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Agronomic evaluation of cowpea cultivars developed for the West African Savannas

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ABSTRACT

The goal of this research was to evaluate diverse cowpea genotypes developed over the past 4 decades in the Nigerian Sudan Savannas for their agronomic performance and to identify groups of cultivars with similar quantitative characters. Characterization would facilitate the efficient synthesis of breeding populations for further improvement of cowpea. Also superior genotypes with desirable characteristics could be identified and disseminated in the dry savannas of West Africa. Significant variations were observed in the agronomic characteristics of the cultivars in this study. Principal component analysis (PCA) and cluster analysis were performed on these genotypes and found that there were significant correlations among the variables measured. Modern cultivars outperformed the older ones and from the results of PCA, it was found that the most important variables for the classification of cowpea cultivars are high canopy, high seed weight, high total dry matter, high HI, and high grain and fodder yield. This suggests that these traits could be used in selection index for genetic improvement of cowpea. Cluster analysis resulted in 5 groups mostly corresponding to era of release except cluster I which contained cowpea cultivars from all eras. Two distinct groups in clusters IV and V were identified. Cultivars in cluster IV which were released in the 1990-2000 eras, had high grain and fodder yield. These cultivars could be evaluated on-farm for eventual release to farmers. They could also be used in breeding program for improvements in grain and fodder yield of cowpea. Cluster V contained two cultivars that distinctly had the highest fodder yield suggesting that they could be used to improve fodder yield of cowpea.

Key words: Cluster analysis, Cowpea, Fodder yield, Grain yield, PCA.

INTRODUCTION

Cowpea *[Vigna unguiculata* (L.) *Walp.]* is an important food legume and an integral part of traditional cropping systems in the semi-arid regions of the tropics (Singh *et al*., 2003). It is used for human consumption and animal feed and also it improves soil fertility when grown, thus it has become very valuable in areas where land use has become intensified. Cowpea has outstanding features: *viz.,* drought tolerance, shade tolerance, quick growth, and rapid provision of ground cover (Singh *et al*., 1997). These characteristics have made cowpea an important component of subsistence agriculture in the dry savannas of the sub-Saharan Africa where it is grown as a companion crop with cereals and other food crops (Singh *et al*., 2003). According to FAO statistics, cowpea is grown on an estimated worldwide area of 14 million ha. However, the bulk of cowpea production comes from the drier regions of northern Nigeria (5 million ha and 2.3 million tons), Niger Republic (3 million ha and 0.4 million tons) and North East Brazil (about 1.9 million ha and 0.7 million tons) (Singh 2000). In(about 1.9 million ha and 0.7 million tons) (Singh 2000). In spite of its importance and wide cultivation, the overall productivity of cowpea is very low with average yield particularly in Africa ranging from 100 to 400 kg ha^{-1}. This is due to several biotic, abiotic and physiological constraints.

Over the years, a great deal of progress has been made by IITA in breeding a range of high yielding cowpea varieties with combined resistance to major diseases, insect pests, and parasitic weeds and also varieties with drought tolerance. Previously, from 1970 to 1988, cowpea research at the IITA was concentrated primarily on developing and distributing grain type cowpea varieties, which have been tested and released in many countries (Singh *et al*., 1997). Because of the importance of cowpea grain and fodder in West Africa, IITA began a systematic breeding program in 1989 to develop dual-purpose cowpea varieties (Singh *et al*., 2003). This program combined breeding for high yield potential for grain as well as fodder with resistance to major biotic and abiotic stresses. The general strategy is to develop a range of cowpea varieties differing in growth habit and maturity, seed type and for sole crop and intercrop in different

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agro-ecologies (Singh *et al*., 2003). Extreme cowpea genotypes have been observed with respect to many traits and genetic studies have identified several desirable genes which control plant pigmentation, plant type, plant height, leaf type, growth habit, photosensitivity and maturity, nitrogen fixation, fodder quality, heat and drought tolerances, root architecture, resistance to major bacterial, fungal and viral diseases, resistance to root knot nematodes, resistance to aphid, bruchid and thrips, and resistance to parasitic weeds such as *Striga gesnerioides* and *Alectra vogelii.* And also genotypes with good pod traits, seed traits and grain quality (Fery and Singh, 1997; Singh, 2002) were identified. Since 1970, several cowpea lines have been developed and distributed to partnership institutions in Nigeria and over 60 other countries all over the world for evaluation and release (Singh *et al*., 2000).

Kamara *et al*. (2011) showed genetic gain of 3.6% in grain yield of cowpea varieties developed from 1970-2004. Yield increases were largely associated with increased harvest index, dry matter and fodder yield. Although a large number of cowpea genotypes have been developed, genetic relationship among these genotypes based on agronomic characters has not been measured. Genetic relationships among individuals and populations can be measured by similarity of any number of quantitative characters, where characters are agronomic parameters of the plant such as duration of growth stage, grain yield, or inflorescence size (Souza and Sorrells, 1991). This assumes that the differences between characters of the genotypes reflect the genetic divergence of the genotypes. Genetic relationships among a large number of cultivars can be summarized using cluster analysis to place similar genotypes into phonetic groups (Souza and Sorrells, 1991). Multivariate analysis of quantitative characters has been used previously to measure genetic relationships within crop species. Examples include barley (*Hordeum vulgate* L.); (Bekele, 1984), Ethiopian wheats (*Triticum aestivum* L.); (Negassa, 1986),durum wheats (*Triticum turgidum* L.); (Jain *et al*.,1975), and rice (*Oryza sativa* L.); (Kanwal *et al*., 1983).

Genetic distance also has been used as an index for parental selection (Souza and Sorrells, 1991). Grafius (1956) first suggested model for prediction of progeny performance based on differences between parents for yield components. The greater the difference between parents in individual components of yield, the greater is the progeny variance. Shamsuddin (1985) reported that genetic distance between spring wheat parents could predict parental specific combining ability in F1 progeny. In oat (*Avena spp*.), two studies have measured genetic relationships among genotypes based on quantitative characters. Sidhu and Mehndiratta (1981) grouped 37 improved and traditional fodder oat cultivars from growing regions around the world into groups of similar quantitative characters. They observed significant agronomic divergence among high yielding fodder oat cultivars and suggested that improvements for yield could be obtained by crossing between clusters of oat cultivars. Cluster analysis of 70 North American oat germplasm produced 4 large groups that generally corresponded to latitude of origin or adaptation with significant variation between characters (Souza and Sorrells, 1991). The goal of this research was to evaluate diverse cowpea genotypes developed over the past 4 decades in the Nigerian Sudan Savannas for their agronomic performance and to identify groups of cultivars with similar quantitative characters. Characterization would facilitate the efficient synthesis of breeding populations for further improvement of cowpea. Also superior genotypes with desirable characteristics could be identified and disseminated in the dry savannas of West Africa.

MATERIALS AND METHODS

Agronomic evaluation: Thirty-one medium-late maturing diverse cowpea genotypes (Table 2) representing cowpea varieties developed for the Nigerian Sudan savannas from 1970 to 2004 were evaluated in this study. For convenience, all cultivars, plant introductions, released varieties, and advanced breeding lines used in this research will be referred to simply as cultivars. These were best performing cultivars selected to represent each decade. The field experiments were conducted under rain-fed conditions in 2007 and 2008 at IITA experimental station at Minjibir (12o 10'42N, 8o 39' 33E, Alt. 453m) in the Sudan savanna of northwest Nigeria.

In both years, the trial was laid out in randomized complete block design with four replications. For all treatments, prior to planting, each field was disc-harrowed and ridged. The planting distance was 0.75 m between rows and 0.25 m between plants. Three seeds of the cowpea varieties were sown and later thinned to two plants stand-1 at two weeks after planting. Immediately after planting, paraquat (1:1-dimethyl- 4, 4'-bipyridinium dichloride) was applied at the rate of 276 g a.i. L^{-1} to control weeds. This was followed by hoe weeding three weeks later. Fertilizer at 15 kg each of N, P and K was applied in the form of NPK 15:15:15 a week after planting. A standard formulation, cypermethrin + dimethoate (Best Action) at the rate of 30 g +250 g a.i. L^{-1} was used to control insect pests at flower bud formation, flowering and podding stages to control insect pests and this was delivered with a knapsack sprayer.

Data were collected on days from sowing to when 50% of the number of plants per net plot reached flowering and to when 95% of the pods reached maturity. Mean number of pods per plant, and total dry matter (leaf, stem, grain and threshed pod) per plant were all taken from a 10-plant sample within the two central rows for each plot when the crop reached physiological maturity. Harvest index was calculated by dividing grain weight per plant by total dry matter per plant. Mean hundred seed weight was recorded for each plot.

Grain yields were determined from all plants harvested from two net 4-m-long central rows when the first flush of pods was mature and dry, and was reported on a 100% dry matter basis in kg ha-1. Similarly, fodder yield was based on all plants that were harvested from the two net central rows for each plot, sun dried to constant weight and calculated as kg $ha^{-1.}$

Data analysis: Data were analysed using the following steps, (i) variance analysis, (ii) estimation of trait means for each cultivar, (iii) derivation of orthogonal, uncorrelated

Table 1: Rainfall and temperature at Minjibir during the trial period

	2007				2008			
Month	Rainfall		Temperature		Rainfall		Temperature	
	(mm)	(Frequency)	oC (max)	oC (min)	(mm)	(Frequency)	oC (max)	oC (min)
JAN	0	0	25.53	15.06	0	0	26.44	16.02
FEB	0	0	34.21	23.36	0	0	28.74	17.71
MAR	0	0	34.58	22.03	0	0	36.08	21.89
APR	0	0	40.00	25.57	0	0	37.63	26.43
MAY	67.5	3	35.8	26.56	0	0	38.69	28.19
JUN	162.6	8	30.62	23.73	102.5	7	36.38	26.45
JUL	249.2	10	31.48	23.44	313.9	10	29.97	23.18
AUG	376	12	28.74	23.05	209.1	12	28.71	22.45
SEP	9.1	1	30.97	23.17	68.3	12	29.8	23.82
OCT	0	0	31.03	24.29	0	0	41.31	22.99
NOV	0	0	33.03	23.72	0	0	32.03	23.03
DEC	0	0	33.17	21.35	0	0	30.68	21.77
Total	864.4				693.8			

Table 2: Cowpea varieties used for the classification

Varieties	Growth habit	Year tested
IT00K-1207	Semi-determinate	2000
IT00K-1263	Determinate	2000
IT00K-227-4	Determinate	2000
IT03K-316-1	Determinate	2003
IT03K-351-9	Semi-determinate	2003
IT04K-217-5	Semi-determinate	2004
IT04K-223-1	Semi-determinate	2004
IT04K-321-2	Semi-determinate	2004
IT04K-332-1	Determinate	2004
IT81D-985	Spreading	1981
IT81D-994	Semi-determinate	1981
IT82D-889	Determinate	1982
IT84S-2246-4	Semi-determinate	1984
IT86D-1010	Determinate	1986
IT86D-719	determinate	1986
IT86D-721	Determinate	1986
IT87D-941-1	Determinate	1987
IT88D-867-11	Semi-determinate	1988
IT89KD-391	Semi-determinate	1989
IT90K-277-2	Semi-determinate	1990
IT97K-1101-5	Determinate	1997
IT97K-461-4	Determinate	1997
IT97K-494-3	Determinate	1997
IT97K-499-35	Determinate	1997
IT98K-131-2	Semi-determinate	1998
IT98K-476-8	Semi-determinate	1998
IT98K-506-1	Determinate	1998
IT98K-628	Determinate	1998
TVx 3236 (SUVITA 4)	Semi-determinate	1976
TVx 456-01F	Determinate	1975
TVx 66-2H (VITA 8)	Determinate	1975
TVx 1836-013J (VITA 10)	Determinate	1976
VITA 4 (TVu 1977-0D)	Semi-determinate	1974
VITA 5 (TVu 4557)	Semi-determinate	1974

Table 3: Mean squares of 11 traits of cowpea genotypes representing four decades of breeding in the Nigerian Sudan savannas

Source of variation	DF	Days to flowering	Days to maturity	Canopy height (cm)	Branch No. per plant	Peduncle No. per plant	Pod No. per plant	Hundred seed weight (g)	Total dry matter (g/plant)	Harvest index	Grain yield (kg ha^{-1})	Fodder yield (kg ha^{-1})
Year (Y)	1	833.15***	2394.61***	466.80***	27.04***	212.96***	89.18**	497.35***	6289.40***	0.007**	105299.01^{ns}	103373521**
Variety (V)	30	117.86***	264.61***	155.18***	2.75***	34.12***	45.55***	33.79***	794.29***	0.012***	608187.04***	1615147.00***
Y x V	29	11.82***	61.58***	48.43**	1.73***	29.42***	33.68***	4.33**	540.15***	0.005	65638.61**	1519372.85***
Error	142	1.69	3.76	30.95	0.62	10.77	13.4	2.36	153.11	0.001	36605.94	1519372.85
CV%		2.82	2.65	12.57	25.3	30.22	27.05	9.49	20.98	9.63	15.04	20.49

** Mean squares significant at <5% probability level

*** =Mean squares significant at <1% probability level

^{ns} =Mean squares not significant at 5% probability level

characters for each cultivar using principal component (PC) analysis (Eigen values) of cultivars on a limited number of PC axes, (iv) clustering cultivars into similarity groups using uncorrelated characters (PC coefficients). All data were subjected to an ANOVA using the PROC MIXED procedure (Littell *et al*., 1996) of SAS (SAS Institute, 2003). Year and replications were treated as random effects; varieties were treated as fixed effects in determining the expected mean square and appropriate F test in the analysis of variance. Differences between two treatment means were compared with the t-test based on the SED at 5% level of probability.

The SAS procedure PRINCOMP (SAS Institute, 2003) was used to perform PC analysis of least squares for cultivar means. The sum of the first three PC axes, representing 75% of total variation, were used in subsequent analyses. The approach used to group cultivars was cluster analysis, which is a well-known method within the multivariate statistical approaches (Hair *et al*., 1995). It is based on the principle of minimizing the variance in the group and maximizing the variance among groups (Johnson and Wicherin, 1992). Cultivars were clustered using UPGMA (un-weighted pair group method using arithmetic averages) calculated by PROC CLUSTER, option AVERAGE (SAS Institute, 2003). Cultivars or the average of cultivar groups were sequentially clustered based on similarity of coefficients in the first three PC axes. All axes were given equal weight in the cluster analysis.

RESULTS AND DISCUSSION

Mean agronomic performance of the cultivars: The combined analysis of variance showed significant differences for the cultivars and years for most traits studied. Grain yield was however, not significantly influenced by year of evaluation (Table 3). There were significant genotype × year interactions for all traits except for harvest index (HI). The year × genotype interactions were expected because of rainfall differences between the two years (Table 1). Rainfall was higher in 2007 than 2008 by 25%. This might have caused slight change in rankings among the genotypes. Kamara *et al*. (2003) reported genotype × year interaction for maize genotypes evaluated in the Guinea savannas of Nigeria due to slight changes in rankings of the genotypes between the years. The variation among the cowpea genotypes is represented by the mean values (Table 4). The ranges for most traits were extremely wide. Modern genotypes generally outperformed older genotypes. Grain and fodder yield ranged from 580-1851 kg ha-1 and 1266-3346 kg ha-1, respectively. The genotype IT04K-321-2 produced the highest grain yield while IT98K-476-8 produced the highest fodder yield. The genotypes also showed a wide range for maturity (63 - 87 days), flowering period (37 - 58 days), total dry matter per plant (38-83 g) and HI (0.25 - 0.45). These wide variations were also reported for soybean genotypes bred in different eras in the Nigerian savannas (Tefera *et al*., 2009).

Table 4: Agronomic performance of some cowpea varieties bred by IITA between 1974 and 2004 in Minjibir

Variety	Days to 50% flowering	Days to 90% maturity	Canopy height (cm)	Branches (No./plant)	Peduncles (No./plant)	Pods (No./plant)	Seed (g/100)	Total dry matter (g/plant)	Harvest index	Grain yield (kg/ha)	Fodder yield (kg/ha)
IT00K-1207	48	83	41.05	3	9	14	13.80	57.30	0.40	1368.39	2045.90
IT00K-1263	45	72	44.25	4	12	14	17.72	55.39	0.40	1401.44	2149.91
IT00K-227-4	46	73	44.24	3	8	13	18.24	62.31	0.43	1198.54	1602.22
IT03K-316-1	46	77	48.25	4	15	15	18.15	70.83	0.38	1707.70	2832.92
IT04K-217-5	52	81	45.96	4	10	9	21.58	64.00	0.41	1360.72	2012.99
IT04K-321-2	49	81	58.41	3	9	16	18.25	83.90	0.39	1850.77	2800.21
IT04K-332-1	43	71	43.73	2	12	15	15.19	60.87	0.38	1574.61	2624.75
IT81D-985	58	87	31.88	3	8	10	17.65	63.30	0.35	1203.72	2253.60
IT81D-994	54	86	38.97	3	6	7	16.83	59.31	0.35	1107.57	2078.85
IT82D-889	42	64	43.60	3	13	15	13.60	65.28	0.37	1034.07	1714.58
IT84S-2246-4	47	73	43.88	3	11	12	14.25	43.61	0.38	930.69	1532.50
IT86D-1010	42	67	44.35	3	12	12	17.39	51.52	0.39	1141.28	1775.75
IT86D-719	45	79	47.88	3	12	13	12.47	52.85	0.34	1097.18	2175.32
IT86D-721	46	77	50.64	2	10	14	15.60	64.92	0.39	1200.96	1880.00
IT88D-867-11	46	75	44.52	2	9	13	19.00	58.88	0.38	1109.56	1834.83
IT89KD-391	52	76	48.51	3	8	12	18.90	50.94	0.38	1195.56	1973.13
IT90K-277-2	46	71	44.34	4	13	17	16.60	61.66	0.43	1651.62	2202.08
IT97K-461-4	37	64	46.08	4	15	15	18.12	53.67	0.36	1414.75	2525.73
IT97K-494-3	45	68	41.36	4	14	17	15.50	55.73	0.42	1587.22	2155.00
IT97K-499-35	42	71	49.02	3	11	13	16.10	57.41	0.39	1548.96	2444.38
IT98K-128-3	49	74	46.28	4	11	16	15.59	81.24	0.31	1413.20	3210.28
IT98K-131-2	46	72	42.86	3	12	19	15.02	69.67	0.45	1439.50	1805.11
IT98K-476-8	49	79	47.25	4	12	14	16.45	71.63	0.32	1560.11	3346.48
IT98K-506-1	42	66	41.13	3	12	13	17.90	49.35	0.40	1356.13	2085.21
IT98K-628	39	65	44.34	3	11	15	15.57	51.31	0.41	1414.12	2005.58
TVX1836-013J	43	64	39.46	2	9	11	13.64	48.76	0.39	865.18	1367.24
TVX3236	47	70	39.57	4	13	14	11.39	43.26	0.25	580.36	1723.29
TVX456-01F	41	63	35.41	2	9	11	17.62	39.58	0.34	778.25	1455.38
TVX66-24	49	71	41.41	2	8	11	13.57	38.83	0.30	740.22	1675.53
VITA4	45	69	43.98	5	12	18	11.95	77.68	0.30	753.93	1855.99
VITA5	47	69	34.99	3	11	15	13.94	56.50	0.35	693.68	1266.46
Mean	45.99	73.11	44.25	3.12	10.86	13.53	16.18	58.97	0.38	1272.12	2119.83
SED	2.073	3.876	4.268	0.705	2.753	3.429	1.719	11.299	0.031	144.738	144.738
P value (Variety)	<.0001	<.0001	<.0001	<.0001	0.0006	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Table 5: Eigen values of the correlation matrix and eigenvectors of the first 3 principal components of some cowpea varieties bred by IITA between 1974 and 2004 in Minjibir.

Variables	PRIN 1	PRIN 2	PRIN 3	PRIN4	PRIN5	PRIN6
Eigenvalues	3.64	2.86	1.76	0.78	0.72	0.46
CPV	0.33	0.59	0.75	0.82	0.89	0.93
Eigenvectors						
Days to 50% flowering	-0.01	0.49	-0.32	0.13	0.25	-0.02
Days to 90% maturity	0.12	0.51	-0.21	-0.06	0.14	-0.17
Canopy height (cm)	0.35	0.04	0.15	-0.58	-0.34	0.47
Branches per plant (no.)	0.32	-0.16	-0.34	0.52	0.03	0.41
Peduncles per plant (no.)	0.25	-0.44	-0.07	0.28	-0.1	-0.17
Pods per plant (no.)	0.31	-0.37	-0.12	-0.19	0.41	-0.09
Seed (g/100)	0.17	0.29	0.41	0.48	-0.28	0.28
Total dry matter (g/plant)	0.4	0.14	-0.22	-0.16	0.32	0.32
Harvest index	0.16	0.04	0.62		0.52	0.52
Grain yield (kg/ha0	0.45	0.1	0.27		0.02	0.02
Fodder yield (kg/ha)	0.43	0.12	-0.17		-0.43	-0.41

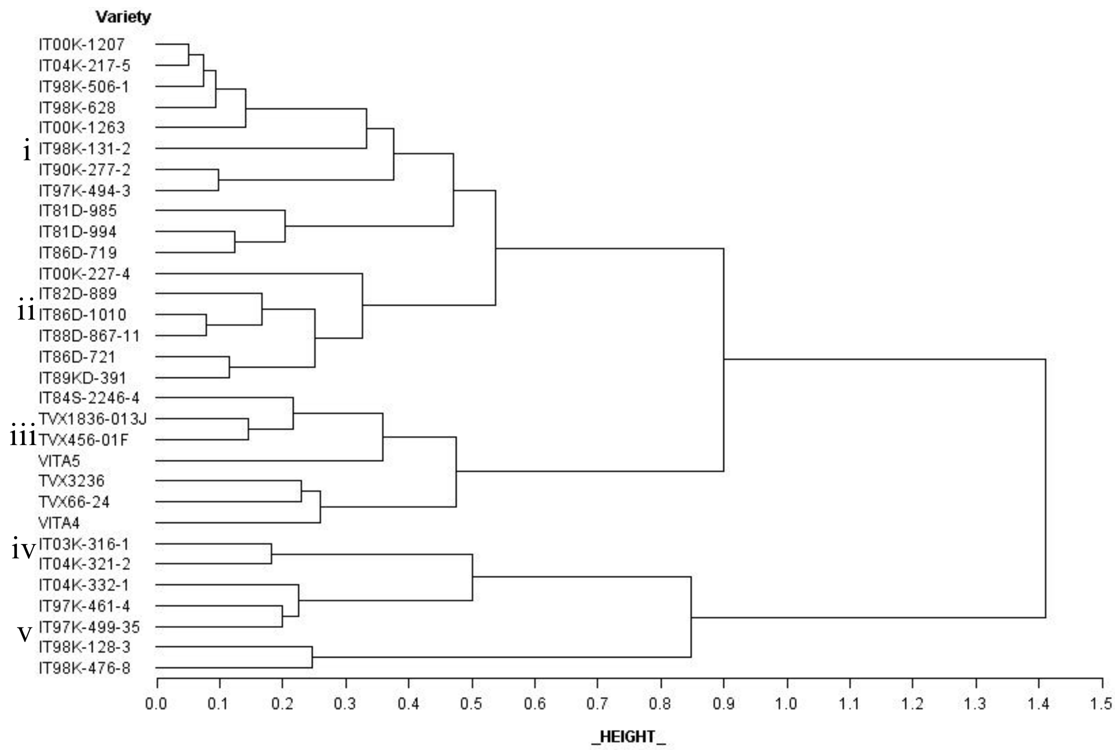

Figure 1: Dendrogram produced from average linkage cluster analysis showing genetic relationship between cowpea varieties bred at IITA from 1974-2004.

The correlation among the variables showed many significant values (Table 6). Knowledge of the relationship among plant characters is useful while selecting traits for yield improvements (Iqbal *et al*., 2010). Grain yield was positively correlated to canopy height (r=0.57), hundred seed weight (r=0.49), total dry matter (r=0.53), HI (r=0.59), and fodder yield (r=0.74). Correlations of grain yield with other traits were not significant. Identifying highly correlated traits could reduce the number of traits needed for germplasm characterization. Yada *et al*. (2010) identified leaf traits to be effective when used with other correlated traits for the characterization of sweet potato collections. Results from the present study suggests that using a selection index that contains high canopy, high seed weight, high total dry matter, high HI, and high fodder yield will improve grain yield of cowpea.

Principal component analysis: Principal component analysis was used to determine the relative importance of the 11 traits

Table 6: Correlation matrix of the variables used in the Principal Component analysis of some cowpea varieties bred by IITA between 1974 and 2004 in Minjibir

Variable	Days to 50% flowering	Days to 90% maturity	Canopy height	Branches	Peduncles	Pods	Hundred seed weight	Total dry matter	Harvest index	Grain yield
Days to 90% maturity	0.848***									
Canopy height	-0.129	0.157								
Branches	0.009	-0.002	0.174							
Peduncles	-0.556***	-0.461***	0.160	0.588***						
Pods	-0.402**	-0.333	0.272	0.476***	0.684***					
Hundred seed weight	0.168	0.258	0.237	-0.005	-0.178	-0.314				
Total dry matter	0.279	0.412**	0.458***	0.472***	0.117	0.445**	0.168			
Harvest index	-0.188	-0.023	0.230	-0.129	0.010	0.109	0.456***	0.086		
Grain yield	-0.011	0.273	0.566***	0.278	0.269	0.348	0.498***	0.529***	0.587***	
Fodder yield	0.146	0.373**	0.502***	0.432**	0.282	0.288	0.263	0.610***	-0.079	0.742***

** and ***: Significant at <5% and <1% probability level

used in the study (Jackson, 1991; Yada *et al*., 2010). The correlation between the 11 traits and their Eigen values was used as a basis for the identification of the principal components (PCs) in the study (Yada *et al*., 2010). Eigen vectors equal to or greater than 0.3 were used as the cut off point when each selected traits made an important contribution to the PC axis. The data revealed that 3 principal components having Eigen values greater than one contributed 75% of the total variation among the 31 cultivars of cowpea (Table 5). Principal component 1 (PC1) contributed 33%, whereas PC 2 and PC3 contributed 26 and 16 % respectively, of the total variation. The traits, which contributed significantly to PCA1, were canopy height (0.35), number of branches per plant (0.32), pods per plant (0.31), total dry matter (0.40), grain yield (0.45), and fodder yield (0.43). Days to 50% flowering (0.49), days to 90% maturity (0.51), number of peduncles per plant (0.44), and number of pods per plant (0.37) had the largest coefficients in the second PC axis. Days to 50% flowering (0.32), number of branches per plant (0.34), 100 seed weight (0.41), and HI (0.62) characterized the third PC axis. It is clear from the principal component analysis that most of the variance among the cowpea genotypes was explained by the first three principal components. This means that there is a high level of variability associated with traits correlated with the first three PCs. According to Yada *et al*. (2010), a large number of PCs will be needed to explain total variance among genotypes. In the current study, 75% of the total variance was explained by the three PCs.

Cluster analysis: Clustering the cultivars based on similarity of quantitative characters produced 5 groups of genotypes. Cluster I included 11 cultivars containing both determinate and semi-determinate cowpea types irrespective of year of release. Cultivars in this cluster had on the average 3 - 4 branches per plant, low pod load, high 100-seed weight of 15 - 21g, high total dry matter but low HI. Eight of the 11 genotypes recorded medium grain yield of 1300 - 1600 kg ha^{-1}. Members of this cluster produced fodder yield of 2000 - 2,200 kg ha^{-1} suggesting that they are dual-purpose in nature. Cluster II contained 6 cultivars mostly released in the 1980s and are characterized by medium maturity, high dry matter accumulation, low branching habit, moderate grain (1000 kg ha^{-1}) and fodder yield (1800 kg ha^{-1}) and fewer peduncles. Seven genotypes were grouped in cluster III. These were mostly the old genotypes bred in the 1970s. These genotypes were mostly early maturing and having lower seed weight, fewer pods, low biomass, low HI, low grain and fodder yield. Cluster IV contained 5 genotypes all released in the late 1990s to early 2000s. They were all determinate type with high canopy height, high number of pods, high seed weight, high dry matter, and medium to high HI. Two of the genotypes (IT03K-316-1 and IT04K-321-2) in this group were highest yielding with yield ranged from 1700 kg/ha-1800 kg ha^{-1}.

The cultivars in this group also had very high fodder yield ranging from 2444 -2833 kg ha^{-1} suggesting that they are dual-purpose and could be suitable parents for breeding dual-purpose cowpea. The high grain and fodder yield of the modern cultivars in this group may be due to emphasis on developing dual-purpose cowpea for grain and fodder production (Singh *et al*., 2000). Two cultivars IT98K-128-3 and IT99K-476-8 were grouped in cluster V. These two cultivars released in late 1990s were late flowering, medium maturing (74 - 79 days to maturity), having high canopy height, high number of branches, medium seed weight, high dry matter, low HI and the highest fodder yield of 3210 - 3346 kg ha^{-1}. Cultivars in this group could be useful parents for the improvement of cowpea cultivars for high fodder production.

CONCLUSIONS

Significant variations were observed in the agronomic characteristics of the cultivars in this study. Modern cultivars outperformed the older ones. There were significant correlations among the variables measured. The results of PCA suggest that the most important variables for the classification of the cowpea cultivars were high canopy, high seed weight, high total dry matter, high HI, and high grain and fodder yield. This suggests that these traits could be used in a selection index for genetic improvement of cowpea. Cluster analysis revealed 5 groups mostly corresponding to era of release except cluster I which contained cowpea cultivars from all eras. Two distinct groups in clusters IV and V were identified. Cultivars in cluster IV which were released in the 1990-2000 eras, had high grain and fodder yield. These cultivars could be evaluated on-farm for eventual release to farmers. They could also be used in breeding program for improvements in grain and fodder yield of cowpea. Cluster V contained two cultivars that distinctly had the highest fodder yield suggesting that they could be used to improve fodder yield of cowpea.

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