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Analyses of Genotypic Diversity and Adaptability of Cowpea to Humid Tropical Ecology

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAI conceived and designed the study and performed the statistical analysis. Authors WBB, JDN and JOS structured the agronomic framework and collected the data. Author MAI analyzed the study. Author WBB managed the literature searches. All authors read and approved the final manuscript.

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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 genotypes obtained from the International Institute of Tropical Agriculture (IITA), Nigeria were evaluated in Calabar (4° 57'N, 8° 19'E) in a randomised complete block design in three replications. All genotypes were collected in southern Nigeria between Latitude 05°05 and 08°30N, and Longitude 03°25 and 15°40E. Twenty-two of the 92 genotypes flowered and had grain yield; TVu-1131, TVu-1132 and TVu-215 had grain yield between 1054.7 and 1093.9 Kg ha^{-1}; 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 genotypes and attributed most of it to the diversity in grain yield and single linkage

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cluster analysis partitioned the genotypes into two groups based on their genetic relationship. There was positive 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 lead to improvement of the yield. For the adaptability, cowpea genotypes that are high yielding, photoperiod insensitive and early maturing are most suitable for the environment, in this study TVu-1131, TVu-1132, TVu-215 were identified as adaptable to the humid agro-ecology.

Keywords: Vigna unguiculata; humid ecology; crop adaptability; cowpea diversity; multivariate analysis.

1. 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 its 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 maturity; flowering within 48 days and reaching pod maturity by 60 days and it is highly digestible; it has high rates of nitrogen (N) fixation, high phosphorus (P) use efficiency and can reproduce itself by seed dispersal [1]. 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 [2]. Cowpea is very rich nutritionally; it has high digestible protein (15 to 26%); carbohydrate 55 – 66%; several minerals and vitamins [3], 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 [4], so N fixation of cowpea has the advantage of remediating this effect. Cowpea is easily adapted into farming systems, such as intercropping because it tolerates shades [5].

Cowpea is a tropical crop, originating from the sub-Saharan Africa [6]; 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 [7]. Since the crop is a warm-season legume, African countries produce about two thirds of the world cowpea; Nigeria and Niger Republic are the world's major producers, jointly producing 49% of the 1.32 million tonnes produced from Africa. The optimal conditions for cowpea production are rainfall between 280 and 4100 mm, annual temperature from 12.5 to 27.8°C, average day and night temperature of 28°C and 22°C respectively, and soil pH range of 4.3 to 7.9 [8].

There is hunger in Africa arising from inadequate food supply to meet the need of the people in the region; the sub-Saharan population rose from 200 million in the 1970s to 520 million in 2000 [9], and the current population estimated is about 1.2 billion [10]. While there was rapid growth in population, 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 [11]. 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 [12]. The solution to African food problem is to intensify cowpea production in all agro-ecologies [13], 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; 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 [14]. 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% [15]. There are also possibilities of infection from bacterial blight, pod rot disease, and infestation from nematodes and insects, such as aphids, pod borers and pod sucking bugs [16,17,18].

However, cowpea is a very resilient crop; [8] noted that specimens have been collected between latitude 40°N and 30°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 in 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.

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted in the University of Calabar Research Farm, Calabar. Calabar (4° 57'N, 8° 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°C with a minimum of 24°C in the mid-year, daily temperature ranges from 23 to 31.7°C. The soils around Calabar is acidic (pH 4.6 – 5.0), low in organic matter, with total nitrogen of 1.0 – 1.9 g kg^{-1}, available phosphorus of 5.8 – 11.9 m g kg^{-1}, exchangeable calcium of 0.4 – 2.8 cmol Kg^{-1} and exchangeable sodium of 0.2 – 0.4 cmol Kg^{-1} [19].

2.2 Experimentation

Nine – two cowpea genotypes (Table 1) were collected from the Genetic Resources Unit (GRU) of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The field was laid out in a randomized complete block design in three replications; the genotypes 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 characters was computed with the GenStat 8.1 package [20], significant differences between means were separated by using Duncan's New Multiple Range Test (DNMRT). The multivariate analyses were computed with Past 3 package [21]; principal components with eigen values greater than one were selected for analysis [22].

3. RESULTS AND DISCUSSION

All the 92 genotypes used in this study were collected by IITA in southern Nigeria, between Latitude 05°5 to 08°30 N and Longitude 03°25 to 15°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 genotypes in its germplasm bank [13]. The second level screening was based on flowering (Table 2) and yield characteristics (Table 3). Twenty two (22) genotypes flowered indicating that 70 genotypes tested would not have grain yield in the humid environment. Some varieties of cowpea are photo-sensitive, this is a very important physiological trait [23]; 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 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 genotypes, producing 1054.7 to 1093.9 Kg/ha, the lowest grain yield per hectare was 544.1 Kg/ha produced by TVu-1358. [24] obtained 590 to 851 Kg/ha and [25] 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.

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

sn	Line	Place of collection	Latitude	Long	sn	Line	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

sn	Line	Place of collection	Latitude	Long	sn	Line	Place of collection	Latitude	Long
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

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

sn	Line	No Seedl Emerg	No Seedl Establ	No Days to flowering	Numb of flowers	sn	Line	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}

sn	Line	No Seedl Emerg	No Seedl Establ	No Days to flowering	Numb of flowers	sn	Line	No Seedl Emerg	No Seedl Establ	No Days to flowering	Numb of flowers
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

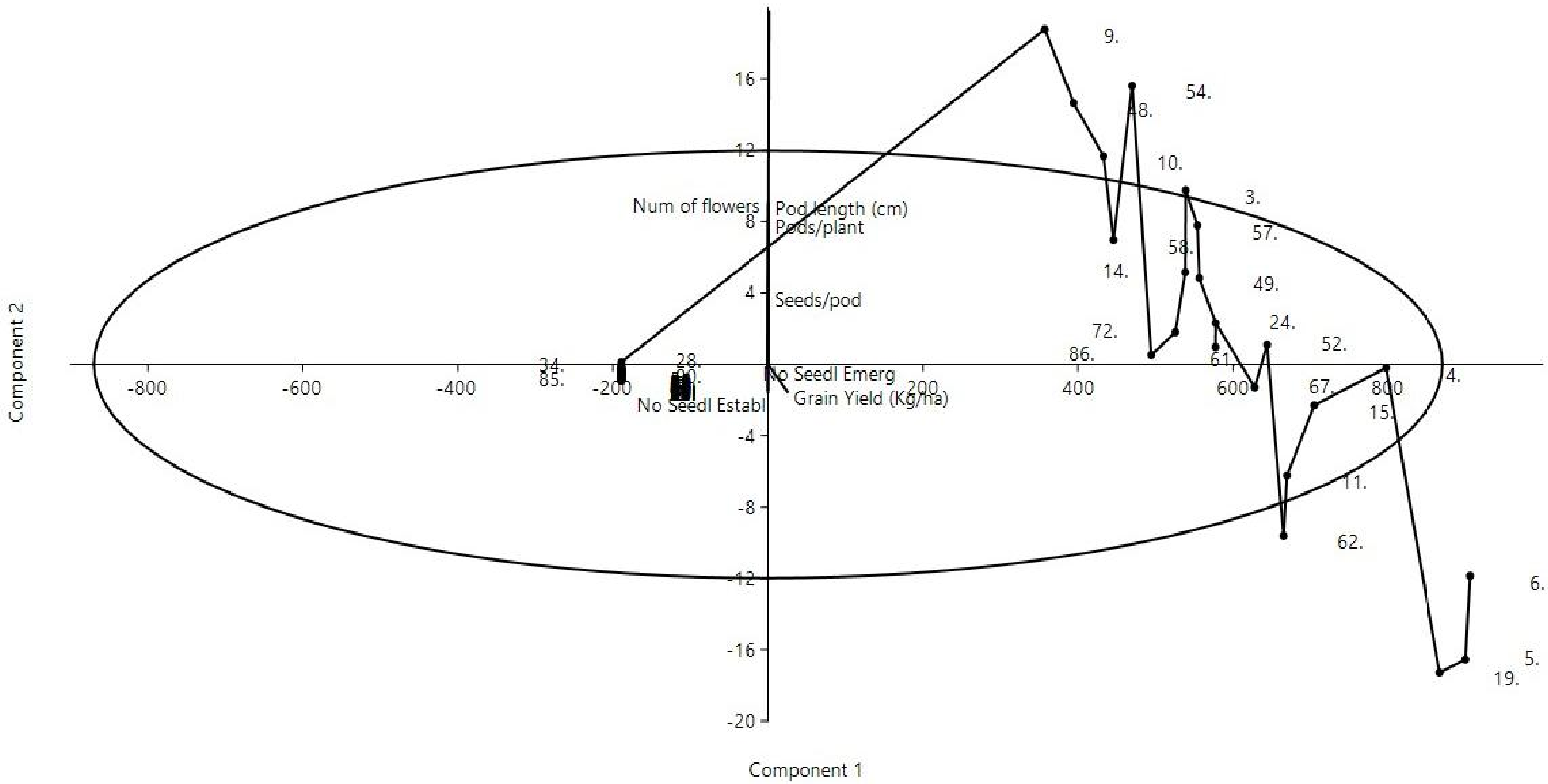

Fig. 1. Scatter plot of the PCA showing 95% ellipsis and minimum spanning tree

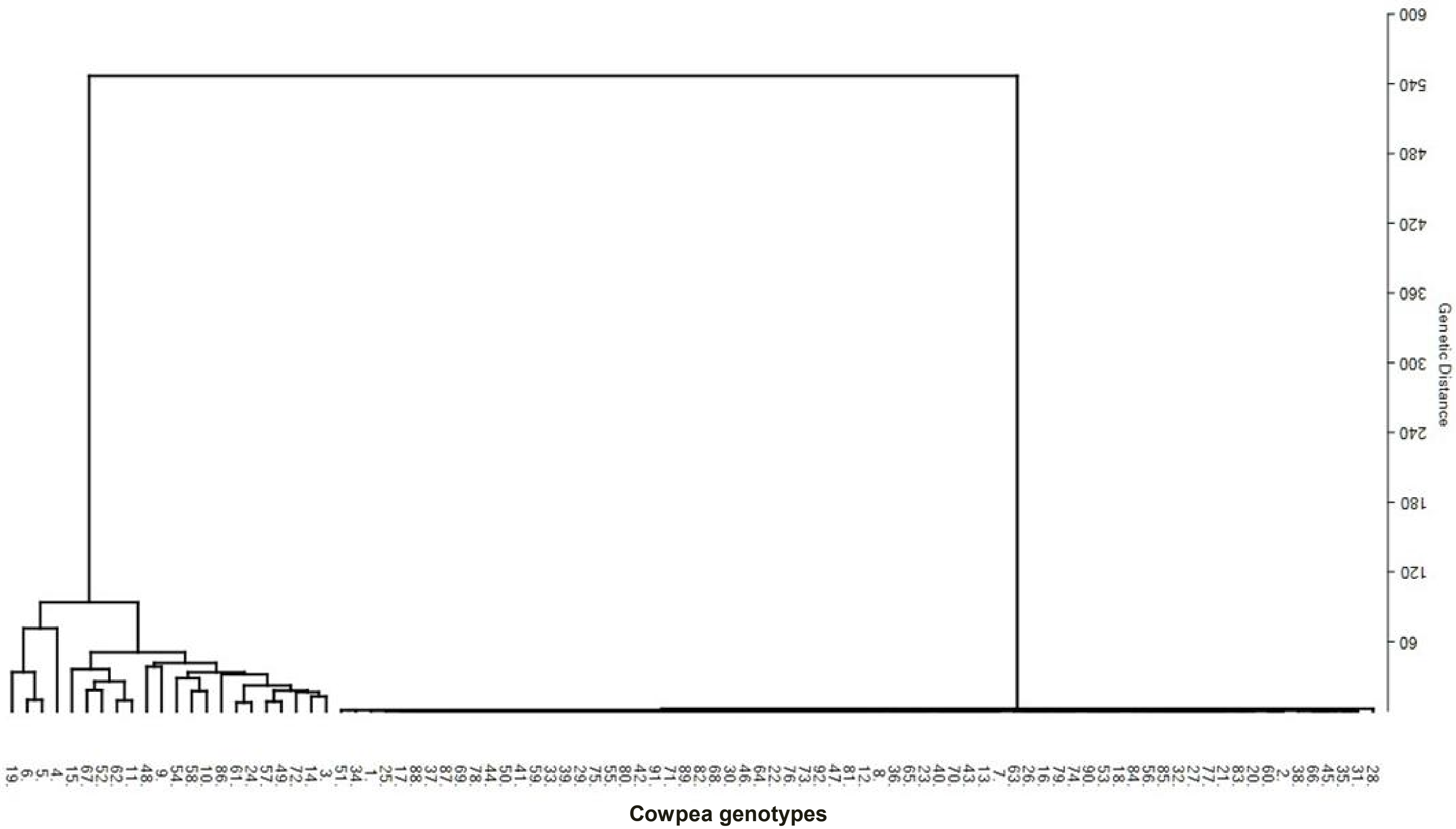

Fig. 2. Dendrogram from single linkage cluster analysis (SLCA) of the cowpea genotypes

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 genotypes 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 (Fig. 1) with 95% ellipses capturing 13 genotypes 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 genotypes was established by the single linkage cluster analysis (SLCA) presented in Fig. 2. Dendrogram was used to detect significant differences between genotypes and the magnitude of deviation among the genotypes. The diversity in the genotypes was partitioned into two major groups, with genetic distance divergence from 0.0 to 320 levels. At the minimum of 0.0 level of similarity, all genotypes were distinct but at the maximum level, all the genotypes were in a single cluster, which indicated that each line had resemblance in character with at least one other line suggesting close relationship.

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 had highly significant correlation with the number of seeds per pod and with the grain yield; the number of pods per plant also had significant correlation with the pod length. The pod length had significant association with the grain yield. Study by [26] reported a positive and significant relationship between grain yield and some pods characteristics, yield and number of days to flowering in groundnut. Characters that have significant and positive correlation can be improved concurrently in a breeding programme [27]; therefore, from this study, grain yield,

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

Sn	Line	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 genotypes 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

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*

number of pods per plant and number of seeds per pod can be improved together. Non significance in the association between some traits may imply lesser contribution to their mutual development or might be due to the effect of the environment on the breeding materials [28]. Therefore, cowpea genotypes 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.

4. CONCLUSION

Twenty two lines have been identified as adaptable to the humid tropical ecology, out of 92 genotypes evaluated in the environment. Of the 22 adaptable lines, TVu-16196, TVu-1131, TVu-1132 and TVu-215 are recommended for cultivation in the humid ecology due to their yield potential, which is similar to that obtained in other locations such as in western Nigeria.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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