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AGRO-MORPHOLOGICAL VARIATION AND GENETIC POTENTIAL IN *Vigna unguiculata* subssp. *unguiculata* var. *spontanea*

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ABSTRACT

Exploring the genetic potentials of wild relatives of crop varieties plays a critical role in broaden the narrow genetic base and introducing novel genetic diversity into the domesticated crop plants. Genetic diversity in 90 accessions of *Vigna unguiculata* subspp *unguiculata* var. *spontanea* and 3 cultivars of *V. unguiculata* subspp *unguiculata* var. *unguiculata* were investigated. Field trials were carried out at Abeokuta (2014 and 2015) and Ibadan (2014), Nigeria in a randomized complete block design with three replicates. Data collected on qualitative and quantitative traits varied among the accessions which indicated unique phenotypic features in the accessions. Early flowering accessions (NGB1140, NGB1083, NGB1136 and NGB1170) and accessions with low leaf defoliation (NGB1089, NGB1108, NGB1142, NGB1150, NGB1171, NGB1085 and NGB1177) among the cultivars were identified. Genetic diversity analysis revealed nineteen (19) homogenous groups among the accessions. Divergence among the groups was attributed more to seed yield (R^2 = 0.90), number of pods/plant (R^2 = 0.86) and days to flowering (R^2 = 0.86). Promising genetic potential in the *V. unguiculata* subspp *unguiculata* var *spontanea* for desirable traits, and their effective use for further improvement of cultivated cowpea through hybridization programme were revealed.

Keyword: cowpea, crop wild-relative (CWR), diversity, insect tolerance, multivariate analysis

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is a common food legume cultivated in the sub-Saharan Africa and parts of Asia, Europe and, Central and South America. It is a cheap, rich source of protein and valuable food supply in Africa. The grain contains about 32% proteins on dry weight basis (José *et al.*, 2014; Ddamulira and Santos, 2015) and high in essential amino acids such as lysine, leucine, phenylalanine, tryptophan and valine (Ukpene and Imade, 2015; Gonçalves *et al.*, 2016). The protein content is close to certain meat type (El-Niely Hanina, 2007). Cowpea also has human health promoting components such as antioxidants, soluble and insoluble dietary fibre and polyphenols (Liyanage *et al.*, 2014; Da Silva *et al.*, 2018). The fodder and shelled pods are also good source of nutritious hay for livestock (Singh *et al.*, 2010; Anele *et al.*, 2012). Cowpea is usually intercropped with other crops to supply their nitrogen requirement due to its nitrogen-fixing ability. The plant is drought-tolerant and used to maintain soil fertility when cultivated as green manure and cover crop (Bationo and Ntare, 2000; Alvey *et al.*, 2001).

Many of the cowpea accessions (over 15,000) including the wild germplasm are maintained in the gene bank of the International Institute of Tropical Agriculture (IITA), and they represent valuable gene pool to identify new and adaptable trait for cowpea breeding (Mahalakshmi *et al.*, 2007). However, the genetic base of cowpea for diverse characters still remains narrow. This can be attributed to continuous cultivation of improved varieties while discarding less superior varieties and consistent use of elite lines in hybridization programs (Fang *et al.*, 2007; Meyer *et al.*, 2012; Olsen and Wendel, 2013). In addition, cowpea is a self-pollinating plant with low gene flow between cultivated and wild accessions (Fatokun, 2007; Asiwe, 2009).

Attempts to broaden the genetic base may require exploring the wild relative for new and diverse traits, and their introgression into existing cultivars (Boukar *et al.*, 2020). Wild relatives of crop provide repository of genes for useful adaptation such as disease resistance, abiotic stress tolerance, increased yield, improved grain quality and earliness to flowering (Fatokun *et al.*, 2002; Ajeigbe *et al.*, 2008; McCouch *et al.*, 2013; Warschefsky *et al.*, 2014). Use of wild species to introduce novel genetic diversity into elite cultivars are documented (Breithaupt, 2008; Maxted and Kel, 2009; Brumlop *et al.*, 2013) but are limited usually due to many undesirable attributes in the genetic resources. Today, molecular tools can be used to eliminate the unattractive characters while exploiting the desirable traits in the wild germplasm (Boukar *et al.*, 2020). *Vigna unguiculata* subspp *unguiculata* var. *spontanea*, are widely distributed in Africa (Pasquet, 1999; Coulibaly *et al.*, 2002, Feleke *et al.*, 2006) and researches exploring the potential benefit of this wild relative are rare. This study is a preliminary assessment with the objective to characterize some accessions of *V. unguiculata* subsp. *unguiculata* var. *spontanea* for potential phenotypic expression.

MATERIALS AND METHODS

Ninety (90) accessions of *V. spontanea* were used in the study (Table 1). The seeds were collected from the Germplasm Units of IITA, Nigeria. The germplasm consists of accessions from different parts of Nigeria. Three cultivars of cowpea (*V. unguiculata*) were also used as check. The genetic materials were planted at the Research Farms of National Centre for Genetic Resources (NACGRAB), Ibadan and Federal University of Agriculture, Abeokuta (FUNAAB), Abeokuta. The field trials were carried out in 2014 and 2015 at Abeokuta, and 2014 at Ibadan to define three environments. Abeokuta is located at the forest-savanna transition with lat. 7°14′N and long. 3°89′E, while Ibadan is located at the derived savanna with lat. 7°37′N and long. 3°89′E. The rainfall was higher at Ibadan than Abeokuta during the experimental period (Table 2).

Table 1. List of cowpea accessions used, collection and their morphological characteristics

S/No	Genotype	Species	Collection	Flower colour	Growth habit	Growth pattern	Leaf texture	Pod curvature	Twining tendency	Pod attachment
1	NGB0964	*V. spontanea*	Abuja	Purple	Acute-erect	Indeterminate	Membraneous	Straight	Intermediate	30° - 90°
2	NGB1068	*V. spontanea*	Adamawa	Purple	Acute-erect	Indeterminate	Membraneous	Slightly curved	Pronounced	30° - 90°
3	NGB1072	*V. spontanea*	Adamawa	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Slightly	30° - 90°
4	NGB1078	*V. spontanea*	Adamawa	Purple	Prostrate	Determinate	Membraneous	Straight	Pronounced	Erect
5	NGB1082	*V. spontanea*	Adamawa	Purple	Climbing	Indeterminate	Membraneous	Straight	Pronounced	Erect
6	NGB1132	*V. spontanea*	Adamawa	Purple	Climbing	Determinate	Membraneous	Straight	Slightly	Erect
7	NGB1134	*V. spontanea*	Adamawa	Purple	Erect	Determinate	Intermediate	Slightly curved	None	30° - 90°
8	NGB1136	*V. spontanea*	Adamawa	Purple	Erect	Indeterminate	Intermediate	Straight	Pronounced	Erect
9	NGB1148	*V. spontanea*	Adamawa	Purple	Erect	Indeterminate	Membraneous	Straight	Slightly	Erect
10	NGB1167	*V. spontanea*	Adamawa	Purple	Acute-erect	Determinate	Membraneous	Straight	Slightly	Erect
11	NGB1176	*V. spontanea*	Adamawa	Purple	Acute-erect	Indeterminate	Cariaceous	Straight	Slightly	Pendant
12	NGB1065	*V. spontanea*	Bauch	Purple	Acute-erect	Indeterminate	Membraneous	Straight	Intermediate	Erect
13	NGB1099	*V. spontanea*	Bauch	Purple	Erect	Indeterminate	Membraneous	Straight	Pronounced	Erect
14	NGB1152	*V. spontanea*	Bauch	Purple	Erect	Indeterminate	Intermediate	Slightly curved	Intermediate	30° - 90°
15	NGB0963	*V. spontanea*	Benue	Purple	Acute-erect	Indeterminate	Intermediate	Straight	Intermediate	Pendant
16	NGB1044	*V. spontanea*	Bornu	Purple	Erect	Determinate	Cariaceous	Straight	Intermediate	Pendant
17	NGB1047	*V. spontanea*	Bornu	Purple	Prostrate	Indeterminate	Intermediate	Straight	Pronounced	Erect
18	NGB1058	*V. spontanea*	Bornu	Purple	Climbing	Determinate	Membraneous	Straight	Intermediate	Erect
19	NGB1079	*V. spontanea*	Bornu	Purple	Climbing	Determinate	Intermediate	Straight	Pronounced	Erect
20	NGB1086	*V. spontanea*	Bornu	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Slightly	Pendant
21	NGB1105	*V. spontanea*	Bornu	Purple	Erect	Indeterminate	Membraneous	Straight	Pronounced	30° - 90°
22	NGB1115	*V. spontanea*	Bornu	Purple	Erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
23	NGB1125	*V. spontanea*	Bornu	Purple	Climbing	Determinate	Intermediate	Straight	Intermediate	30° - 90°
24	NGB1126	*V. spontanea*	Bornu	White	Semi-erect	Determinate	Intermediate	Straight	None	Erect
25	NGB1130	*V. spontanea*	Bornu	Purple	Erect	Indeterminate	Membraneous	Slightly curved	Slightly	30° - 90°
26	NGB1151	*V. spontanea*	Bornu	Purple	Erect	Indeterminate	Intermediate	Straight	Slightly	Erect
27	NGB1090	*V. spontanea*	Jigawa	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Slightly	Erect
28	NGB1100	*V. spontanea*	Jigawa	Purple	Semi-erect	Indeterminate	Intermediate	Curved	Intermediate	Erect
29	NGB1109	*V. spontanea*	Jigawa	Purple	Erect	Indeterminate	Membraneous	Slightly curved	None	Erect
30	NGB1111	*V. spontanea*	Jigawa	Purple	Erect	Determinate	Intermediate	Slightly curved	Intermediate	30° - 90°
31	NGB1133	*V. spontanea*	Jigawa	Purple	Acute-erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
32	NGB1150	*V. spontanea*	Jigawa	Purple	Erect	Indeterminate	Intermediate	Straight	Pronounced	Erect
33	NGB1165	*V. spontanea*	Jigawa	Purple	Acute-erect	Indeterminate	Intermediate	Slightly curved	Pronounced	30° - 90°
34	NGB1027	*V. spontanea*	Kaduna	Purple	Erect	Indeterminate	Membraneous	Straight	Intermediate	Erect
35	NGB1028	*V. spontanea*	Kaduna	Purple	Erect	Determinate	Membraneous	Straight	Slightly	Erect
36	NGB1081	*V. spontanea*	Kaduna	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Pronounced	Erect
37	NGB1094	*V. spontanea*	Kaduna	Purple	Erect	Determinate	Membraneous	Straight	Slightly	30° - 90°
38	NGB1123	*V. spontanea*	Kaduna	Purple	Erect	Determinate	Intermediate	Slightly curved	None	30° - 90°
39	NGB1127	*V. spontanea*	Kaduna	White	Semi-erect	Determinate	Intermediate	Straight	None	Erect
40	NGB1163	*V. spontanea*	Kaduna	Purple	Acute-erect	Determinate	Membraneous	Slightly curved	Slightly	30° - 90°
41	NGB1171	*V. spontanea*	Kaduna	Purple	Acute-erect	Indeterminate	Intermediate	Straight	Pronounced	Erect
42	NGB1014	*V. spontanea*	Kano	Purple	Acute-erect	Determinate	Intermediate	Straight	Slightly	Erect
43	NGB1022	*V. spontanea*	Kano	White	Acute-erect	Determinate	Intermediate	Straight	Slightly	Erect
44	NGB1038	*V. spontanea*	Kano	Purple	Erect	Indeterminate	Membraneous	Straight	Pronounced	Erect
45	NGB1053	*V. spontanea*	Kano	White	Acute-erect	Indeterminate	Membraneous	Straight	Slightly	Pendant
46	NGB1089	*V. spontanea*	Kano	Purple	Acute-erect	Indeterminate	Membraneous	Straight	Slight	30° - 90°
47	NGB1113	*V. spontanea*	Kano	Purple	Erect	Indeterminate	Membraneous	Straight	Intermediate	Erect

Source: National Centre for Biotechnology and Genetic Resources (NACGRAB)

Table 1 (continued)

S/No	Genotype	Species	Collec-tion	Flower colour	Growth habit	Growth pattern	Leaf texture	Pod curvature	Twining tendency	Pod attachment
48	NGB1118	*V. spontanea*	Kano	Purple	Prostrate	Determinate	Membraneous	Slightly curved	Intermediate	30° - 90°
49	NGB1140	*V. spontanea*	Kano	Purple	Climbing	Indeterminate	Intermediate	Straight	Intermediate	Erect
50	NGB1158	*V. spontanea*	Kano	Purple	Acute-erect	Determinate	Membraneous	Straight	Slightly	Erect
51	NGB1166	*V. spontanea*	Kano	Purple	Erect	Determinate	Membraneous	Slightly curved	None	30° - 90°
52	NGB1069	*V. spontanea*	Nasarawa	Purple	Prostrate	Determinate	Intermediate	Straight	None	Erect
53	NGB1093	*V. spontanea*	Nasarawa	Purple	Erect	Indeterminate	Intermediate	Curved	Intermediate	Erect
54	NGB1160	*V. spontanea*	Nasarawa	Purple	Erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
55	NGB1162	*V. spontanea*	Nasarawa	Purple	Acute-erect	Indeterminate	Membraneous	Slightly curved	Slightly	30° - 90°
56	NGB0952	*V. spontanea*	Niger	Purple	Acute-erect	Determinate	Cariaceous	Straight	Intermediate	Erect
57	NGB1006	*V. spontanea*	Niger	Purple	Erect	Indeterminate	Intermediate	Straight	Pronounced	30° - 90°
58	NGB1018	*V. spontanea*	Niger	Purple	Semi-erect	Determinate	Intermediate	Straight	None	30° - 90°
59	NGB1063	*V. spontanea*	Niger	Purple	Erect	Indeterminate	Intermediate	Straight	Slightly	Erect
60	NGB1098	*V. spontanea*	Niger	Purple	Erect	Indeterminate	Intermediate	Straight	Slightly	30° - 90°
61	NGB1135	*V. spontanea*	Niger	Purple	Erect	Indeterminate	Membraneous	Straight	Pronounced	30° - 90°
62	NGB1170	*V. spontanea*	Niger	Purple	Acute-erect	Determinate	Intermediate	Straight	Intermediate	Erect
63	NGB1175	*V. spontanea*	Niger	Purple	Prostrate	Indeterminate	Intermediate	Straight	Pronounced	Erect
64	NGB1177	*V. spontanea*	Niger	Purple	Acute-erect	Determinate	Cariaceous	Straight	Intermediate	Pendant
65	NGB0975	*V. spontanea*	Oyo	Purple	Acute-erect	Determinate	Intermediate	Straight	Intermediate	Erect
66	NGB1054	*V. spontanea*	Oyo	Purple	Acute-erect	Intermediate	Intermediate	Straight	Slightly	Erect
67	NGB1040	*V. spontanea*	Sokoto	Purple	Erect	Indeterminate	Membraneous	Straight	Slightly	Erect
68	NGB1060	*V. spontanea*	Sokoto	Yellow	Erect	Indeterminate	Cariaceous	Slightly curved	Intermediate	Erect
69	NGB1071	*V. spontanea*	Sokoto	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
70	NGB1075	*V. spontanea*	Sokoto	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
71	NGB1087	*V. spontanea*	Sokoto	Yellow	Semi-erect	Determinate	Cariaceous	Slightly curved	Slightly	30° - 90°
72	NGB1124	*V. spontanea*	Sokoto	Purple	Erect	Indeterminate	Membraneous	Straight	Intermediate	Pendant
73	NGB1128	*V. spontanea*	Sokoto	Purple	Prostrate	Indeterminate	Intermediate	Straight	Intermediate	30° - 90°
74	NGB1137	*V. spontanea*	Sokoto	Purple	Semi-erect	Determinate	Intermediate	Straight	None	30° - 90°
75	NGB1159	*V. spontanea*	Sokoto	Purple	Climbing	Indeterminate	Membraneous	Straight	Pronounced	Pendant
76	NGB1174	*V. spontanea*	Sokoto	Yellow	Semi-erect	Determinate	Intermediate	Straight	None	30° - 90°
77	NGB1106	*V. spontanea*	Taraba	White	Acute-erect	Determinate	Membraneous	Slightly curved	Intermediate	Erect
78	NGB1108	*V. spontanea*	Taraba	Purple	Erect	Indeterminate	Membraneous	Straight	Intermediate	Erect
79	NGB1110	*V. spontanea*	Taraba	Purple	Acute-erect	Indeterminate	Membraneous	Straight	Pronounced	Erect
80	NGB1017	*V. spontanea*	Taraba	Purple	Acute-erect	Indeterminate	Membraneous	Straight	Slightly	Erect
81	NGB1143	*V. spontanea*	Taraba	Purple	Semi-erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
82	NGB1050	*V. spontanea*	Yobe	Purple	Acute-erect	Determinate	Intermediate	Slightly curved	Intermediate	Erect
83	NGB1083	*V. spontanea*	Yobe	White	Erect	Indeterminate	Membraneous	Slightly curved	Slightly	Erect
84	NGB1116	*V. spontanea*	Yobe	Purple	Erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
85	NGB1141	*V. spontanea*	Yobe	Purple	Semi-erect	Determinate	Intermediate	Slightly curved	Intermediate	Erect
86	NGB1142	*V. spontanea*	Yobe	Purple	Erect	Indeterminate	Intermediate	Straight	Intermediate	Erect
87	NGB1146	*V. spontanea*	Yobe	Purple	Erect	Indeterminate	Intermediate	Straight	Slightly	30° - 90°
88	NGB1168	*V. spontanea*	Yobe	Purple	Acute-erect	Indeterminate	Membraneous	Slightly curved	None	30° - 90°
89	NGB1169	*V. spontanea*	Yobe	Purple	Erect	Indeterminate	Membraneous	Straight	Pronounced	Erect
90	NGB1173	*V. spontanea*	Yobe	Purple	Acute-erect	Determinate	Intermediate	Slightly curved	None	Pendant
91	IFE-BPC	*V. unguiculata*	Oyo	Yellow	Erect	Indeterminate	Intermediate	Straight	Slightly	Erect
92	IFE Brown	*V. unguiculata*	Osun	White	Erect	Determinate	Intermediate	Slightly curved	Intermediate	Pendant
93	SAM-PEA10	*V. unguiculata*	Kano	Purple	Acute-erect	Determinate	Cariaceous	Slightly curved	Intermediate	Erect

Source: National Centre for Biotechnology and Genetic Resources (NACGRAB)

Table 2. Average weather conditions of the experiment from September to December during the experimental period

Geographical data	Abeokuta		Ibadan
	2014	2015	2014
Research station	FUNAAB		NACGRAB
Ecological zone	Forest-savanna transition		Derived savanna
Longitude	03°26′E		3°89'E
Latitude	7°14′N		7°37'N
Altitude (masl)	162		184
Min. temperature (°C)	22.56	22.15	25.9
Max. temperature (°C)	31.75	32.25	35.2
Mean temperature (°C)	27.03	27.20	26.83
Mean rainfall (mm)	75.41	66.33	82.93
Relative humidity	65.09	59.88	70.3

Sources: Agro-meteorology stations of Federal University of Agriculture, Abeokuta (FUNAAB) and National Centre for Genetic Resources and Biotechnology (NACGRAB), Ibadan

The experiment was laid out in a randomized complete block design with three replicates. The accessions were planted in single-row plots of 3 m length and inter-plot spacing of 0.75 m to minimize variation within the blocks. Two seeds were planted per hole at 0.30 m apart and emerging seedlings were thinned to one plant stand at 2 weeks after sowing. Five plants were selected randomly from the middle plants and measured for plant traits following the descriptor of Bioversity International (BT, 1983). The characters include plant height at flowering (cm), number of main branches, days to 50% flowering, pod length (cm), number of seeds per pod, number of pods per plant, 100-seed weight (g) and seed yield per plant (g). Flower colour, growth habit and pattern, leaf texture, pod curvature, twining tendency and pod attachment were scored. Insect infestation was considered as leaf defoliation based on visual examination of the cowpea leaflets. Five leaf defoliation intensity were defined: 0% insect infestation with 0 to 19% leaf damage; 25% (20 to 39%), 50% (40 to 59%), 75% (60 to 79%) and 100% (80 to 100%) (Rahman *et al.*, 2008).

Agronomic data were subjected to analysis of variance using the GLM procedure in SAS version 9.1.1 (SAS Institute, 2002), where accession and environment were considered as fixed factors and block as a random factor. Standard error of mean difference was used to separate the means performance of the accessions. Genetic diversity among the 90 accessions of *V. spontanea* was determined based on their genetic distance using the FASTCLUS and Canonical procedures in SAS.

RESULTS

The flower colour of the accessions varied from purple to white and yellow. Over 60% of the accessions were indeterminate, with most ranging from acute erect to erect and semi-erect. The leaf texture and pod curvature were mostly membranous and straight, respectively. Pod attachment was erect for most of the accessions (Table 1).

Significant ($p < 0.01$) variation was revealed among the wild relative of cowpea for yield and other agronomic characters (Table 3). The influence of the environment on the expression of the characters was revealed by the significant ($p < 0.01$) effect of accession × environment interaction (GEI). Of the total source of variation, GEI contributed most to the total variation for days to 50% flowering, pod length and 100-seed weight. Accession effect also contributed considerably to the variation in these traits including plant height and number of pods/plant. The coefficient of variation (Table 4) revealed high variability among the accessions for plant height at flowering (37.91), number of pods/plant (28.51), 100-seed weight (24.65) and yield (33.60) over the environment. The variation was high for number of seeds/pod (30.63) at Ibadan. The mean of the traits, except for days to flowering, pod length and number of pods/plant, varies considerably with environment.

NGB1140 and NGB1170 had fewer days to flowering at Abeokuta (43 days) in 2014 (Table 5). Days to flowering was also low in NGB1140 (43 days), NGB1083 (43 days) and NGB1136 (42 days) at Ibadan. The least average for the trait, over the three environments was observed in NGB1140 and NGB1170 (45 days). NGB1079, NGB1130 (Bornu), NGB1118, NGB1140 (Kano), NGB1177 (Niger), NGB1087, NGB1063 (Sokoto) exhibited high pod length at Abeokuta (2014) and Ibadan. NGB1132 (Adamawa) had high pod length in the environments, and NGB1081 (Kaduna) in Ibadan and Abeokuta (2015). Accessions with high number of pods in at least two environments include NGB1167 (Adamawa), NGB1047 (Bornu), NGB1133 (Jigawa), NGB1140 (Kano), NGB1075, NGB1060 (Sokoto), NGB1108 (Taraba) and NGB1141 (Yobe).

Table 3. Mean squares of seven agronomic characters in 90 accessions of *V. spontanea* and 3 genotypes of *V. unguiculata* over two locations

Source of variation	Block (envr) (df = 6)	Accession (A) (df = 92)	Environment (E) (df = 2)	A x E (df = 184)	Error (df = 552)	Proportion in Total SS (%)		
						Accession	Location	A x L
Plant height at flowering (cm)	278.90	2814.70**	103980.04**	795.36**	182.42	36.19	29.06	20.45
Days to 50% flowering	0.57	101.50**	2304.44**	62.44**	0.73	36.14	17.84	44.46
Pod length (cm)	1.15	10.27**	0.32**	5.67**	1.93	30.87	0.02	34.10
Number of seeds/pod	2.90	22.14**	3746.58**	27.55**	2.36	12.79	47.07	31.84
Number of pods/plant	26.05	111.40**	64.74**	35.04**	12.77	42.65	0.54	26.83
100-seed weight (g)	0.20	11.59**	548.14**	7.03**	0.31	29.40	30.25	35.67
Seed yield/plant (g)	1.99	141.49**	15496.25**	131.47**	5.15	18.32	43.62	34.04

* significant at $p < 0.05$, ** significant at $p < 0.01$

Table 4. Mean and Variation of Characters Evaluated in the Cowpea Accessions over three Environments

Line	Plant height at flowering (cm)	Days to 50% Flowering	Pod length (cm)	Number of seeds/pod	Number of pods/plant	100-seed weight (g)	Seed yield/plant (g)
Abeokuta 2014							
Mean	46.40	53.31	9.39	11.28	12.94	2.78	15.26
Range	110.34	25.00	12.50	8.34	25.17	6.14	45.81
CV (%)	32.75	2.30	13.39	17.31	31.75	27.14	11.31
Ibadan 2014							
Mean	47.14	53.32	9.32	4.52	12.66	0.67	1.39
Range	110.67	26.00	7.23	12.00	24.67	2.83	4.61
CV (%)	37.41	1.14	12.14	30.63	32.74	33.35	40.14
Abeokuta 2015							
Mean	13.34	48.34	9.34	10.37	12.00	3.32	3.61
Range	10.88	2.50	16.88	7.00	14.00	18.06	45.33
CV (%)	17.40	1.17	18.30	11.21	17.16	16.20	96.60
Pooled							
Mean	35.63	51.66	9.35	8.72	12.53	2.26	6.75
Range	72.31	16.67	7.45	6.31	18.02	8.32	22.71
CV (%)	37.91	1.65	14.86	17.61	28.51	24.65	33.60

Coefficient of variation (CV)

Table 5. Days to flowering, pod length and number of pods/plant in accessions of *V. spontanea*

Origin	Days to 50% Flowering			Pod length (cm)			Number of pods/plant		
	Abk_2014	Iba_2014	Abk_2015	Abk_2014	Iba_2014	Abk_2015	Abk_2014	Iba_2014	Abk_2015
Abuja									
Min/Max	46.00	58.00	48.00	10.33	10.17	10.33	15.00	15.00	10.52
Adamawa									
Min	46.00	42.00	47.50	5.00	5.00	7.44	2.33	2.33	9.60
Max	68.00	68.00	49.08	10.67	11.00	10.85	26.67	26.67	16.50
Mean	54.90	56.23	48.36	8.84	9.15	9.30	11.00	11.00	12.02
Bauchi									
Min	48.00	45.00	48.92	8.67	7.53	8.82	10.67	9.33	10.00
Max	56.00	56.00	49.00	9.33	9.20	11.27	13.00	13.00	15.00
Mean	52.67	49.67	48.97	8.91	8.32	10.11	12.00	11.00	12.09
Benue									
Min/max	55.00	49.00	49.50	10.45	8.83	10.92	16.00	10.00	10.30
Bornu									
Min	46.00	46.00	47.00	8.43	7.03	7.17	9.67	9.67	9.42
Max	62.00	62.00	49.33	13.20	12.23	10.75	27.50	22.33	17.50
Mean	53.27	51.00	48.12	9.73	9.41	8.97	13.08	12.54	12.80
Jigawa									
Min	45.00	46.00	47.50	7.67	8.33	7.25	7.33	7.33	9.00
Max	56.00	57.00	48.92	10.40	10.87	10.10	22.33	22.33	17.00
Mean	51.67	53.00	48.44	9.23	9.71	8.85	12.71	12.71	11.75
Kaduna									
Min	45.00	45.00	47.50	9.00	8.33	8.77	10.33	9.93	9.55
Max	68.00	65.00	48.58	17.50	10.33	10.67	18.33	18.33	20.00
Mean	55.00	54.50	48.10	10.83	9.55	9.81	13.75	13.07	12.46
Kano									
Min	43.00	43.00	47.00	8.33	6.37	7.88	5.00	5.00	9.00
Max	57.00	57.00	49.17	11.33	11.00	10.03	26.67	26.67	22.00
Mean	49.20	51.47	48.23	9.73	9.60	9.11	14.13	14.17	12.09
Nasarawa									
Min	47.00	54.00	48.00	8.73	7.23	8.38	7.33	7.33	9.46
Max	61.00	59.00	49.50	10.67	10.90	10.37	11.00	13.67	10.02
Mean	52.50	57.25	48.38	9.52	9.34	9.65	9.75	10.67	9.75
Niger									
Min	43.00	45.00	47.00	6.57	7.97	8.06	8.00	8.00	8.00
Max	61.00	63.00	49.00	11.50	11.33	10.68	14.33	14.33	16.00
Mean	52.00	54.04	48.27	9.13	9.85	9.36	11.28	11.52	10.44
Oyo									
Min	57.00	57.00	49.00	8.67	7.53	8.80	9.33	9.33	14.00
Max	59.00	59.00	49.17	11.67	9.40	9.09	14.33	14.33	16.50
Mean	58.00	58.00	49.09	10.17	8.47	8.95	11.83	11.83	15.25
Sokoto									
Min	46.00	45.00	47.50	7.67	7.57	7.85	6.00	6.00	8.32
Max	68.00	63.00	49.00	12.67	11.10	9.50	27.00	27.00	20.67
Mean	57.40	53.37	48.46	9.10	9.24	8.61	15.23	14.42	12.30
Taraba									
Min	46.00	50.00	47.83	8.13	7.17	7.65	4.00	4.00	15.00
Max	59.00	59.00	48.58	9.67	10.47	9.78	22.33	22.33	17.50
Mean	53.20	55.00	48.20	8.99	8.49	8.67	13.87	13.73	16.10
Yobe									
Min	45.33	43.00	47.00	7.67	8.50	7.96	8.00	8.00	8.93
Max	62.00	59.00	49.00	10.00	10.40	9.55	23.33	23.33	13.00
Mean	54.15	53.44	48.05	8.87	9.37	8.92	12.93	12.93	10.17
Check									
IFEBPC	55.00	47.00	49.00	8.73	8.53	10.40	13.33	10.00	10.63
IFE-BROWN	47.33	45.00	49.00	8.43	8.73	10.63	13.00	11.67	9.52
SAM-PEA10	46.67	45.00	48.50	8.00	8.27	10.28	13.67	15.33	10.62
SED	1.00	0.50	0.46	1.03	0.92	1.40	3.35	3.38	1.68

Standard error of mean difference (SED)

Considerable higher number of seeds/pod was exhibited among the *V. spontanea* (11 to 14 seeds) accessions than the checks (7/8 seeds) at Abeokuta in 2014 (Table 6). Of these accessions, only NGB1111 (Jigawa) produced higher number of seeds/pod (12) than the checks at Ibadan. The following accessions had similar number of seeds to the checks in Abeokuta (2015): NGB1109 (Jigawa), NGB1163 (Kaduna), NGB0952, NGB1135 (Niger), NGB1040, NGB1174 (Sokoto), NGB1106 (Taraba), NGB1116, NGB1173 (Yobe). Genetic potential for higher seed yield was observed in NGB1134 (Adamawa), Bornu (NGB1125), NGB1150 (Jigawa) NGB1171 (Kaduna), NGB1089 (Kano), NGB1098 (Niger), NGB1054 (Oyo), NGB1137 (Sokoto) and NGB1108 (Taraba) in Abeokuta (2014). Yield in Ibadan was low due to high rate of insect infestation compared to Abeokuta in 2014. However, NGB1158 (Kano), NGB1093 (Nasarawa) and NGB1137 (Taraba) produced significantly higher yield than the check. Insect infestation was controlled at Abeokuta in 2015, and highest yields were obtained in the checks during this period. Insect infestation ranged from 0 – 75% in Abeokuta (2014) and 50 – 100% in Ibadan. Minimum insect infestation (0%) was observed in NGB1082 (Adamawa), NGB1150 (Jigawa), NGB1171 (Kaduna), NGB1089 (Kano), NGB1128, NGB1071 (Sokoto), NGB1108 (Taraba), and NGB1142 (Yobe) at Abeokuta compared to the checks (50 – 75%). However, NGB1089, NGB1108, NGB1142, NGB1150, NGB1171 had 75% insect infestation and NGB1071, NGB1082, NGB1128 (100%) at Ibadan. NGB1085 (Bornu) maintained a 50% infestation in both environments while NGB1177 (Niger) had 25% and 50% infestation at Abeokuta and Ibadan, respectively.

The cowpea accessions were separated into nineteen homogenous groups based on pooled mean and FASTCLUS procedure of SAS (Table 7). The multivariate analysis separated IFEBROWN, NGB1078 (Adamawa), NGB1068 (Bornu), and NGB1167 (Adamawa) in clusters 5, 13, 14 and 18 respectively, and the D^2 distance (longest) revealed genetic distinctness of IFEBROWN and NGB1167 from the other accessions. The closest genotype to IFEBROWN were NGB1171 (Kaduna), NGB1089 (Kano) and NGB1137 (Kano), while NGB1047 (Bornu), NGB1075 (Sokoto) were closer to NGB1167. The cowpea accessions were not distributed into the clusters following the States of collection which suggested a close origin among the genetic materials. Divergence among the 19 clusters was attributed more to yield followed by number of pods and days to flowering based on the coefficient of determination (Table 8). High yield was related to the check (IFEBROWN) in Cluster 5, then NGB1171 (Kaduna), NGB1089 (Kano), NGB1137 (Sokoto) in Clusters 3 and NGB1134 (Adamawa), NGB1150 (Jigawa) and NGB1098 in Cluster 10. Accessions in Cluster 18 were revealed as high pod-bearing plants with high number of seeds/pod. NGB1047 (Bornu), NGB1075 (Sokoto), NGB1108 (Taraba) in Cluster 15 and NGB1060 (Sokoto), NGB1141 (Yobe) in Cluster 11 were also classified as plants with high number of pods/plant. Cluster 6 with NGB1014 and NGB1140 (Kano) was described as early flowering group with high number of pods/plant. Cluster 3 (NGB1171, NGB1089, NGB1137) was revealed as group with considerable high yielding plants and high number of seeds/pod.

Table 7. Nineteen clusters among 93 accessions of cowpea and squared distance (D^2) to cluster

Cluster	Accession	Distance	
		Shortest	Longest
1	NGB1127 (Kaduna), NGB1166, NGB1022 (Kano), NGB1162 NGB1160 (Nasarawa), NGB0952, NGB1063 (Niger), NGB1159, NGB1174 (Sokoto), NGB1142, (Yobe)	8.40** (19)	232.93** (5)
2	NGB1093 (Nasarawa), NGB1094 (Kaduna)	24.28** (9)	232.11** (5)
3	NGB1171 (Kaduna), NGB1089 (Kano), NGB1137 (Sokoto)	18.88** (10)	180.75** (18)
4	NGB1071 (Sokoto), NGB0975 (Oyo), NGB1065 (Bauchi), NGB1110 (Taraba), NGB1123 (Kaduna)	14.74** (19)	181.54** (5)
5	IFEBROWN	44.61** (3)	376.58** (18)
6	NGB1014, NGB1140 (Kano)	41.59** (8)	268.59** (5)
7	NGB1132 (Adamawa), NGB0963 (Benue), NGB1044, NGB1126, NGB1115, NGB1130, NGB1105 (Bornu), NGB1028, NGB1027, NGB1081 (Kaduna), NGB1069 (Nasarawa), NGB1018 (Niger), NGB1087 (Sokoto), NGB1017 (Taraba), NGB1169 (Yobe)	6.98** (16)	236.43** (5)
8	NGB1113, NGB1158 (Kano), NGB1106 (Taraba)	10.56** (17)	132.69** (5)
9	NGB1090, NGB1109 (Jigawa), NGB1099, NGB1152 (Bauchi), NGB1083 (Yobe), NGB1170, NGB1177 (Niger),	9.00** (17)	184.27** (5)
10	NGB1134 (Adamawa), NGB1150 (Jigawa), NGB1098 (Niger),	10.54** (12)	154.95** (18)
11	NGB1060 (Sokoto), NGB1141 (Yobe)	32.24** (19)	300.34** (5)
12	NGB1006 (Niger), NGB1163 (Kaduna), NGB1054 (Oyo)	10.54** (9)	117.70** (5)
13	NGB1078 (Adamawa)	23.16** (4)	278.86** (5)
14	NGB1068 (Adamawa)	27.65** (1)	280.42** (5)
15	NGB1047 (Bornu), NGB1075 (Sokoto), NGB1108 (Taraba)	30.49** (12)	199.14** (5)
16	NGB1148, NGB1136 (Adamawa), NGB1118, (Kano), NGB1050, NGB1100, NGB1175 (Niger), NGB1168 (Yobe),	6.98** (7)	181.17** (5)
17	IFEBPC, SAMPEA10, NGB1086, NGB1125, NGB1079 (Bornu), NGB1111, NGB1133 (Jigawa), NGB1038 (Kano), NGB1135 (Niger), NGB1128 (Sokoto), NGB1143, (Taraba)	9.00** (9)	147.54** (18)
18	NGB1167 (Adamawa)	35.92** (15)	376.58** (5)
19	NGB0964 (Abuja), NGB1072, NGB1082, NGB1176 (Adamawa), NGB1151, NGB1058 (Bornu), NGB1165 (Jigawa), NGB1040, NGB1053, NGB1124 (Sokoto), NGB1116, NGB1146, NGB1173 (Yobe),	8.40** (1)	218.29** (5)

** significant at $p < 0.01$

Table 8. Divergence Among the 19 Clusters in 93 Cowpea Accessions for Yield and Yield-Related Traits

Cluster	Days to 50% flowering	Pod length (cm)	Number of pods/ plant	Number of seeds/ pod	Seed yield/plant (g)
1	54.95 (1.07) †	9.40 (0.80)	9.85 (1.83)	9.35 (1.79)	5.06 (1.27)
2	51.36 (1.92)	13.18 (1.19)	9.28 (1.65)	9.67 (0.86)	5.53 (0.57)
3	49.23 (2.03)	8.62 (0.81)	16.33 (1.79)	10.00 (0.51)	16.30 (2.63)
4	55.33 (1.43)	8.61 (0.78)	13.09 (2.27)	6.58 (0.48)	7.87 (1.45)
5	47.11 (0.00)	9.27 (0.00)	11.39 (0.00)	8.83 (0.00)	24.34 (0.00)
6	45.50 (0.71)	10.17 (0.09)	19.27 (2.67)	7.99 (1.43)	2.52 (0.93)
7	49.93 (1.23)	9.68 (0.97)	10.86 (1.53)	7.61 (1.00)	3.42 (1.22)
8	50.57 (0.36)	9.03 (1.12)	16.90 (1.07)	9.37 (1.62)	9.24 (2.19)
9	48.17 (1.82)	9.53 (0.89)	10.99 (0.67)	10.48 (0.38)	5.65 (0.74)
10	52.47 (0.36)	8.99 (0.48)	11.96 (0.48)	8.82 (1.61)	14.37 (1.69)
11	54.41 (0.69)	8.49 (0.03)	20.20 (2.31)	6.06 (0.71)	2.61 (1.17)
12	55.66 (1.19)	9.89 (0.29)	13.77 (1.12)	9.21 (1.89)	12.29 (0.64)
13	61.44 (0.00)	8.69 (0.00)	13.28 (0.00)	8.50 (0.00)	6.34 (0.00)
14	53.00 (0.00)	6.57 (0.00)	4.76 (0.00)	9.83 (0.00)	3.62 (0.00)
15	57.08 (1.51)	8.91 (0.83)	21.37 (1.11)	8.71 (1.29)	9.66 (2.33)
16	49.97 (1.41)	9.27 (0.88)	8.64 (1.29)	7.89 (1.18)	6.40 (1.22)
17	48.85 (1.75)	9.33 (1.09)	12.62 (1.09)	8.69 (1.52)	8.84 (1.41)
18	61.67 (0.00)	10.36 (0.00)	22.78 (0.00)	11.17 (0.00)	4.25 (0.00)
19	52.62 (1.33)	9.08 (0.61)	13.22 (1.31)	9.42 (1.15)	4.61 (1.48)
R^2	0.86	0.48	0.86	0.48	0.90

† standard deviation within cluster
Coefficient of determination (R^2)

DISCUSSION

This study was an important step to identify valuable agronomic traits in wild-relative of cowpea; *Vigna unguiculata* subspp. *unguiculata* var. *spontanea*, and select them for further utilization in breeding programmes of cowpea. Morphological variation in growth pattern/habit and flower colour are important for the classification of the cowpea accessions. Significant differences observed among the 90 *spontanea* accessions for agronomic traits revealed presence of natural variation, and possibility of selecting parental genotypes with valuable traits. Knowledge of genetic variation is inevitable for identifying genetic potentials in breeding programmes (Undals *et al*., 2011). Significant effect of GEI demonstrated the dependence of the accession on the environment for the expression of the traits therefore, possibility to maximize the adaptive variation of the accessions in diverse environments. However, small seed size and twinning growth habit are wild and undesirable attributes common in the cowpea accessions. Days to flowering, number of pods/plant and seed yield are important agronomic traits to distinguish among the *spontanea* accessions. Early flowering accessions which include NGB1140, NGB1083, NGB1136 and NGB1170 were identified and could be selected as promising parental material for development of the trait. Another significant trait was low insect infestation. Low leaf damage observed in some of the *spontanea* accessions which include NGB1089, NGB1108, NGB1142, NGB1150, NGB1171, NGB1085 and NGB1177 could provide a good level of resistance to create tolerance to insect-pest in the cultivated cowpea. Outstanding *spontanea* accessions within clusters 6, 11, 15 and 18 (high number of pods/plant) clusters 3, 9 18 (high number of seeds/pod) and clusters 3 and 10 (high seed yield) can be selected for yield-related traits and improvement of yield in the cultivated cowpea through hybridization program. In conclusion, exploring the genetic potential in *Vigna unguiculata* subspp *unguiculata* var. *spontanea* through characterization of the agro-morphological variation present in the available genetic resource is an important step. Although, var. *spontanea* has been described as the progenitor of var. *unguiculata* (Pasquet 1999), adaptability of this wild variety for agro-morphological characters are crucial for further improvement of the cultivated cowpea, especially in the midst of present and predictable climate change.

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