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Variability, seasonal effects and principal component analysis of cowpea (*Vigna unguiculata*) genotypes in Uyo, Nigeria

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ABSTRACT: Field experiments were conducted in 2017 early and late cropping seasons at National Cereals Research Institute, Uyo Out Station, Owot Uta, Ibesikpo Asutan LGA of Akwa Ibom State to determine variability, seasonal effects and principal components of growth characters, yield and yield components of seven cowpea genotypes. The experiments were laid out in a randomized complete block design in four replications. Fourteen characters were studied namely; percentage establishment (%), plant height (cm), number of leaves, leaf area (cm^2), number of branches per plant, days to first flowering, days to 50% flowering, length of pods (cm), girth of pods (cm), number of pods per plant, number of seeds per pod, weight of pods (g), weight of 100 seeds (g) and seed yield (kg/ha). Significant differences ($p<0.05$) were observed among the cowpea genotypes in plant height, number of leaves, number of branches per plant, number of pods per plant, number of seeds per pod and seed yield (kg/ha). The cowpea genotypes IT89KD391B was superior in 5 characters, namely plants heights (cm), number of leaves, leaf area (cm^2), length of pods (cm), girth of pods and weight of 100 seeds, followed by Ife brown for days to first flowering, days to 50% flowering, number of pods per plant, number of seeds per pod and seed yield (kg/ha) while IT89KD260 recorded the highest percentage establishment and number of branches per plant. First 4PC with Eigen values greater than 1.0 jointly explained 89.3% of the total variations in the genotypes. Significant seasonal effects were observed on plant height, number of leaves, number of branches, number of pods, number of seeds per pod, and seed yield (kg/ha). The result identified late cropping season as the best season for cowpea production in Uyo, Southern Nigeria.

Keywords: Cowpea, principal component, seasons, yield.

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp) is an annual herbaceous and autogamous legume grown for vegetable and to lesser extent as fodder crops (Remison, 2012; Oyewale and Bamary, 2013). It is also grown extensively as one of the important food legumes in the lowlands and mid altitude regions of Africa particularly in the dry savanna (Uarrota, 2010). Despite its importance in human and livestock nutrition, cowpea produces averagely 500kg/ha in farmers' fields in Nigeria which is considered low and unprofitable (Adipala *et al*., 1997). It plays important role in the food and nutrition system of developing countries in the tropics and sub-tropics especially in sub-saharan Africa, Asia, Central and South America (Singh *et al.,* 1997).

Cowpea contributes significantly to household food security in West Africa. It forms a major staple in the diet of African and Asian continents (Awe, 2008). It has been referred to as "poor man meat" because of its high protein content of 20 to 25% (Sharma *et al*., 2013). According to Ileke *et al*. (2013) cowpea is the principal source of protein for rural and urban people. It complements protein in cereals and tuber crops and also satisfies the food needs of many people in the developing countries. Cowpea is considerably cheaper than rice. Its low production cost and good adaptation to rainfall pattern and the possibility of mechanized harvesting makes it an ideal food crop for Sub-Saharan Africa (Ayenlere *et al.,* 2012). It serves as cover crop and also improves soil fertility by fixing atmospheric nitrogen into the soil (Pungulant *et al*., 2012). Cowpea is an excellent crop for erosion control and weed suppression because of it long and wide tap root and good vegetative cover (Clark, 2007).

Nigeria produces nearly 5.2 million metric tonesof cowpea from estimated 4.5 million hectares annually, making it the largest producer in Africa and fourth largest producer in the world (FAO, 2017). Africa alone accounts for about 91 % of the global production; West Africa with 10.7 million hectares represents 75% of Africa's production (FAOSTAT, 2008). The principal cowpea producing countries are Nigeria, Niger, Brazil, Senegal, Mali, Burkina Faso and Ghana (FAOSTAT, 2017), with Nigeria, Niger and Mali leading the production in Africa (FAOSTAT, 2012). In Nigeria, the principal cowpea producing States include Bornu (445.77 million metric tonnes (mmt), Bauchi (224.48 mmt), Zamfara (160.08 mmt), Kano (98.90 mmt), Gombe (84.76 mmt), Katsina (69.03 mmt) and Yobe (56.51 mmt) (NAERLS and 2012). Low grain yield and fodder production from cowpea have been attributed to photo-sensitivity of the crop (Mukhtar and Singh, 2006; Uma and Kalubowila, 2010).

Selection of desirable parental genotypes with good agronomic traits under planned breeding programme requires knowledge of seasonal effect characters' association and principal component analysis (Uguru, 2005). Correlation study is important in selection programme when highly heritable characters are associated with yield. It is very good in quantifying the size and direction of trait associations. Principal component analysis is the excellent means of studying effects of interrelated components of complex traits. Correlation analysis shows the direct effect of one component with other ones on yield as well as the interrelationship among them (Bizeti *et al*., 2004).

Since yield is a quantitative trait that is a function of many characters, a simultaneous improvement of most yield characters is important. The purpose of the study is therefore to assess the variability, seasonal effects and principal components of cowpea genotypes in Uyo, southeastern Nigeria.

MATERIALS AND METHODS

Field experiments were sited at the National Cereals Research Institute, Uyo, Out-Station, Owot-Uta, Akwa Ibom State, Nigeria. The area lies within latitudes4°32' and 5°33' North and longitudes of 7°25' and 8°25' East (Ekpeh, 1994). The area lies within humid tropical rainforest zone of Southeastern Nigeria, with annual rainfall of 2000 to 3500 mm. The rainfall pattern is bimodal and the rain starts in March and ends in November, with a short period of relative moisture stress in August, normally referred to as August break (Peters *et al*., 1989). The average temperature is 28°C and highest in the month of February through March. The relative humidity ranges from 79 - 95% (lowest in January and highest in July) with evaporation rate of 2.6 cm^2.

Seven genotypes of cowpea with contrasting characteristics were used for the study namely, Ife brown, IT89KD260, RC-I38, IT89KD391B, Aloka (brown), Sampea-IV and IT97K4003. Three of them were obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria namely; IT89KD260, IT89KD391B and IT97K4003. The cowpea genotypes Sampea-IV and RCl-38 were obtained from the Institute for Agricultural Research (IAR), Samaru, Zaira, while Ife brown and Aloka (brown) were obtained from National Institute of Horticultural Research (NIHORT), Ibadan, Oyo State, Nigeria.

Experimental area measuring 30.0 m x 10.2 m was manually cleared with cutlass and tilled with the use of spade. The experiment was laid out in a Randomized complete block design with three replications. Seeds of the cowpea genotypes were sown 70 cm inter row and 30 cm intra row in a depth of 2 cm. Four seeds were sown and thinned to two plants per stand two weeks after sowing, giving a total of 24 plant per plot, equivalent to 42,833 plant per hectare. Weeds were controlled manually with the use of weeding hoe at two weeks after sowing and subsequently at 4 and 6 weeks after sowing.

Insect pests were controlled with the use of Cypermethrin EC at the rate of 5ml to 20 ml of water and sprayed fortnightly. Data were collected on plant establishment (%), plant height (cm), number of leaves, leaf area (cm^2), number of branches per plant, days to first flowering, days to 50% flowering, length of pods (cm), girth of pods (cm), number of pods per plant, number of seeds per pod, weight of pod per plant (g), dry weight of 100 seeds (g) and seed yield (kg/ha). Data from all the variables measured were subjected to analysis of variance (ANOVA) to estimate variability in morphological characters among the cowpea genotypes and the means separated with Duncan Multiple Range Test at 5% probability level using Genstat 2011 Software. The general linear model in SAS (SAS, 2016) used for determination of t-test of paired observation to compare the two seasons. Principal Component Analysis was determined using the procedure described by Wahua (1999).

RESULTS AND DISCUSSION

Variability and seasonal effect on morphological characters and yield of cowpea genotypes

Data on growth and yield of the cowpea genotypes is presented in Tables 1, 2, 3 and 4. The result showed significant differences ($p<0.05$) among the cowpea genotype s for most of the traits. However, no significant

Table 1. Percentage establishment, plant height, number of leaves, leaf area and number of branches of cowpea genotypes in 2017 early and late cropping seasons.

Genotypes	Plant establishment (%)		Plant height (cm) WAP		Number of Leaves WAP		Leaf area (cm^2) WAP		Number of branches per plant WAP	
	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Ife brown	95.66^c	96.00^{cd}	92.15^a	90.00^a	110.07^c	110.05^a	4374.50^b	4672.21^b	15.88^b	12.00^b
T89KD 260	98.50^a	99.00^a	89.65^a	70.73^b	97.56^b	100.30^b	3509.10^c	3998.23^c	18.00^a	15.00^a
IT89KD 391B	96.79^b	97.29^{abc}	98.50^a	92.24^a	115.50^a	71.44^c	4765.30^a	5653.04^a	15.50^b	13.00^b
Sampea IV	94.55^d	97.11^{bc}	74.60^c	63.00^b	52.70^d	55.24^d	1714.70^f	1928.22^e	11.18^c	9.03^c
Aloka (brown)	97.60^{ab}	98.00^{ab}	90.30^b	88.26^a	55.15^e	46.70^f	2534.10^d	1766.13^f	9.10^d	10.03^c
RCI- 38	93.55^e	93.11^e	56.17^e	51.27^c	47.11^f	50.91^e	1868.60^e	3225.18^d	8.50^e	5.40^e
IT97K4003	92.62^c	95.17^d	66.17^d	68.40^b	30.03^d	38.40^f	2787^d	3111.04^d	5.00^f	7.00^d

Means with different letters are significantly different at 5% probability.

Table 2. Phenological characters and yield components of cowpea genotypes in 2017 cropping seasons in Uyo, Nigeria.

Genotypes	DFF		D50F		L.P		G.P	
	Early	Late	Early	Late	Early	Late	Early	Late
Ife brown	63.00^a	57.00^a	69.50^a	64.00^a	12.58^c	13.10^c	1.05^a	1.00^a
IT89KD 260	57.00^b	54.00^b	63.50^b	60.20^b	13.09^c	13.23^c	0.78^c	0.66^c
IT89KD 391B	54.50^c	52.00^c	62.63^b	60.00^b	15.59^a	16.08^a	1.14^a	1.19^a
Sampea IV	50.00^d	48.00^d	56.51^c	55.03^c	14.76^{ab}	15.50^{ab}	0.90^b	0.80^b
Aloka (brown)	44.00^e	45.00^e	51.53^d	53.06^d	9.70^d	10.16^d	1.13^a	1.07^a
RCI- 38	43.50^e	42.00^f	50.50^d	50.16^e	13.73^{bc}	14.21^{bc}	0.75^c	0.70^{bc}
IT97K 4003	40.50^f	40.00^g	48.58^e	47.00^f	13.15^c	14.01^{bc}	0.73^c	0.76^{bc}

Means with different letters are significantly different at 5% probability level. DFF = Days to First Flowering, D50F = Days to 50% Flowering, LP = Length of Pods, GP = Girth of Pods.

Table 3. Number of pods per plant, number of seeds per pod and weight of pods (g) in early and late cropping seasons in Uyo, Nigeria.

Genotypes	No. of Pods/ Plant		No. of Seeds/ Pod		Weight of Pods (g)	
	Early	Late	Early	Late	Early	Late
Sampea IV	10.10^d	14.10^d	13.93^{bc}	13.86^b	13.15^e	13.20^c
IT89KD 391B	13.58^c	16.16^d	14.58^b	14.00^{ab}	12.60^d	14.20^e
RCI-38	13.56^c	18.13^c	10.11^d	10.23^c	13.67^{cd}	14.80^{bc}
IT97K 4003	10.06^d	13.13^e	9.52^{de}	10.05^{cd}	13.25^{cd}	13.30^{cd}
IT89KD 260	10.03^e	15.06^d	12.05^c	12.10^{bc}	15.71^b	16.20^b
Ife brown	19.10^a	22.20^a	11.58^{cd}	12.16^{bc}	14.63^{bc}	15.10^{bc}
Aloka (brown)	17.00^b	20.00^b	15.59^a	14.20^a	20.15^a	20.50^a

Means with different letters are significantly different at 5% probability. N.P = Number of pods per plant, NS = Number of seeds per pod, WP = Weight of pods.

differences ($p<0.05$) were observed among cowpea genotypes for both seasons in percentage establishment, leaf area (cm^2), days to first flowering, days of 50% flowering, length of pods, girth of pods, weight of pods and 100 seed weight (Table 5). The cowpea genotype, IT89KD391B showed superior performance over other genotypes in 5 characters namely plant height (98.50 cm), number of leaves (115.50 cm), leaf area (5653.04 cm^2), length of pods (15.59 cm) and girth of pods (16.08 cm), followed by Ife brown for 4 characters namely; days to first flowering (63.00), days to 50% flowering (69.50), number of pods per plant (22.20) and seed yield (kg/h) (1175.94)

Table 4. Weight of 100 seeds and seed yield of cowpea genotypes in early and late cropping seasons.

Cowpea genotypes	W100S		Sy (kg/h)	
	Early	Late	Early	Late
IT89KD 391B	37.10^{a}	36.20^{a}	578.72^{c}	1065.20^{cd}
Aloka (brown)	16.15^{b}	20.20^{b}	840.59^{a}	1169.70^{b}
IT89KD 260	15.60^{b}	16.20^{c}	703.12^{bc}	1030.74^{d}
Ife brown	11.10^{b}	15.10^{cd}	850.23^{a}	1178.74^{a}
RCI-38	15.12^{b}	14.10^{de}	774.17^{b}	1072.90^{c}
IT97K 4003	13.68^{c}	13.30^{e}	426.39^{d}	660.57^{e}
Sampea IV	13.58^{c}	14.08^{de}	433.99^{e}	658.43^{e}

Means with different letters are significantly different at 5% probability level. W100S = Weight of 100 seeds, Sy/kg/ha = Seed yield in kilogram per hectare.

Table 5. Comparative performance of cowpea genotypes in 2017 and 2018 early and late planting seasons.

Plant character	t-cal
Plant establishment	**0.0205^{ns}**
Plant heights	4.1724*
Number of leaves	2.9287*
Leaf of areas	0.6058^{ns}
Number of branches	2.2250*
Days to first flowering	0.1106^{ns}
Days to 50% flowering	0.1299^{ns}
Length of pods	0.0926^{ns}
Girth of pods	0.0698^{ns}
Number of pods	**3.265***
Number of seeds/pods	3.573*
Weight of pods	**0.0254^{ns}**
100 seed weight	0.2322^{ns}
Seed yield	**3.821***

t-tab ($p < 0.05$) = 2.0211.

while Aloka brown had 3 characters namely, percentage establishment, number of seed pods (15.59) and weight of pods (kg) (20.50). In the early cropping season, IT89KD391B (96.50 cm) produced the tallest plants while RCI-38 (56.17 cm) gave the shortest plants. A similar observation by Agbogidi and Ofuoku (2005) indicated that plant respond differently to environmental factors based on their genetic make up and adaptation. The performance of cowpea genotypes increased in late cropping season. The highest number of leaves was obtained from IT89KD391B (115.50 cm) which was significantly (p<0.05) higher than the other genotypes for the character. The least number of leaves was given by Sampea (IV) (38.40) for both seasons. IT89KD391B produced the largest (5653.04 cm^2) while Aloka (brown) gave the smallest leaf area (1766.13cm^2) in both seasons. The result agrees with Wannows *et al*. (2010) that high yield potential in maize is associated with and caused by the development of a high leaf area. In turn, those leaves which persisted until the grain filling stage, together with other green surface, provided the photosynthetic capacity for carbon fixation and hence, the supply of carbohydrate to the grains. However, crop photosynthesis is a function of leaf area and the rate of photosynthesis per unit leaf area. The highest number of branches per plant was recorded by IT89KD260 (18.00) while the least was given by IT97K4003 (5.00) in the early cropping season. But in the late cropping season IT89KD260 (16.00) recorded the highest number of branches per plant while RCI-38 (5.40) gave the least values. Asuquo (2002) attributed branching propensities entirely to plant culture without mentioning the genetic factors.

Days to first flowering among cowpea genotypes were significantly different (p<0.05) among themselves. The highest number of days to first flowering was observed in Ife (brown) (63.0) while the shortest number of days to first flowering (40.0) was given by IT97K4003. Similarly, days to 50% flowering varied significantly among the genotypes. The highest being recorded by Aloka brown (69.50) while the lowest number of days to 50% flowering was given by IT97K4003 (47 days) in both seasons. A breeder prefers shorter days to first flowering as this will encourage early flowering and maturity of the cowpea genotypes (Nausherwan *et al*. 2007).

Similarly, length of pods differed significantly (p<0.05) among the cowpea genotypes, IT89KD391B (16.08 cm) produced the longest pods which were significantly higher than other genotypes while the shortest pods was given by Aloka brown (9.70 cm) in both seasons. Also, IT89KD391B produced the largest pod girth while IT89KD260 (0.66 cm) gave the least pod girth for both seasons. The result revealed that Ife brown recorded the highest number of pods per plant (22.20) while Sampea (iv) produced the lowest number of pods per plant (10.10) in both seasons. Number of seeds per pod also varied among the cowpea genotypes, the highest number of seeds per pod was obtained from Ife brown (15.58), followed by IT89KD391B (14.58) and Sampea IV with 13.93 while IT97K4003 (9.57) produced the least number of seeds per pod in both seasons. The result for dry weight of pods per plant showed that Aloka brown produced the highest weight of pods (20.20g), followed by IT89KD260 (15.60 g) while

Table 6. Principal Component Analysis (PCA) of late planting season.

Plant Characters	P1	P2	P3	P4
Percentage establishment	0.4136	0.7894	-0.2893	-0.2537
plant height (12 weeks)	0.8144	0.4040	-0.0345	-0.3972
Number of leaf (12wks)	0.8926	-0.3023	-0.1456	-0.0882
leaf are (12wks)	0.7795	-0.3466	-0.1952	0.1408
Number of branches (12wks)	0.6405	0.6984	-0.1878	-0.1770
Days to 50% flowering	0.5355	-0.7485	0.2587	-0.2580
Days to flowering	0.4357	-0.8143	0.2314	-0.2742
Girth of Pods	0.7453	-0.0140	0.3090	-0.1507
Length of pods	0.0379	-0.2099	-0.7531	0.6165
Number of pods per plant	0.0133	0.8241	0.2538	0.0273
Number of seeds/pod	0.6228	-0.0129	-0.5176	-0.1704
Weight of pods	0.8481	0.1170	0.1230	0.4594
Weight of 100 seeds	0.7197	0.0141	0.1357	0.6383
Seed yield (Kg/ha)	0.2946	0.3359	0.7678	0.3869
Eigenvalue	5.3947	3.5593	1.9179	1.6235
Variability (%)	38.5337	25.4236	13.6990	11.5962
Cumulative %	38.5337	63.9573	77.6562	89.2524

IT89KD391B (12.20 g) had the lowest weight of pods for both seasons. Weight of 100 seeds differed significantly ($p<0.05$) among the cowpea genotypes, IT89KD391B (37.10 g) had the highest weight of 100 seeds, followed by Aloka brown (20.20 g) while IT89KD260 had the lowest (15.60 g). Ife brown produced the lowest 100 seeds weight (11.10 g) for both seasons. The highest seed yield (kg/ha) of cowpea was obtained from Ife brown (1178.28 kg/ha), followed by Aloka (brown) with (1169.70 kg/ha), while RCI-38 recorded (1072.90 kg/ha). The lowest seed yield of 426.39 kg/ha was given by IT97K4003.

However, the performance of cowpea genotypes in the two cropping seasons (early and late) differed significantly ($p<0.05$) in six characters namely; plant height, number of leaves, number of branches per plant, number of pods per plant, number of seeds per pod and seed yield (kg/ha). No significant differences ($p<0.05$) were observed in eight characters namely; percentage establishment, leaf area, days to first flowering, days to 50% flowering, length of pods, girth of pods, weight of pods and weight of 100 seeds (Table 5).

Sharma (1996) noted that variability among species is a prerequisite, particularly at the evaluation stage for a breeding programme to succeed. According to Adeniji and Kehinde (2003), information on genetic variation of different characters in a crop could help to identify useful genes necessary for hybridization. Osekita *et al*. (2000) asserted that once genetic variability has been ascertained in a population, improvement is possible by using appropriate selection methods. Based on the result, incorporation of the three cowpea genotypes (Ife brown, IT89KD39IB and Aloka (brown) into hybridization programme could improve seed yield (kg/ha) and other agronomically desirable characters. This in turn could improve the economic wellbeing of cowpea farmers.

In order to improve complex character like yield, it is essential to have comprehensive knowledge of principal components of the genotypes. Complex character like yield is greatly influenced by environment. Correlation studies indicate a true picture of association between pair of characters. Principal component can assist cowpea breeders to determine the nature and magnitude of association between traits for achievement of high seed yield in cowpea. Significant and positive correlation coefficients found between seed yield and it components constitute desirable attributes that may contribute significantly to seed yield.

Principal component analysis on morphological and yield components of parental cowpea genotypes

The principal component analysis revealed that the first, second, third and fourth components accounted for 38.53, 25.42, 13.69 and 11.59% respectively of the total variation. The eigenvectors presented in Table 6 revealed on principal component 1, showed that number of leaves contributed the highest load of 0.8926, followed by weight of pods (0.8481), plant height (0.8144), leaf area (0.7795), girth of pods (0.7453) and weight of 100 seeds (0.7197), respectively for the variation among the genotypes. For the principal components 2, number of pods per plant contributed the highest load of 0.8241 followed by percentage establishment (0.7894), number of branches per plant (0.6984), plant height (0.4040) and seed yield (kg/ha) (0.3359) respectively for the total variation among the cowpea genotypes. For the principal component 3, seed yield (kg/ha) contributed the highest load of 0.7670,

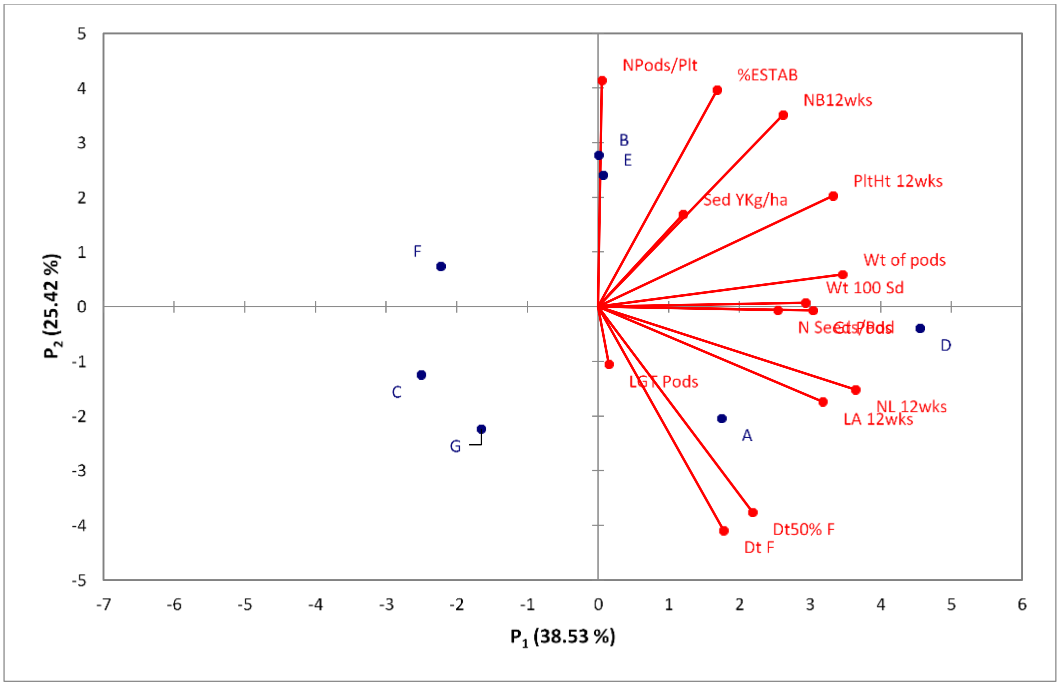

Figure 1. Biplot (Axes P_1 and P_2: 63.96%).

followed by girth of pods (0.3090), days to first flowering (0.2587) and number of pods per plant (0.2538), respectively for the total variation among the cowpea genotypes. For the principal component 4, weight of 100 seeds contributed the highest load of 0.683, followed by length of pods (0.6165), weight of pods (0.4594) and seed yield (kg/ha) (0.3869), respectively for the total variation among the cowpea genotypes.

GGE biplot analysis (Figure 1) showed that genotype x season interaction was responsible for the greater variation (63.96%) due to genotypes, season and genotype x season interaction. First 4PC with Eigen values greater than 1.0 jointly explained 89.25% of the total variation in the genotypes. PC1 with the Eigenvalue of 5.39 contributed 38.53% of the total variation. PC2 with the Eigenvalue of 3.55 contributed 25.42% of the total variation. PC3 with the Eigenvalue of 1.99 contributed 13.69% of the total variations while P_{C4} with the Eigenvalue of 1.62 contributed 11.59% of the total variation (Table 6) observed among the seven cowpea genotypes in Uyo, Akwa Ibom State.

Conclusion

This study identified IT89KD391B, Ife brown and Aloka brown as the most high yielding cowpea genotypes in the environment. Based on the result ife brown could be recommended to farmers in southeastern Nigeria. Observed variability in many characters in PC1, PC2, PC3 and PC4 affirms the need for crossing of high yielding genotypes for the development of hybrid varieties for the area.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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