UNDER PEER REVIEW

Original Research Article

Analyses of genotypic diversity and adaptability of cowpea to humid tropical ecology

Abstract

In Africa, cowpea (*Vigna unguiculata* (L) Walp.) is more appreciated in the food habit than other legumes. It is a popular pulse cultivated mainly in the semi – arid region of West Africa, but its production cannot meet the demand, therefore, this study assessed yield potential and adaptability of cowpea to humid agro-ecology. Ninety two accessions obtained from International Institute of Tropical Agriculture, Nigeria were evaluated in Calabar (4^0 57'N, 8^0 19'E) in a randomised complete block design in three replications. All the accessions were collected in southern Nigeria between Latitude $05^0$05 and $08^0$30N, and Longitude $03^0$25 and $15^0$40E. Twenty-two of the 92 accessions flowered and had grain yield in the humid agro-ecology; TVu-1131, TVu-1132 and TVu-215 had grain yield between 1054.7 and 1093.9 Kg/ha; this yield is within range of the cowpea yield in West Africa. Principal component analysis (PCA) explained the contribution of 99.9 % of the morphological variation in the accessions and attributed most of it to the diversity in grain yield and single linkage cluster analysis partitioned the accessions into two groups based on their genetic relationship. There was positive correlation in the relationship between the characters studied and significant correlation between grain yield and number of days to flowering, number of flowers per plant, number of pods per plant, number of seeds per pod and the pod length; thereby indicating that selection for these pods and seeds characters would invariably lead to improvement of the yield. For the adaptability, cowpea accessions that are high yielding, photoperiod insensitive and early maturing are most suitable, in this study TVu-1131, TVu-1132, TVu-215 have identified as prospects.

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Keywords: *Vigna unguiculata*, humid ecology, crop adaptability, cowpea diversity, multivariate analysis

Introduction

Cowpea (*Vigna unguiculata* (L) Walp.) is one of the few pulses commonly found in West African cropping systems. It plays a major role in the farming systems of the tropics as an invaluable source of plant protein, by contributing to the nutrient economy. It is a severely neglected crop because it originated from Africa. it has many useful attributes that encourages it consumption as whole bean or ground into paste to make *akara* or *moi-moi* and other snacks. The valuable properties of the crop are early maturing; flowering within 48 days and reaching pod maturity by 60 days and it is highly digestibility; it has high rates of nitrogen (N) fixation, high phosphorus (P) use efficiency and can reproduce itself by seed dispersal (Singh et al., 1997). The crop is also desired for forage or cover crop and can improve soil structure with its deep roots as well as decrease erosion and weeds through its rapid growth and soil coverage (Ola *et al.*, 2015). Cowpea is very useful nutritionally; it has high digestible protein, 15 to 26 %; carbohydrate 55 – 66 %; several minerals and vitamins (Umoren, 1997), the leaves and green pods are also consumed as a leafy vegetable. Because cowpea can fix atmospheric nitrogen in the soil, it is beneficial for soil fertility; excessive use of chemical fertilizers leads to diminishing reserves of high quality raw material, such as, humus and increases energy costs (Kaur *et al*. 2015), so N fixation of cowpea has the advantage of remediating this effect. Cowpea is easily adapted into farming systems, such as intercrop because it tolerates shades (de Albuquerque, *et al*., 2015).

Cowpea is a tropical crop, originating from the sub-Saharan Africa (Padulosi and Ng, 1997); it is a warm-weather, tolerant to drought and well - adapted to the drier regions of the tropics, where other food legumes do not perform well. the world annual production of cowpea is approximately 2.5 million tonnes from about 12.5 million hectares (FAO, 1998). Since the crop is a warm – season legume, African countries produce about two thirds of the world

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cowpea; Nigeria and Niger Republic are the world's major producers, jointly producing 49 % of the 1.32 million tonnes produced from Africa. The most favourable conditions for the crop production are rainfall between 2.8 and 41 dm, annual temperature from 12.5 to 27.8 ^{0}C, average day and night temperature of 28 ^{0}C and 22 ^{0}C respectively, and soil pH range of 4.3 to 7.9 (Craufurd *et al*., 1997).

Wekundah and Aghan (2003) observed that there is hunger in Africa arising from inadequate food supply to meet the population's need; the sub-Saharan population rose from 200 million in the 1970s to 520 million in 2000, while there was corresponding decline in food production due to (1) conflicts in several regions that barred farmers from food production (2) drought and other disasters that devastated plants and animals and (3) refocusing in economic goals and policies, for example, in Nigeria there was interest shift from agrarian to petroleum industry. The highest population density in Africa is located in the forest regions; about half the people live on less than 40 % of the land (IITA, 1988). In Nigeria, more than 41.6 million people (46.7 %) live in the forest region of southern Nigeria, compared to 16.1 million (18.2 %) in Guinea savannah and 31.2 million (35.1 %) in Sudan and Sahel savannah (NPC, 1998). The solution to African food problem is to intensify cowpea production in all agro-ecologies (Quin, 1997), by this means, more food, especially affordable protein would be produced to meet the demand for food.

Cowpea can be adapted into the cropping systems in the humid tropical agro-ecology; Lambot (2002) stated that cowpea is more popular and appreciated than soybean and other legumes in West African food habit; the crop is part of the diet of more than 100 million people already. Expectedly, the excess atmospheric and rhizospheric moisture shall pose challenges, such as, waterlogged soils, which has been reported to reduce seed yield in cowpea by more than 50 % (Minchin *et al*., 1978), infection from bacterial blight, pod rot

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disease, and infestation from insects, such as aphids, pod borers and pod sucking bugs (Prakash and Shivashanker, 1982; Emechebe and Shoyinka, 1985; Singh and Jackai, 1985).

However, cowpea is a very resilient crop; Craufurd *et al*., (1997) noted that specimens have been collected between latitude 40 ^{0}N and 30 ^{0}S of the Equator. The crop has the genetic variability, which should be exploited to develop exotic cultivars for the humid agro-ecology. Such project would increase the area under cowpea cultivation and boost production; remove haulage cost from the total cost of production, decrease incidence of infection in stored grains and make the grains readily available to people in the humid regions. The objectives of the study were to evaluate the diversity of cowpea, analyse the yield potential of the genotypes and assess the adaptability in humid tropical ecology. Genetic variability in a given plant population is essential to the success of its breeding programme.

Materials and methods

Study area

The experiment was conducted in the University of Calabar Research Farm, Calabar. Calabar (4^0 57'N, 8^0 19'E) is located in southeast of southern Nigeria; the vegetation is tropical rain forest type, with annual rainfall of about 2915 mm; Calabar has rains all year round. The average monthly temperature is about 26.5 ^{0}C with a minimum of 24 ^{0}C in the mid – year, daily temperature ranges from 23 to 31.7 ^{0}C. Amalu (1998) described the soils around Calabar as acidic (pH 4.6 – 5.0), low in organic matter, with total nitrogen of 1.0 – 1.9 g per Kg, available phosphorus of 5.8 – 11.9 mg per Kg, exchangeable calcium of 0.4 – 2.8 cmol per Kg and exchangeable sodium of 0.2 – 0.4 cmol per Kg.

Experimentation

Nine – two cowpea accessions (Table 1) were collected from the Genetic Resources Unit (GRU) of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The field

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was laid out in a randomized complete block design in three replications; the accessions were randomly allocated to the plots. Planting was carried out in the second week of October, the intra-row spacing was 0.5 m, inter-row spacing was 1.0 m and the inter-block spacing was 1.5 m, two seeds were planted per hole in three row plots, 5 m long; the mid – single rows were sampled. The number of seedlings per stand was later thinned leaving 10 plants per plot for sampling. Data were taken on the seedling emergence at seven days after planting (DAP), seedling establishment at 21 DAP, number of days to 50 % flowering per plot, number of seeds per pod, pod length at first harvest, weight of 100 seeds, grain yield per plot and yield per hectare.

Analysis of variance (ANOVA) of the morphological characteristics was computed with the GenStat 8.1 package (GenStat, 2005), significant differences between means were compared by using Duncan's New Multiple Range Test (DNMRT). The multivariate analyses were computed with Past 3 package (Hammer *et al*., 2001); principal components with eigen values greater than one were selected for analysis (Jeffers, 1967)

Results and discussion

All the 92 accessions used in this study were collected by IITA in southern Nigeria, between Latitude $05^0$5 – $08^0$30 N and Longitude $03^0$25 - $15^0$40 E or some location in southern Nigeria (Table 1). This was the first level screening for adaptability to the humid tropical agro-ecology, IITA holds more than 16000 accessions in its germplasm bank (Quin, 1997). The second level screening was based on flowering (Table 2) and yield characteristics (Table 3). Twenty two (22) accessions flowered indicating that 70 accessions tested would not have grain yield in the humid environment. Some varieties of cowpea are photo-sensitive, this is a very important physiological trait (Umar *et al.* 2010); the time of flowering of photo-sensitive varieties is dependent on time and location of sowing and may be as long as 100 days or

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more, 100 days period of time is too long if cowpea is to be cultivated in humid environment, due to the all year round rainfall.

TVu-1131, TVu-1132 and TVu-215 were the highest yielding among the accessions, producing 1054.7 to 1093.9 Kg/ha, the lowest grain yield per hectare was 544.1 Kg/ha produced by TVu-1358. Porbeni *et al*. (2016) obtained 590 to 851 Kg/ha and Oladejo *et al*. (2016) obtained 356.8 to 1068.2 Kg/ha in western Nigeria, therefore, the yield obtained in this study is comparable to the range in western Nigeria.

The principal component (PC) matrix describing the similarity among the genotypes is presented in Table 4. PC analysis is a useful tool for partitioning of variation among germplasm; six of the principal components had eigen values greater than 1.0. The first principal component (PC 1) explained 99.9 % of the morphological variation in the accessions and was loaded on the grain yield. The PC 2 was loaded on the number of days to flowering, numbers of flowers per plant, number of pods per plant and pod length; PC 3 was loaded on two variables; the number of days to seedling emergence and the number of days to seedling establishment. A more discriminative structure was observed in the scatter diagram (Figure 1) with 95 % ellipses capturing 13 accessions showing similarity on the right axis of component 1.

Numerical taxonomy assumes that similarity within species is a measure of their genetic relationship. Thus, the association within the accessions was established by the single linkage cluster analysis (SLCA) presented in Figure 2. Dendrogram was used to detect significant differences between lines and the magnitude of deviation among the genotypes. The diversity in the accessions was partitioned into two major groups, with genetic distance divergence from 0.0 to 320 levels. At minimum of 0.0 level of similarity, all genotypes were distinct but

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at the maximum level, all the accessions were in a single cluster, which pointed that each accession had at least one neighbour.

The correlation matrix showing the relationship between morphological traits is presented in Table 5. All the eight traits considered in this study had positive relationship with each other. There was significant and positive correlation between the number of seedling at emergence and the number of seedlings at establishment. The number of days to flowering had positive and significant association with grain yield and the number of flowers per plant had highly significant and positive relationship with the number of pods per plant. Early flowering and maturity are very important attributes in legumes and other short duration crops in the humid agro-ecology because the plant can utilise the diminutive dry season to complete its growth cycle. The number of pods per plant has highly significant relationship with the number of seeds per pod and with the grain yield and the number of pods per plant also had significant relationship with the pod length. The pod length had significant association with the grain yield. Ittah *et al.* (2016) reported a positive and significant relationship found between grain yield and number of seeds per pod, number of pods per plant and number of days to flowering in groundnut. Significant and positive correlation between characters indicates that the characters can be improved simultaneously in a breeding programme (Idahosa *et al.*, 2010). Non significance in the association between some traits may imply lesser contribution to their mutual development or might be due to genetic constitution differences in the breeding materials evaluated (Maji and Shaibu, 2012). Therefore, cowpea accessions that are high yielding, early maturing, photoperiod insensitive and have secondary attributes like long pods and are multi-seeded are adaptable to the humid agro-ecology. TVu-16196, TVu-1131, TVu-1132 and TVu-215 are recommended for cultivation in the humid tropical ecology.

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Table 1. Place of collection of the cowpea accessions by IITA

sn	Accession	Place of collection	Latitude	Long	sn	Accession	Place of collection	Latitude	Long
1.	TVu-10859	Ex Ogbomoso	0810N	0415E	**47.**	TVu-7821	Ewa Ex Oye Ekiti	0745N	0520E
2.	TVu-10864	Ex Warri	0550N	1540E	**48.**	TVu-7823	Ewa Ex Ijan Ekiti	0745N	0525E
3.	TVu-10983	Ex Alagbado	0820N	0440E	**49.**	TVu-7833	Ewa Ex Emure	0710N	0530E
4.	TVu-1130	Ibadan 14			**50.**	TVu-7834	Ewa Ex Oke Igbo Mkt	0710N	0445E
5.	TVu-1131	Ibadan 27			**51.**	TVu-7852	Ewa Ex Ago Are	0830N	0325E
6.	TVu-1132	Ibadan 36			**52.**	TVu-7853	Ewa Ex Ogbomosho	0810N	0414E
7.	TVu-1260	Ibadan 3(-A)			**53.**	TVu-7855	Ewa Ex Ipapo Settlement	0810N	0330E
8.	TVu-13402	Ex Owo	0715N	0535E	**54.**	TVu-7857	Ewa Ex Ago Are	0830N	0325E
9.	TVu-1358	Erect multipod			**55.**	TVu-7858	Ewa 2 Km Ago Are To Iseyin	0830N	0325E
10.	TVu-1515	Local speckle			**56.**	TVu-7871	Ex Owo	0720N	0550E
11.	TVu-1516	Local white			**57.**	TVu-7878	Ex Sango	0750N	0650E
12.	TVu-1517	Local white			**58.**	TVu-7887	Ex Akpayan	0800N	0700E
13.	TVu-15676	IT86D-1010			**59.**	TVu-7889	Ex Karara Egbe	0800N	0640E
14.	TVu-15687	IT86D-719			**60.**	TVu-7891	Ex Felele	0800N	0645E
15.	TVu-16196	IT86D-880			**61.**	TVu-7906	Ex Kabishanni	0810N	0710E
16.	TVu-212	Ibasmooth			**62.**	TVu-7915	Ex Sekona, Oyo State	0800N	0420E
17.	TVu-213	Ibatan			**63.**	TVu-7916	Ex Sekona, Oyo State	0800N	0420E
18.	TVu-214	Ibapink			**64.**	TVu-7917	Ex Sekona, Oyo State	0800N	0420E
19.	TVu-215	Ibabrown			**65.**	TVu-8084	Ewa Ex Olodo	0720N	0335E
20.	TVu-4041	Kr309	0657N	0616E	**66.**	TVu-8177	Ewa Ex Olodo		
21.	TVu-4062	Kr323	0523N	0707E	**67.**	TVu-8178	Ewa 2 Km From Uaro		
22.	TVu-4063	Kr323	0523N	0707E	**68.**	TVu-8180	Ewa Ex Ado Odo		
23.	TVu-4064	Kr324	0523N	0707E	**69.**	TVu-8571	Ewa Alagbado	0820N	0440E
24.	TVu-4065	Kr324	0523N	0707E	**70.**	TVu-8581	Ex Owode	0820N	0414E
25.	TVu-4066	Kr324	0523N	0707E	**71.**	TVu-8582	Ex Od Oba	0810N	0405E
26.	TVu-4067	Kr328	0505N	0650E	**72.**	TVu-8585	Ex Ogidi	0750N	0650E
27.	TVu-4068	Kr328	0505N	0650E	**73.**	TVu-8586	Ex Sango	0750N	0650E
28.	TVu-4069	Kr328	0505N	0650E	**74.**	TVu-9146	Ex Awe	0745N	0358E
29.	TVu-4070	Kr328	0505N	0650E	**75.**	TVu-9147	Oyo No1	0750N	0355E
30.	TVu-4071	Kr328	0505N	0650E	**76.**	TVu-9154	Ex Ogbomosho	0810N	0415E
31.	TVu-4073	Kr335	0510N	0743E	**77.**	TVu-9155	Ogbomosho No 2	0810N	0415E
32.	TVu-4074	Kr335	0510N	0743E	**78.**	TVu-9156	Ex Ede	0745N	0425E
33.	TVu-4075	Kr335	0510N	0743E	**79.**	TVu-9174	25 Km S. Ogbomosho	0750N	0425E
34.	TVu-4076	Kr336	0510N	0743E	**80.**	TVu-9175	25 Km S. Ogbomosho	0750N	0425E
35.	TVu-4078	Ke341	0506N	0721E	**81.**	TVu-9176	25 Km S. Ogbomosho to Oyo	0750N	0425E
36.	TVu-4085	Ke367	0629N	0912E	**82.**	TVu-9190	10 Km N. Ado Aweiye-Iseyin	0750N	0330E
37.	TVu-4468	Ex Enugu			**83.**	TVu-9191	Ex Ifefedo	0710N	0440E
38.	TVu-527	Ibadan1			**84.**	TVu-9192	35 Km E. Ife to Ondo	0710N	0440E
39.	TVu-530	Ibadan2			**85.**	TVu-9201	Atsegba No 1	0740N	0525E
40.	TVu-640	Ibadan3			**86.**	TVu-9202	Atsegba No 2	0740N	0525E
41.	TVu-7264	Ex Ibadan Mkt			**87.**	TVu-9203	Atsegba No 3	0740N	0525E
42.	TVu-7265	Ex Ibadan Mkt			**88.**	TVu-9273	28 Km W. Omuo to Ikole	0740N	0530E
43.	TVu-7266	Ex Ibadan Mkt			**89.**	TVu-9294	Ex Ondo	0705N	0450E
44.	TVu-15546	IAR 48			**90.**	TVu-9332	Ado Ekiti No 1	0740N	0515E
45.	TVu-7810	Ewa Ex Afami			**91.**	TVu-9333	Ado Ekiti No 2	0740N	0515E
46.	TVu-7818	Ewa Ex Abeokuta Mkt			**92.**	TVu-9334	Ado Ekiti No 3	0740N	0515E

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Table 2. Seedling and flowering characteristics of cowpea accessions in humid ecology

sn	Accession	No Seedl Emerg	No Seedl Establ	No Days to flowering	Numb of flowers	sn	Accession	No Seedl Emerg	No Seedl Establ	No Days to flowering	Numb of flowers
1.	TVu-10859	9.4^{ab}	9.8^{a}	No flower	0^{d}	**47.**	TVu-7821	6.8^{c}	6.5^{cd}	No flower	0^{d}
2.	TVu-10864	10^{a}	10^{a}	No flower	0^{d}	**48.**	TVu-7823	9.1^{ab}	8.7^{bc}	40^{a}	16^{b}
3.	TVu-10983	10^{a}	10^{a}	42^{a}	24^{a}	**49.**	TVu-7833	5.6^{de}	5.2^{def}	40^{a}	16^{b}
4.	TVu-1130	6.9^{c}	6.2^{d}	44^{a}	26^{a}	**50.**	TVu-7834	5.4^{de}	5.2^{def}	No flower	0^{d}
5.	TVu-1131	9.4^{ab}	9.0^{bc}	40^{a}	18^{b}	**51.**	TVu-7852	3.8^{f}	2.6^{g}	No flower	0^{d}
6.	TVu-1132	8.8^{b}	7.5^{c}	43^{a}	22^{a}	**52**	TVu-7853	7.5^{bc}	6.6^{cd}	40^{a}	21^{ab}
7.	TVu-1260	7.5^{bc}	7.4^{c}	No flower	0^{d}	**53**	TVu-7855	8.8^{b}	8.1^{bc}	No flower	0^{d}
8.	TVu-13402	6.0^{cd}	6.0^{de}	No flower	0^{d}	**54**	TVu-7857	5.0^{def}	3.4^{f}	42^{a}	23^{a}
9.	TVu-1358	9.4^{ab}	9.0^{bc}	42^{a}	16^{b}	**55**	TVu-7858	6.4^{cd}	5.6^{de}	No flower	0^{d}
10.	TVu-1515	5.6^{de}	5.6^{de}	41^{a}	24^{a}	**56**	TVu-7871	9.4^{ab}	8.8^{bc}	No flower	0^{d}
11.	TVu-1516	8.1^{b}	7.5^{c}	38^{a}	18^{b}	**57**	TVu-7878	5.7^{cd}	5.0^{def}	44^{a}	20^{ab}
12.	TVu-1517	6.5^{cd}	6.5^{cd}	No flower	0^{d}	**58**	TVu-7887	8.0^{b}	6.4^{cd}	42^{a}	15^{b}
13.	TVu-15676	7.5^{bc}	7.5^{c}	No flower	0^{d}	**59**	TVu-7889	5.4^{de}	4.5^{ef}	No flower	0^{d}
14.	TVu-15687	5.6^{de}	5.0^{def}	40^{a}	14^{b}	**60**	TVu-7891	10^{a}	10^{a}	No flower	0^{d}
15.	TVu-16196	10^{a}	9.6^{ab}	44^{a}	17^{b}	**61**	TVu-7906	6.6^{cd}	5.6^{de}	40^{a}	16^{b}
16.	TVu-212	8.1^{b}	7.8^{bc}	No flower	0^{d}	**62**	TVu-7915	8.1^{b}	7.4^{c}	38^{a}	15^{b}
17.	TVu-213	7.0^{c}	7.0^{cd}	No flower	0^{d}	**63**	TVu-7916	8.0^{b}	7.3^{cd}	No flower	0^{d}
18.	TVu-214	8.8^{b}	8.0^{bc}	No flower	0^{d}	**64**	TVu-7917	6.9^{c}	6.1^{d}	No flower	0^{d}
19.	TVu-215	10^{a}	10^{a}	38^{a}	18^{b}	**65**	TVu-8084	7.5^{bc}	6.4^{cd}	No flower	0^{d}
20.	TVu-4041	8.8^{b}	8.6^{bc}	No flower	0^{d}	**66**	TVu-8177	4.6^{ef}	3.5^{f}	No flower	0^{d}
21.	TVu-4062	10^{a}	9.5^{ab}	No flower	0^{d}	**67**	TVu-8178	8.1^{b}	8.0^{bc}	40^{a}	14^{b}
22.	TVu-4063	6.9^{c}	6.2^{d}	No flower	0^{d}	**68**	TVu-8180	6.3^{cd}	5.4^{de}	No flower	0^{d}
23.	TVu-4064	7.5^{bc}	6.5^{cd}	No flower	0^{d}	**69**	TVu-8571	5.5^{de}	4.8^{ef}	No flower	0^{d}
24.	TVu-4065	8.1^{b}	7.5^{c}	38^{a}	22^{a}	**70**	TVu-8581	7.5^{bc}	7.3^{cd}	No flower	0^{d}
25.	TVu-4066	6.5^{cd}	5.0^{def}	No flower	0^{d}	**71**	TVu-8582	6.4^{cd}	6.2^{d}	No flower	0^{d}
26.	TVu-4067	8.0^{b}	7.6^{c}	No flower	0^{d}	**72**	TVu-8585	8.8^{b}	6.7^{cd}	42^{a}	6^{c}
27.	TVu-4068	10^{a}	9.3^{ab}	No flower	0^{d}	**73**	TVu-8586	7.0^{c}	6.6^{cd}	No flower	0^{d}
28.	TVu-4069	1.3^{g}	0.9^{h}	No flower	0^{d}	**74**	TVu-9146	8.3^{b}	6.9^{cd}	No flower	0^{d}
29.	TVu-4070	5.1^{de}	4.6^{ef}	No flower	0^{d}	**75**	TVu-9147	5.3^{de}	4.2^{ef}	No flower	0^{d}
30.	TVu-4071	6.0^{cd}	5.2^{def}	No flower	0^{d}	**76**	TVu-9154	6.9^{c}	6.6^{cd}	No flower	0^{d}
31.	TVu-4073	4.4^{ef}	3.7^{f}	No flower	0^{d}	**77**	TVu-9155	10^{a}	9.4^{ab}	No flower	0^{d}
32.	TVu-4074	9.6^{a}	9.1^{ab}	No flower	0^{d}	**78**	TVu-9156	5.7^{cd}	4.9^{def}	No flower	0^{d}
33.	TVu-4075	5.2^{de}	4.6^{ef}	No flower	0^{d}	**79**	TVu-9174	8.0^{b}	6.7^{cd}	No flower	0^{d}
34.	TVu-4076	3.1^{f}	2.1^{g}	No flower	0^{d}	**80**	TVu-9175	6.4^{cd}	5.8^{de}	No flower	0^{d}
35.	TVu-4078	4.4^{ef}	3.8^{f}	No flower	0^{d}	**81**	TVu-9176	6.5^{cd}	6.6^{cd}	No flower	0^{d}
36.	TVu-4085	7.5^{bc}	6.8^{cd}	No flower	0^{d}	**82**	TVu-9190	6.3^{cd}	5.4^{de}	No flower	0^{d}
37.	TVu-4468	6.8^{c}	5.6^{de}	No flower	0^{d}	**83**	TVu-9191	9.1^{ab}	8.5^{bc}	No flower	0^{d}
38.	TVu-527	4.4^{ef}	4.3^{ef}	No flower	0^{d}	**84**	TVu-9192	10^{a}	8.8^{bc}	No flower	0^{d}
39.	TVu-530	5.0^{def}	4.6^{ef}	No flower	0^{d}	**85**	TVu-9201	9.8^{a}	9.2^{ab}	No flower	0^{d}
40.	TVu-640	7.4^{bc}	7.2^{cd}	No flower	0^{d}	**86**	TVu-9202	9.3^{ab}	8.7^{bc}	40^{a}	6^{c}
41.	TVu-7264	5.2^{de}	5.0^{def}	No flower	0^{d}	**87**	TVu-9203	6.0^{cd}	5.6^{de}	No flower	0^{d}
42.	TVu-7265	6.4^{cd}	5.7^{de}	No flower	0^{d}	**88**	TVu-9273	7.0^{c}	5.4^{de}	No flower	0^{d}
43.	TVu-7266	7.5^{bc}	7.6^{c}	No flower	0^{d}	**89**	TVu-9294	6.2^{cd}	5.3^{de}	No flower	0^{d}
44.	TVu-75546	5.7^{cd}	5.1^{def}	No flower	0^{d}	**90**	TVu-9332	8.5^{b}	8.1^{bc}	No flower	0^{d}
45.	TVu-7810	4.4^{ef}	3.4^{f}	No flower	0^{d}	**91**	TVu-9333	6.5^{cd}	6.0^{de}	No flower	0^{d}
46.	TVu-7818	6.9^{c}	6.0^{de}	No flower	0^{d}	**92**	TVu-9334	6.9^{c}	6.5^{cd}	No flower	0^{d}

Key: [a] Means with the same letter under the same heading are not significantly different at 5 % probability level of DNMRT; No Seedl Emerg = Number of seedlings at emergence; No Seedl Establ = Number of seedlings at establishment

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Table 3. Yield characteristics of the cowpea accessions that flowered in humid tropical ecology

Sn	Accession	Pods per plant	Seeds per pod	Pod length (cm)	Grain Yield (Kg/ha)
3	TVu-10983	19.4[b]	10.8[c]	16.0[cd]	726.1[cd]
4	TVu-1130	24.3[a]	15.5[a]	18.3[b]	984.9[ab]
5	TVu-1131	21.0[ab]	10.5[cd]	12.8[ef]	1088.0[a]
6	TVu-1132	18.6[bc]	14.3[ab]	16.5[cd]	1093.9[a]
9	TVu-1358	21.3[ab]	10.9[c]	16.1[cd]	544.1[e]
10	TVu-1515	9.6[g]	13.1[ab]	11.8[f]	620.3[de]
11	TVu-1516	14.7[d]	9.2[cde]	12.5[ef]	857.6[b]
14	TVu-15687	16.4[bc]	10.2[cd]	18.7[b]	725.9[cd]
15	TVu-16196	12.4[ef]	13.5[ab]	18.1[bc]	892.4[b]
19	TVu-215	16.3[bc]	11.6[bc]	13.4[def]	1054.7[ab]
24	TVu-4065	15.4[cd]	8.6[de]	16.4[cd]	765.3[c]
48	TVu-7823	16.0[cd]	8.4[de]	21.0[ab]	581.6[e]
49	TVu-7833	19.5[ab]	7.5[e]	17.4[bc]	744.1[c]
52	TVu-7853	16.8[bc]	12.4[bc]	17.7[bc]	831.6[bc]
54	TVu-7857	18.9[bc]	13.0[abc]	19.1[ab]	656.8[de]
57	TVu-7878	19.5[ab]	8.4[de]	12.1[ef]	741.3[c]
58	TVu-7887	10.1[fg]	6.7[e]	10.5[f]	633.4[de]
61	TVu-7906	13.9[de]	10.2[cd]	14.2[de]	765.2[c]
62	TVu-7915	6.9[h]	8.1[de]	12.7[ef]	853.4[b]
67	TVu-8178	19.4[b]	10.4[cd]	14.1[de]	815.6[bc]
72	TVu-8585	14.7[d]	9.8[cd]	13.2[def]	713.4[cd]
86	TVu-9202	8.6[gh]	9.2[cde]	14.8[de]	682.4[d]

Key: [a] Means with the same letter under the same heading are not significantly different at 5 % probability level of DNMRT

Table 4. Eigen values of the principal components (PC) matrix for morphological characteristics of cowpea accessions in humid agro-ecology

PC	No Seedl Emerg	No Seedl Establ	Days to flowering	Num of flowers	Pods per plant	Seeds per pod	Pod length (cm)	Grain Yield (Kg/ha)	**Eigen value**	**% variance**
1.	0.0013	0.0012	0.0491	0.0216	0.0197	0.0130	0.0184	0.9981	120833	99.967
2.	-0.0552	-0.0619	0.7811	0.3514	0.3186	0.1579	0.3597	-0.0609	22.9212	0.0189
3.	0.6350	0.6681	0.2327	-0.2901	-0.0811	-0.0212	0.0707	-0.0063	6.66171	0.0055
4.	0.2343	0.2935	-0.4438	0.7150	0.3752	0.0968	-0.0235	-0.0025	5.16832	0.0043
5.	-0.0332	-0.0438	-0.1870	-0.4983	0.8177	-0.0859	0.1939	0.0015	3.00653	0.0025
6.	-0.0206	-0.0076	-0.3178	-0.047	-0.2803	0.2636	0.8650	0.0029	1.37261	0.0011
7.	0.0223	-0.0252	-0.0093	-0.1705	0.0590	0.9421	-0.2805	-0.0041	0.612805	0.0005
8.	0.7326	-0.6790	-0.0181	0.0306	0.0016	-0.0258	0.0149	0.0001	0.088783	0.00007
										99.99987

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Table 5. Pearson correlation matrix of morphological traits of cowpea in humid agro-ecology

	No Seedl Establ	Days to flowering	Num of flowers	Pods per plant	Seeds per pod	Pod length (cm)	Grain Yield (Kg/ha)
No Seedl Emerg	0.973*	0.230	0.186	0.210	0.226	0.219	0.251
No Seedl Establ		0.192	0.165	0.176	0.188	0.180	0.213
No Days to flowering			0.953	0.908	0.932	0.921	0.921*
Num of flowers				0.881**	0.905*	0.869	0.877*
Pods per plant					0.952**	0.959*	0.948**
Seeds per pod						0.968*	0.970**
Pod length (cm)							0.952*

Key: * and ** = significant at 5 % and 1 % level of probability respectively; No seedl Emerg = number of seedlings at emergence; No seedl Establ = number of seedlings at establishment; num of flowers = number of flowers per plant

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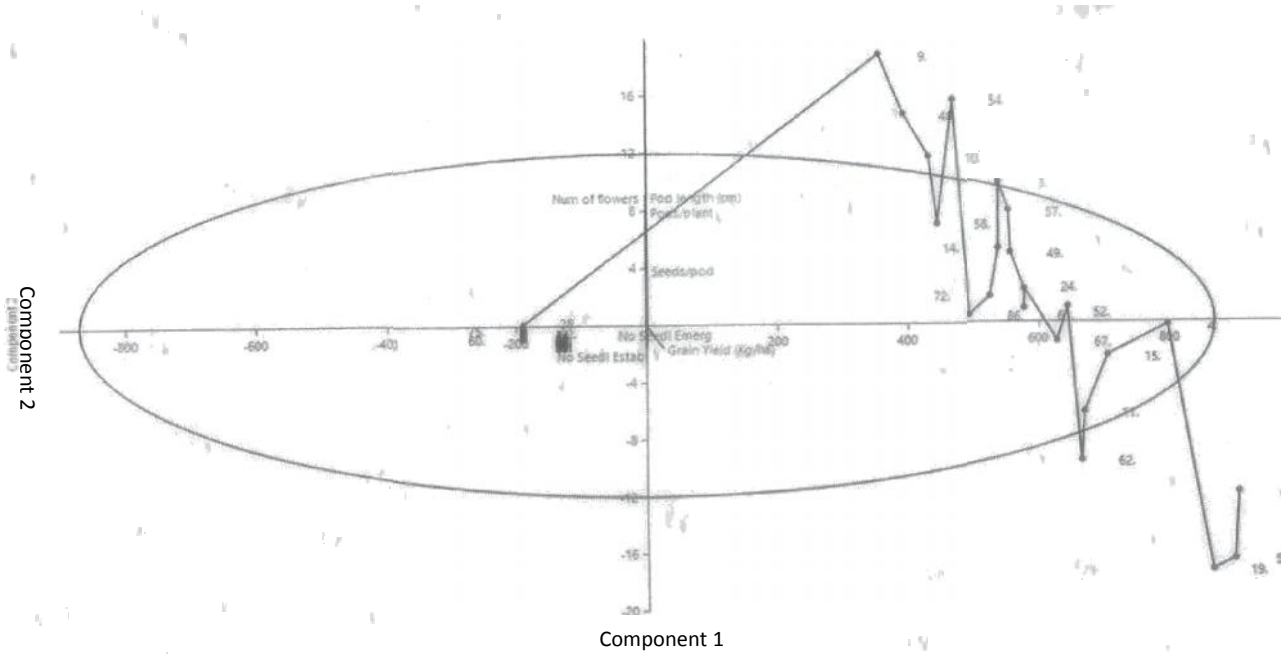

Figure 1. Scatter plot of the PCA showing 95 % ellipsis and minimum spanning tree

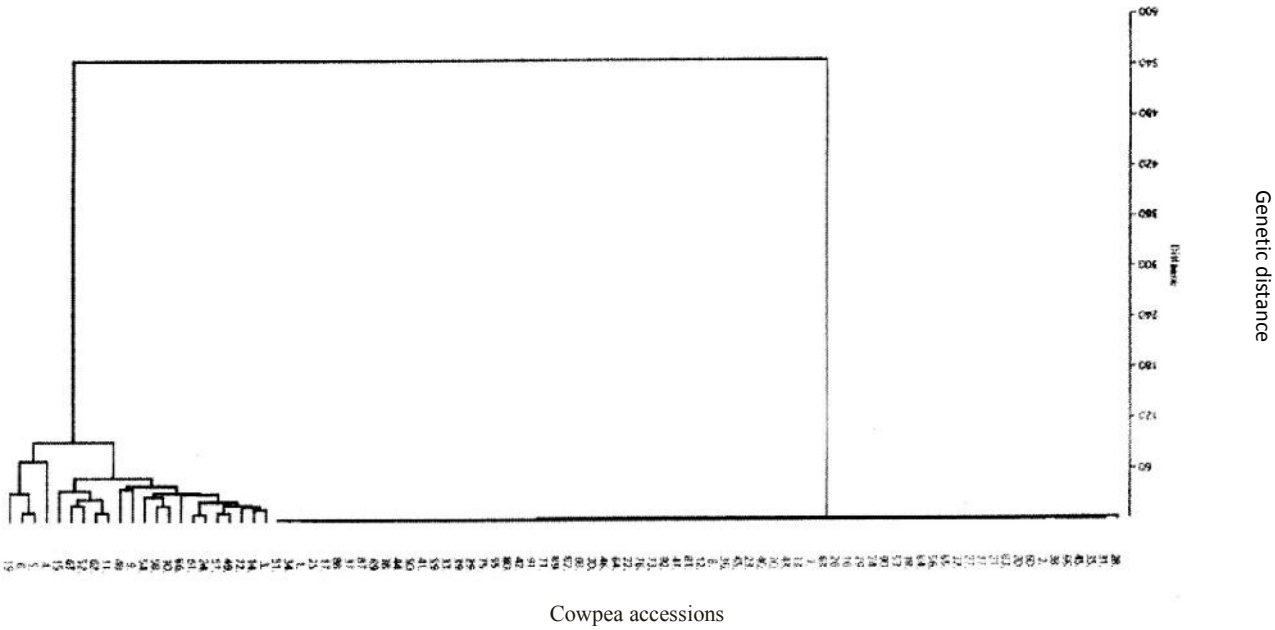

Figure 2. Dendrogram from single linkage cluster analysis (SLCA) of the cowpea accessions

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References

Amalu, U. C. (1998) Evaluation of properties of selected soils of Cross River area and their management for increased cassava yields. *Global Journal of Pure and Applied Sciences* 4: 243 – 249

Craufurd, P. Q., Summerfield, R. J., Ellis, R. H. And Roberts, E. H. (1997) Photoperiod, temperature on the growth and development of cowpea, pp 75 – 86. *In* Advances in cowpea research, by B. B. Singh, D. R. Mohan Raj, K. E. Dashiell and L. E. N. Jackai (eds). International Institute of Tropical Agriculture (IITA), Nigeria and Japan International Research Centre for Agricultural Sciences, Japan.

de Albuquerque, J. d'A., de Campos Oliva, L. S., Alves, J. M. A., Uchôa, S. C. P. and de Melo, D. A. (2015) Cultivation of cassava and cowpea in intercropping systems held in Roraima's savannah, Brazil. *Revista Ciência Agronômica*, 46: 388 – 395

Emechebe, A. M. and Shoyinka, S. A. (1985) Fungal and bacterial diseases of cowpea in Africa pp 173 – 192. In Cowpea Research, Production and Utilization. S. R. Singh and K. O. Rachie (eds) John Wiley and Sons UK.

FAO (1998) Food and Agriculture Organisation (FAO) statistics of food and agriculture, 53 pp.

GenStat (2005) GenStat 8.1 for PC per Windows Copyright 2005, Lawes Agricultural Trust, (Rothamsted Experimental Station) Registered to: TEAM TBE 2005-08-13

Hammer, O., Harper, D.A. T. and Ryan, P. D. (2001). PAST: Paleontological Statistic software package for education and data analysis. *Paleontologia Electronica* 4(1): 9 pp.

Idahosa, D.O, Alika J. E and Omoregie A. U. (2010) Genetic variability, heritability and expected genetic advance as indices for yield and yield components selection in cowpea (*Vigna unquiculata* (L) Walp). www.sceincepub.net/academia

UNDER PEER REVIEW

IITA (1988) IITA strategic plan 1989 – 2000. International Institute of Tropical Agriculture (IITA) Production, Ibadan, Nigeria. 108 pp.

Ittah, M. A., Binang, W. B., Shiyam, J O. and Idu, P O. (2016) Genetic and correlation analyses of the variation in yield traits in x-ray irradiated groundnut mutants. *SCIREA Journal of Agriculture* 1: 64 – 77

Jeffers, J. N. R. (1967). Two case studies in the application of principal component analysis. *Applied Statistics*, 16: 225-236.

Kaur, H.; Gangwar, M. and Kalia, A. (2015) Diversity of actinomycetes from fodder leguminous plants and their biocontrol potential. *International Journal of Advanced Research* 3: 1141 – 1151

Lambot, C. (2002) Industrial potential of cowpea, pp 367. In Challenges and opportunities for enhancing sustainable cowpea production. C. A. Fatokun, S. A. Tarawali, B. B. Singh, P. M. Kormawa and M. Tamo.IITA, Ibadan, Nigeria

Maji, A. T. and Shaibu, A. A. (2012) Application of principal component analysis for rice germplasm characterization and evaluation. *Journal of Plant Breeding and Crop Science*. 4: 87-93

Minchin, F. R., Engelsham, A. R. J. And Steward, K. A. (1978) Effects of short term water logging on growth and yield of cowpea (*Vigna unguiculata*) . *Journal of Agricultural Science* 90: 335 – 336.

NPC (1998) 1991population census of the Federal Republic of Nigeria: analytical report at the national Level. National Population Commission (NPC), Nigeria 455pp.

Ola, A.; Dodd, I. C. and Quinton, J. N. (2015) Can we manipulate root system architecture to control soil erosion? *Soil* 1: 603 – 612

UNDER PEER REVIEW

Oladejo, A. S., Toyinbo, J. O. and Obisesan, I. O. (2016) Principal components as measures of morphological and physiological descriptors of yield in cowpea (*Vigna unguiculata* L. Walp). *Nig. J. Genetics* 31: 65 – 73

Padulosi, S and Ng, N. Q. (1997) Origin, taxonomy and morphology of *Vigna unguilata* (L) Walp. *In* Advances in cowpea research by B. B. Singh, D. R. Mohan Raj, K. E. Dashiell and L. E. N. Jackai (eds). International Institute of Tropical Agriculture (IITA), Nigeria and Japan International Research Centre for Agricultural Sciences, Japan, pp 1 – 2

Porbeni, J. B. O., Olaolorun, B. M., Sansa, O. and Idehen, E. O. (2016) Digital imaging of pollen characteristics and estimating yield related components of some mutant cowpea (*Vigna unguiculata* (L) Walp) lines. *Nig. J. Genetics* 30: 52 – 59

Prakash, C. S. and Shivashanker, G. (1982) Evaluation of cowpea genotypes for resistance to bacterial blight. *Tropical Pest Management* 28: 131 – 135

Quin, F. M. (1997) Introduction pp ix – xv. In Advances in Cowpea Research. B. B. Singh, D. R. Mohan Raj, K. E. Dashiell and L. E. N. Jackai (eds). International Institute of Tropical Agriculture and Japan International Research Centre for Agricultural Sciences, Ibadan.

Singh, B. B., Chambliss, O. L., and Sharma, B. (1997). Recent advances in cowpea breeding, 30 - 49. *In* Advances in cowpea research, by B. B. Singh, D. R. Mohan Raj, K. E. Dashiell and L. E. N. Jackai (eds). International Institute of Tropical Agriculture (IITA), Nigeria and Japan International Research Centre for Agricultural Sciences, Japan.

Singh, S. R. And Jackai, L. E. N. (1985) Insect pests of cowpeas in Africa: their life cycle, economic importance and potential for control, pp 217 – 231. In Cowpea Research,

UNDER PEER REVIEW

Production and Utilization. S. R. Singh and K. O. Rachie. John Wiley and Sons Ltd, UK

Umar, M. L.; Sanusi, M. G. and Lawan, F. D. (2010) Relationships between some quantitative characters in selected cowpea germplasm (*Vigna unguiculata* L. (Walp) Muh. *Notulae Scientia Biologicae* 2: 125 – 128

Umoren, U. E. (1997) Proximate chemical and mineral composition of cowpea and *in vitro* protein digestibility of some *Vigna* varieties. *Global Journal of Pure and Applied Science* 3: 185 – 194

Wekundah, J. M. and Aghan, D. (2003) Biotechnology for food and Agriculture. Paper presented at Sullivan Summit, Abuja, Nigeria.