crop [7-8]. Cowpea is a diploid species, with 2n = 22, it is a *Dicotyledonea* in the order *Fabales,* family *Fabaceae,* tribe *Phaseoleae,* genus *Vigna,* species *unguiculata* and section *Catiang* [9-10]. Previous researches used the pod, seed and ovule traits of the cultivated cowpea to classify it into five cultivar groups namely: *V. unguiculata*, *V. biflora*, *V. melanophthalmus*, *V. sesquipedalis* and *V. textilis* [10-12]. The *V. unguiculata* species complex consists of other 10 subspecies, viz. *aduensis*, *baoulensis*, *burundiensis*, *letouzeyi*, *pawekiae*, *alba*, *dekindtiana*, *pubescens*, *stenophylla* and *tenuis* which are perennial and may have originated from South Africa [13], although the

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hypothesis about their origin is yet to be corroborated by genetic studies [12]. The first five subspecies are mainly recognized by their floral traits, they possess allogamous flora morphology and are adapted to humid environments whereas; the others are autogamous and are identified by their vegetative traits with adaptation to drier and coastal environments [14-15]. On the other hand, *unguiculata* is an annual cultivated variety, primarily self-pollinating, grown mainly in the drier parts of sub-Saharan Africa [16] and widely grown in West Africa. Domestication through natural selection has made the cultivated (*V. unguiculata*) differ from the wild cowpea subspecies for sets of traits [17]. The improvement observed in the former over the latter includes: loss in seed dormancy, pod dehiscence and increase in pod and seed size [11].

Commonly, in crop breeding and improvement programmes wild relatives and landraces are genetic resources recognized as essential pool of genetic variation [18-19]. Wild relatives possess high level of genetic diversity and are a potential source of novel alleles which may be beneficial in the prevention of genetic vulnerability [20]. Dwivedi et al. [21] described wild relatives as gene pool with the potential for improved nutritional quality, resistance to pests and diseases, drought and extreme temperature tolerant. For instance, cowpea wild relatives possess some unique qualities in their leaf, stem and petiole which may be useful in breeding for resistance to diseases and pests [22-23]. Thus, wild relatives of cowpea that are cross compatible with the cultivated varieties may be a potential additional source of variation for cowpea improvement [24-26]. These variabilities can then be exploited for the improvement of quantitative and qualitative traits [27-28].

International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria gene bank plays a major role in the global conservation strategy and distribution of cowpea genetic resources as a result of its mandate for cowpea improvement [29] and many of the genetic resources are yet to be evaluated for their potential usefulness. Characterization, evaluation and actual utilization of genetic resources are priority task for successful breeding programme [30]. Valuable information gleaned from the evaluation shared with genetic resources community and germplasm provider may accelerate cowpea improvement programmes. Exploitation of the genetic potential of wild and close relatives of cowpea for enhancing cowpea productivity has not been well documented [31]. To achieve efficient utilization of cowpea genetic resources there must be documented information on the magnitude of variability existing for different traits. This will enable identification of promising wild relatives useful in crop improvement programmes and related researches. Hence, it is important to continually screen the cowpea wild subspecies in order to identify diversities among collected accessions, and select wild relatives with desirable traits that can be introgressed into the cultivated variety, thereby, solving production constraints. The present research evaluates the agronomic performance and association of traits among cowpea wild subspecies.

2. Material and methods

2.1. Germplasm

Twenty germplasm accessions of *V. unguiculata,* belonging to three subspecies (Subsp. *dekindtiana*, Subsp. *stenophylla* and Subsp. *tenuis*) obtained from the Genetic Resource Center of the International institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were used for this study. The details of accessions used, are given in Table 1.

2.2. Data collection and analysis

The experiment was carried out at the crop garden of the department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria (Latitude 7^{o} 23' 28.19" N, Longitude 3^{o} 54' 59.99" E, altitude 277 m above sea level). The annual rainfall range is between 1258mm – 1437mm, with average daily temperature ranging from 22^{o}C - 31^{o}C. The trial was laid out in a Randomized Complete Block Design (RCBD) with four replicates. Prior to planting, the seeds were scarified with sharp razor blade in order to break dormancy, facilitate water imbibition and allow prompt germination. Spacing between rows was 60 cm and within row 30 cm. Three seeds were sown in 1.0 cm depth because of the small seed size.

The seedlings were later thinned to one plant per stand two weeks after emergence. Cyperforce was applied to control aphids *(Aphis craccivora)* at 3 weeks after planting and the application was also repeated at 8 weeks after planting in order to check the build-up of aphids and pod sucking bugs such as *Clavigralla tomentosicollis* and *Anoplocnemis curvipes*, as well as flower thrips: *Megalurothrips sjostedti.* The plots were manually weeded with a hand hoe to suppress the weed population when required. From each accession, six plants were randomly selected to measure agronomic traits. The data collected include plant height (PH) (cm), number of leaves per plant, number of days to first flower (DFF), number of main branches at flowering (BPP), number of days to first ripe pod (DPR), number of peduncles per plant (PDPP), number of pods per plant (PPP), number of seeds per pod (SPP), number of ovules per pod (OPP), 100 -

seed weight (HSW) (g), total seed weight (SW) (g). All quantitative data were measured according to the recommendation of International Board for Plant Genetic Resources (IBPGR) [32] cowpea descriptor standard. Data were first summarized using the descriptive statistical method in the excel spreadsheet. The data were further subjected to the analysis of variance (ANOVA) to test for significant difference among the accessions, followed by mean separation with Duncan's Multiple Range Test [33] and Pearson correlation using Statistical Analysis System (SAS) program version 9.4 [34].

Table 1 Germplasm accession number, country of origin and identification of wild cowpea subspecies used in this study

No.	Germplasm accession number	Subspecies	Country of origin	Standard colour	Seed	Flower
1	TVNu207	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
2	TVNu290	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
3	TVNu353	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
4	TVNu363	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
5	TVNu389	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
6	TVNu519	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
7	TVNu539	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
8	TVNu573	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
9	TVNu714	*stenophylla*	Botswana	mauve -lilac pale	Long	Small
10	TVNu1088	*tenuis*	Mozambique	deep purple	Short	Small
11	TVNu1345	*tenuis*	Zimbabwe	deep purple	Short	Small
12	TVNu1498	*stenophylla*	South Africa	mauve -lilac pale	Long	Small
13	TVNu1503	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
14	TVNu1558	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
15	TVNu1561	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
16	TVNu1562	*stenophylla*	South Africa	mauve -lilac pale	Long	Small
17	TVNu1816	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
18	TVNu1817	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
19	TVNu1822	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large
20	TVNu1839	*dekindtiana*	Nigeria	white-light mauve purple	Long	Large

3. Results and discussion

3.1. Variation in growth traits

Means squares from analysis of variance showed significant ($P < 0.001$) variation for all traits measured. This indicates inherent variability in plant morphology among the wild cowpea subspecies as earlier reported by Padulosi and Ng [14] and Pasquet [12]. A wide range of significant ($P < 0.001$) variation was observed in plant height (47.00 - 266.50 cm), number of days to pod ripening (27 - 108 days), and number of days to first flower (22 - 97 days) (Table 2). Number of main branches per plant, number of seeds per pod, number of ovules per pod and 100 - seed weight also showed significant ($P < 0.05$) variations. The variation observed among these accessions may be valuable for their identification, description and utilization [34].

The mean plant heights were similar within the subspecies *stenophylla* and *tenuis* whereas for subsp. *dekindtiana* mean plant height were significantly different (P < 0.05) within and among other accessions (Table 3) as a result of the heterogeneous nature of the accessions. The tallest accession was TVNu573 of the subsp. *dekindtiana* and the shortest was accession TVNu1088 of the subsp. *tenuis*. The mean plant height of the wild cowpea subspecies was higher than those reported for germplasm accessions in literature [36-37]. The numbers of branches per plant ranged between (0.75 – 5.00) which is comparable to the results obtained by Ajayi and Adesoye [38], but lower than the report of Kandel et al. [37]. Accession TVNu539 of the subsp. *dekindtiana* had the earliest ripe pod and latest number of days to first ripe pod was observed in accession TVNu573 of the same subsp.

The average difference between the earliest and latest ripened accession was 81 days. This gives a possibility for choice of either early or late accessions of wild cowpea subspecies suitable for relevant production or research. Accessions TVNu290, TVNu353, TVNu363, TVNu539 of the subsp. *dekindtiana* and TVNu1498 of the subsp. *stenophylla* flowered around 23 - 64 days which confirms non-photosensitive and they may be grouped as early maturing as classified by Singh and Ajeigbe [39] and Dugje et al. [40]. In contrast, Molsiwa et al. [41] who worked on phenotypic variation in cowpea accessions reported a higher range of 39 - 168 days for number of days to first flower.

Table 2 Descriptive statistics and variance of wild cowpea subspecies evaluated under a rainforest agro-ecology in Nigeria.

Traits	Mean	Minimum	Maximum	Difference	Variance
Plant Height (cm)	139.14±6.53	47.00	266.50	219.50	3415.86***
Days to pod ripening	86.49±2.06	27.25	108.75	81.50	340.63***
Branches per plant	3.53±0.11	0.75	5.00	4.25	0.95*
Days to first flower	72.14±1.84	22.70	97.50	74.80	270.09***
Pods per plant	16.40±1.60	0.50	38.25	37.75	205.97***
Peduncles per plant	25.31±1.97	0.75	53.00	52.25	311.39***
Seed per pod	8.45±0.33	1.25	13.75	12.50	8.59*
Ovules per pod	10.98±0.37	1.75	16.25	14.50	11.06*
100 - seed weight (g)	1.67±0.08	0.45	2.86	2.41	0.47*
Total seed weight (g)	8.46±1.05	1.40	30.71	29.31	87.86***

*, **, *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively

It is important to note that only accession TVNu539 flowered in 3 weeks and produced ripe pods in 4 weeks of planting, making it a potential parent when breeding for early maturity.

3.2. Variation in seed parameters

A wide range significant variation was observed in total seed weight (1.40 - 30.71 g). Accession TVNu290 had the highest mean value for number of ovules per pod and number of seeds per pod while the lowest values for both traits was observed in accession TVNu539, both belonging to the subsp. *dekindtiana* (Table 2). The mean value for number of seeds per pod is similar with the report of Ajayi and Adesoye [38] who worked on variability among cowpea accessions. Accession TVNu1816 had the highest 100- seed weight but accession TVNu1839 had highest mean value for total seed weight. On the other hand the lowest mean value for 100 - seed weight and total seed weight was observed in accession TVNu539. Similar mean values for seed parameters in species of wild *Vigna* have been reported by Popoola et al. [42]. Wild relatives of the subsp. *dekindtiana* were not significantly different from each other but were different from those of subspecies *stenophylla* and *tenuis* (Table 3).

Table 3 Mean values of growth, seed and yield parameters of the 20 wild cowpea subspecies evaluated under a rainforest agro-ecology in Nigeria

Subspecies	Accession	PH (cm)	DPR	BPP	DFF	PPP	PDPP	SPP	OPP	HSW(g)	SW (g)
dekindtiana	TVNu207	66.50^{hi}	84.75^{ab}	3.25^{abc}	75.75^{abcde}	5.7^{cde}	8.75^{e}	5.00^{efg}	7.00^{edf}	1.27^{cdefg}	2.25^{b}
dekindtiana	TVNu290	73.75^{ghi}	78.00^{ab}	3.25^{abc}	63.50^{bcde}	9.50^{cde}	11.50^{de}	13.75^{a}	16.25^{a}	1.78^{bcde}	3.19^{b}
dekindtiana	TVNu353	208.25^{ab}	65.50^{b}	4.00^{ab}	52.50^{e}	35.00^{a}	48.25^{a}	11.25^{abc}	14.00^{abc}	1.62^{cde}	10.04^{b}
dekindtiana	TVNu363	157.00^{bcdefg}	70.00^{ab}	4.75^{a}	55.50^{de}	35.5^{a}	41.50^{abc}	10.00^{abcd}	12.50^{abcd}	1.36^{cdefg}	9.22^{b}
dekindtiana	TVNu389	197.25^{ab}	98.00^{ab}	5.00^{a}	97.5^{a}	3.25^{e}	6.25^{e}	8.00^{bcdef}	10.50^{abcde}	1.62^{cde}	1.62^{b}
dekindtiana	TVNu519	176.75^{bcde}	93.35^{ab}	3.75^{ab}	65.25^{bcde}	17.50^{bcd}	42.50^{ab}	10.50^{abc}	13.75^{abc}	2.10^{abcd}	7.13^{b}
dekindtiana	TVNu539	68.00^{hi}	27.25^{c}	0.75^{d}	22.75^{f}	0.5^{e}	0.75^{e}	1.25^{g}	1.75^{f}	0.45^{g}	1.40^{b}
dekindtiana	TVNu573	266.50^{a}	108.75^{a}	4.00^{ab}	87.00^{abc}	19.00^{bc}	46.25^{a}	9.00^{bcde}	12.00^{abcd}	1.72^{cde}	9.21^{b}
stenophylla	TVNu714	104.33^{defghi}	88.00^{ab}	2.33^{bc}	80.00^{abcde}	1.50^{e}	8.00^{e}	7.00^{cdef}	9.33^{bcde}	0.93^{efg}	1.82^{b}
tenuis	TVNu1088	47.00^{i}	101.5^{ab}	3.5^{abc}	85.50^{abcd}	2.50^{e}	9.5d^{e}	3.75^{fg}	5.25^{ef}	0.58^{fg}	1.46^{b}
tenuis	TVNu1345	80.50^{fghi}	84.75^{ab}	3.5^{abc}	72.25^{abcde}	4.50^{de}	6.50^{e}	8.00^{bcdef}	10.67^{abcde}	1.12^{efg}	2.42^{b}
stenophylla	TVNu1498	135.33^{bcdefgh}	71.75^{ab}	2.00^{cd}	80.33^{abcde}	7.75^{cde}	19.00^{cde}	5.70^{edf}	8.50^{cde}	1.80^{bcde}	2.10^{b}
dekindtiana	TVNu1503	182.50^{bcd}	83.00^{ab}	4.75^{a}	60.00^{cde}	35.50^{a}	53.00^{a}	8.25^{bcde}	11.50^{abcd}	2.82^{a}	9.12^{b}
dekindtiana	TVNu1558	92.67^{efghi}	82.67^{ab}	2.67^{bc}	68.67^{abcde}	6.25^{cde}	11.67^{de}	9.00^{bcde}	11.67^{abcd}	1.27^{cdefg}	2.52^{b}
dekindtiana	TVNu1561	109.00^{cdefghi}	102.00^{ab}	3.5^{abc}	72.75^{abcde}	3.00^{e}	8.75^{e}	6.75^{cdef}	10.00^{bcde}	1.41^{cdef}	2.64^{b}
stenophylla	TVNu1562	109.00^{cdefghi}	96.00^{ab}	4.00^{ab}	77.00^{abcde}	4.00^{de}	22.00^{bcde}	8.00b^{cdef}	11.00^{ab}	1.20^{defg}	2.31^{b}
dekindtiana	TVNu1816	163.75^{bcdef}	106.00^{ab}	4.00^{ab}	89.00^{abc}	29.25^{ab}	32.75^{abcd}	12.00^{ab}	15.00^{ab}	2.86^{a}	21.05^{a}
dekindtiana	TVNu1817	148.25^{bcdefgh}	106.50^{ab}	3.75^{ab}	90.50^{ab}	38.25^{a}	40.25^{abc}	9.75^{abcd}	13.25^{abc}	2.64^{ab}	25.79^{a}
dekindtiana	TVNu1822	193.00^{abc}	99.00^{ab}	4.00^{ab}	81.00^{abcde}	32.25^{a}	44.50^{ab}	10.7^{5abc}	13.50^{abc}	2.18^{abc}	23.21^{a}
dekindtiana	TVNu1839	203.50^{ab}	83.00^{ab}	3.75^{ab}	66.00^{bcde}	37.25^{a}	44.50^{ab}	11.25^{abc}	14.00^{abc}	2.64^{ab}	30.71^{a}

PH = plant height, DPR = days to pod ripening, BPP = branches per plant, DFF = days to first flower, PPP = pods per plant, PDPP = peduncles per plant, SPP = seed per pod, OPP = ovules per pod, HSW = 100 - seed weight, SW = total seed weight

Means followed by the same alphabet within a column are not significantly ($P < 0.05$) different from each other.

3.3. Variation in yield components

A wide range significant variation was observed in number of pods per plant (0.50 - 38.25) and number of peduncles per plant (0.75 - 53.00). Accession TVNu1817 had the highest mean value and accession TVNu539 had the lowest mean value for number of pods per plant (Table 2). The highest mean value for number of peduncles per plant was recorded in accession TVNu1503 and lowest mean value was 0.75 for accession TVNu539. The distinctions observed among yield parameters (Table 3) confirm that these cowpea wild subspecies have great potential as an additional source of variation which may be used in hybridization to initiate a breeding programme [13, 24, 43].

The subsp. *dekindtiana* showed some desirable traits such as early flowering, early maturity, many branches at flowering, higher number of pods per plant, seeds per pod, peduncles per plant, 100 - seed weight and total seed weight. Additionally, the outstanding performance of accession TVNu1839 in number of days to flowering and pod ripening, number of main branches at flowering, number of seeds per pod, 100 - seed weight and total seed weight implies that the accession has a high yield potential. The conglomeration of these traits in the subsp. *dekindtiana* could be explained by making reference to taxonomy which has it that the present cowpea cultivars are domesticated from subspecies *dekindtiana* [44-47]. For all measured traits, we observed variations for same traits among the accessions from the subsp. *dekindtiana* whereas, the accessions from the subspecies *stenophylla* and *tenuis* showed similar performance. This closeness may be due to their morphological and geographical distribution similarities, in addition to the fact that they are genetically closer to one another than to other wild taxa [14].

3.4. Correlation among agronomic traits

Dependable criteria for selection in crop improvement programme should not be yield alone, but also on other associated agronomic traits, the strength of association between traits could be used in constructing an indirect selection index for yield [48]. Highly significant ($P < 0.001$) and very strong correlation coefficient (r) were observed between number of days to first ripe pod and number of days to flowering ($r = 0.88$), number of pods per plant and number of peduncles per plant ($r = 0.91$), number of seeds per pod and number of ovules per pod ($r = 0.98$), number of peduncles per plant and total seed weight ($r = 0.85$) (Table 4). Furthermore, strong positive significant ($P < 0.001$) correlation was found between plant height, number of main branches at flowering, number of pods per plant, number of peduncles per plant, number of seeds per pods, 100 - seed weight and total seed weight. Taller plants may have influence on the ability to intercept sunlight and this goes a long way to enhance the photosynthetic capability of the plant and this in turn determines the rate of assimilate partitioning at the pod filling stage. It has been suggested that biological yield can be increased by increasing the photosynthetic capability of individual leaves and improving the light interception characteristics of the crop [49]. Therefore, association between plant height, vegetative and reproductive traits emphasize the significance of taller plants for solar reception which may facilitate improvement in seed yield [50]. These significant correlations may be exploited in cowpea improvement programmes.

Table 4 Pearson's correlation coefficient (r) of agronomic traits of wild cowpea subspecies evaluated under a rainforest agro-ecology in Nigeria.

	PH (cm)	DPR	BPP	DFF	PPP	PDPP	SPP	OPP	HSW (g)
DPR	0.28**								
BPP	0.56***	0.59***							
DFF	0.20	0.88***	0.43***						
PPP	0.66***	0.12	0.52***	-0.04					
PDPP	0.79***	0.21	0.56***	-0.00	0.91***				
SPP	0.51***	0.35***	0.56***	0.2	0.61***	0.58***			
OPP	0.54***	0.41***	0.60***	0.24	0.61***	0.61***	0.98***		
HSW (g)	0.62***	0.39***	0.50***	0.28**	0.76***	0.72***	0.67***	0.69***	
SW (g)	0.57***	0.27**	0.34***	0.17	0.85***	0.71***	0.56***	0.54***	0.77***

, * Significant at 0.01 and 0.001 probability levels, respectively.
PH = plant height, DPR = days to pod ripening, BPP = branches per plant, DFF = days to first flower, PPP = pods per plant, PDPP = peduncles per plant, SPP = seed per pod, OPP = ovules per pod, HSW = 100 - seed weight, SW = total seed weight.

The number of days to first ripe pod showed strong positive significant (P < 0.001) correlation with only number of main branches at flowering and number of days to flowering. The number of main branches at flowering showed strong positive significant (P < 0.001) correlation with number of pods per plant, number of peduncles per plant, number of seeds per pod and number of ovules per pod. This association corroborates the report of Hanchinal et al. [51] who suggested that number of main branches at flowering should be considered as one of the important characters in determining seed yield. Likewise, the number of pods per plant also showed strong positive significant (P < 0.001) correlation with number of peduncles per plant, number of seeds per pod, number of ovules per pod, 100 - seed weight and total seed weight. These traits may be considered as a secondary trait when selecting for improved pods per plant. Also, these reproductive and yield related traits may be useful in the selection of parent accessions whose progenies may increase productivity. Similarly, the number of peduncles per plant showed strong positive significant (P < 0.001) correlation with number of seeds per pod, number of ovules per pod, 100 - seed weight and total seed weight consistent with the report of Aliyu and Makinde [52].

Thus, the higher the number of peduncle per plant the more the productivity, besides selection for this trait could also result in higher economic yield. The number of seeds per pod showed strong positive significant (P < 0.001) correlation with number of ovules per pod, 100 - seed weight and total seed weight. These traits can be considered as a selection criterion for number of seeds per pod. The number of ovules per pod showed strong positive significant (P < 0.001) correlation with 100 - seed weight and total seed weight.

Lastly, there was strong positive significant (P < 0.001) correlation between 100 - seed weight and total seed weight. This is expected because aggregate weight contributes to the total. Our results emphasize that plant height, number of pods per plant, number of peduncles per plant, number of seeds per pod, number of ovules per pod and 100 - seed weight can be used to select for higher yield. More so, information gathered from the correlation of traits among cowpea wild subspecies will aid selection index in cowpea improvement programmes.

4. Conclusion

Variations were observed among the accessions for all traits measured. The subsp. *dekindtiana* showed high variation which may be exploited in cowpea improvement programmes. Accession TVNu1839 combines desirable traits with potential to enhance cowpea gene pools. In as much as the subsp. *dekindtiana* is cross compatible with the cultivated cowpea and favorable genes can be introgressed, these subspecies may be a beneficial source of genetic variation needed for the improvement of cowpea varieties.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors of this article have no conflict of interest to declare.

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