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Genotypic diversity of cowpea from lower eastern Kenya

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Key words: *Vigna Unguiculata*, Diversity, Climate adaptation, Crop selection, Marginal areas.

Abstract

Cowpea is an important pulse crop widely grown in marginal areas of Kenya. There is limited information on diversity among the Kenyan cowpea as it is widely grown from landraces. The aim of this study was to evaluate variation among cowpea landraces obtained mainly from lower eastern region and other marginal areas of Kenya. One hundred and ten cowpea accessions were planted in a Randomized Complete Block Design with three replications. Quantitative and qualitative data were collected and analyzed. Even distribution of accessions across traits of the characters was observed for immature pod color, leaf color, seed shape and testa texture, whereas uneven distribution was observed for terminal leaflet shape, raceme position, pod attachment, pod curvature, mature pod color, flower color and eye color. ANOVA revealed significant differences (p=0.05) of accessions for number of days to 50% emergence, pod length, number of pods per plant and the number of seeds per pod. The first five principal components; 19.8, 18, 15.9, 12.4 and 11.22 respectively accounted for 77% of total variation. Correlation analysis revealed significant relationship (p=0.05) for 50% emergence to 50% flowering, number of pods per plant, terminal leaflet length and terminal leaflet width. The accessions were grouped into two, with one cluster having 103 accessions that included all registered varieties. Therefore, cowpeas grown in marginal lower eastern region of Kenya are variable and closely related to the registered cowpea varieties. The set of accessions could therefore be used for identification of preferred lines for this region.

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Introduction

Cowpea is an important tropical legume crop grown in Kenya for its leaves, green pods, grain, and stover (Muniu, 2017; Sariah, 2010) The crop is highly resilient to drought and is mainly cultivated by small-holder farmers under some of the extreme conditions within the arid and semi-arid areas of Kenya (Muñoz-Amatriaín, *et al.*, 2017). It is a drought tolerant crop that is relied on as a source of protein in the marginal lands where alternative protein foods; meat and fish are expensive and inaccessible (Gómez, 2004). Cowpea is sometimes referred to as a poor man's meat and contains about 23-30% proteins. Cowpea is also an alternative source of income in the marginal areas where it thrives well (Garko, *et al*, 2016; Gonné *et al.*, 2013).

The Lower Eastern region of Kenya (often referred to as Ukambani), is in the arid and semi-arid Agro Ecological Zone IV (Jaetzold and Schimidt, 1983). The region is characterized by poor soils, low and unreliable rainfall and high temperatures (Mburu *et al*, 2014). Because of its resilience, cowpea is one of the most important food legume crops in this region together with green gram and pigeon pea (Muthoni and Nyamongo, 2010). The average cowpea yield obtained by farmers is 50-300kg/ha compared to 1500-3000kg/ha obtained under research station conditions and hence there is potential to improve crop's productivity. Low yields in cowpea could be attributed to limited amount of rains, poor adaptation to the drought conditions, pest and disease infestation and lack of improved and quality seed (Onduru *et al*, 2008; Kuruma, 2004).

Limited number of improved cowpea lines is available to farmers in Kenya. The number of improved cowpea varieties at the Registrar of Plant Varieties at the Kenya Plant Health Inspectorate Service (KEPHIS 2019) is very low; 22, in spite of the wide cultivation of the crop. The registered lines have been bred and selected for specific attributes and are high yielding and uniform usually with a narrow genetic base. The adoption rate of these improved cowpea lines by farmers is low, despite the fact that seeds of improved types have previously been promoted and supplied though government agencies in drought mitigation strategies.

Most cowpea farmers still grow their own saved seed from previous harvest (Stoilova and Pereira, 2013). The saved seed however does not go through the rigors of seed certification processes leading to contamination and loss of genetic integrity of original lines, subsequently resulting in mixed varieties and segregating populations. Through farmers' propagation of own saved seed, and careful selection for desirable crop characteristics, farmers have maintained certain preferred traits within their cultivars resulting in the land races (Ashworth and Whealy, 2012).

For sustainable improvement of the crop, diversity within the genetic resources is crucial. Farmers have continued to grow landraces and shared seed amongst neighbors over the years in the lower eastern region. The objective of this study was to determine variation among cultivars that from the lower eastern region of the country. Diversity among the lines shall provide information on the potential for selection among the collection, and inform lines that have potential to be selected for breeding and wide adoption in the region.

Materials and methods

Experimental site

The trial was conducted at the experimental farm of Jomo Kenyatta University of Agriculture and Technology in Juja. Juja is located in central Kenya at 1°11′0′′ south, 37°7'0" East. This area has semi-arid conditions under AEZ IV (Jaetzold and Schmidt, 1983) with two distinct rain seasons. The long rains fall from March to May while the short rains fall between October and December; with an average annual rainfall of 989 mm. The daily temperature ranges from 10-30°C depending on the season. The area has rich black cotton soils.

Plant materials

One hundred and ten accessions (Table 1) were used for this study. Collections from farmers in lower eastern region of Kenya comprising of 82 accessions were procured from the National Gene Bank of Kenya. These comprised of accessions from Machakos (74), Makueni (3), Kitui (5). Twenty-three landraces from Machakos (14) and Baringo (9), were collected directly from farmers and five commercial lines (K80, M66, Kenkunde, KAR 1 and KVU-27-1) were obtained from registered seed companies.

Table 1. Cowpea accessions used in the study and their collection area of origin.

	Accession	Source County	Locality
1	GBK-003642 A	Machakos	KDFS
2	GBK-003642 B	Machakos	KDFS
3	GBK-003645	Machakos	KDFS
4	GBK-003650	Machakos	KDFS
5	GBK-003651	Machakos	KDFS
6	GBK-003652	Machakos	KDFS
7	GBK-003654	Machakos	KDFS
8	GBK-003657	Machakos	KDFS
9	GBK-003658	Machakos	KDFS
10	GBK-003660	Machakos	KDFS
11	GBK-003662	Machakos	KDFS
12	GBK-003663	Machakos	KDFS
13	GBK-003666	Machakos	KDFS
14	GBK-003667	Machakos	KDFS
15	GBK-003668 D	Machakos	KDFS
16	GBK-003669	Machakos	KDFS
17	GBK-003670 A	Machakos	KDFS
18	GBK-003670 B	Machakos	KDFS
19	GBK-003674	Machakos	KDFS
20	GBK-003675	Machakos	KDFS
21	GBK-003676 A	Machakos	KDFS
22	GBK-003676 B	Machakos	KDFS
23	GBK-003680	Machakos	KDFS
24	GBK-003682	Machakos	KDFS
25	GBK-003685 A	Machakos	KDFS
26	GBK-003685 B	Machakos	KDFS
27	GBK-003687 A	Machakos	KDFS
28	GBK-003687 B	Machakos	KDFS
29	GBK-003688	Machakos	KDFS
30	GBK-003689	Machakos	KDFS
31	GBK-003690	Machakos	KDFS
32	GBK-003693	Machakos	KDFS
33	GBK-003694 A	Machakos	KDFS
34	GBK-003694 B	Machakos	KDFS
35	GBK-003695	Machakos	KDFS
36	GBK-003696	Machakos	KDFS
37	GBK-003697	Machakos	KDFS
38	GBK-003698	Machakos	KDFS
39	GBK-003699	Machakos	KDFS
40	GBK-003700	Machakos	KDFS
41	GBK-003701 A	Machakos	KDFS
42	GBK-003701 B	Machakos	KDFS
43	GBK-003705	Machakos	KDFS
44	GBK-003706	Machakos	KDFS
45	GBK-003707	Machakos	KDFS
46	GBK-003709	Machakos	KDFS
47	GBK-003711 A	Machakos	KDFS
48	GBK-003711 B	Machakos	KDFS
49	GBK-003713	Machakos	KDFS
50	GBK-003714	Machakos	KDFS
51	GBK-003717 A	Machakos	KDFS
52	GBK-003717 B	Machakos	KDFS
53	GBK-003718	Machakos	KDFS
54	GBK-003720	Machakos	KDFS
55	GBK-003723	Machakos	KDFS
56	GBK-003724	Machakos	KDFS
57	GBK-003726	Machakos	KDFS
58	GBK-003727	Machakos	KDFS
59	GBK-003780	Machakos	KDFS
60	GBK-003796	Machakos	KDFS
61	GBK-003804	Machakos	KDFS
62	GBK-003814	Machakos	KDFS
63	GBK-003816 A	Machakos	KDFS
64	GBK-003816 B	Machakos	KDFS
65	GBK-003820	Machakos	KDFS
66	GBK-003876	Machakos	KDFS
67	GBK-003888	Machakos	KDFS
68	GBK-003916	Machakos	KDFS
69	GBK-003985	Machakos	KDFS
70	GBK-005173 A	Machakos	KDFS
71	GBK-005173 B	Machakos	KDFS
72	GBK-027036	Machakos	Ndalani Loc. (Ndalani Maktano)
73	GBK-027079	Machakos	Ndalani Loc. (Ndalani Maktano)
74	GBK-027089	Machakos	Mukuyuni, Kibwezi
75	GBK-026941 A	Kitui	Kanyangi Loc. Wangata
76	GBK-026941 B	Kitui	Kanyangi Loc. Wangata
77	GBK-026958 A	Kitui	Mutha Loc.
78	GBK-026958 B	Kitui	Mutha Loc.
79	GBK-046540	Kitui	Maliku – Kitui
80	GBK-034722 A	Makueni	Sakai ; 13km Kilata Tawa Road
81	GBK-034722 B	Makueni	Sakai ; 13km Kilata Tawa Road
82	GBK-036582	Makueni	Sakai ; 13km Kilata Tawa Road
83	K80	Commercial	Commercial
84	KENKUNDE	Commercial	Commercial
85	KVU-27-1	Commercial	Commercial
86	M66	Commercial	Commercial
87	KAR 1	Commercial	KALRO
88	KAT 1	Machakos	Katumani
89	KAT 3	Machakos	Katumani
90	KOL 1	Machakos	Kola
91	KOL 2	Machakos	Kola
92	KOL 2	Machakos	Kola
93	KOL 5	Machakos	Kola
94	KOL 6	Machakos	Kola
95	KOL 8	Machakos	Kola
96	KOL 9 A	Machakos	Kola
97	KOL 9 B	Machakos	Kola
98	KOL 9 B	Machakos	Kola
99	MAC 1	Machakos	Machakos
100	MAC 2	Machakos	Machakos
101	MAC 3	Machakos	Machakos
102	MAR.2	Baringo	Margat
103	MAR.3	Baringo	Margat
104	MAR.5	Baringo	Margat
105	MBL	Baringo	Mbili mbili
106	LAM 4	Baringo	Lambwe
107	KIP 1	Baringo	Kipsarum
108	KIP 2	Baringo	Kipsarum
109	KAB 1	Baringo	Kabartonjo
110	KAB 3	Baringo	Kabartonjo

GBK=Gene Bank of Kenya; KDFS=Katumani Dryland Farming Station; A, B, D=Selections within the accession.

Experimental Design

The trial was laid down in a Randomized Complete Block Design (RCBD) with three replications. Each replicate measured 12m by 24m comprising of 110 plots. Cowpea seeds were sown in three lines per plot at inter- and intra-row spacing of 0.6m and 0.3m respectively. Two cowpea seeds were planted per hole and later thinned to a single plant per hole after two weeks from date of germination. Irrigation was done immediately after planting and whenever it became necessary. Weeding was done manually three weeks from date of planting followed by rouging of weeds whenever they emerged.

Data collection

Qualitative and quantitative agronomic data was collected and recorded from five plants in the middle row of each plot according to IBPGR (1983). Data collected at emergence was; the number of days it took for 50% of the plants to emerge. Data for vegetative stage, was recorded at six weeks and included; growth habit, growth pattern, twining tendency, pigmentation, terminal leaflet shape, leaf color, terminal leaflet length, terminal leaflet width and number of main branches. At flowering stage, data recorded included raceme position, pod attachment, immature pod pigmentation, pod curvature, flower color, pod length, number of seeds per pod and pods per plant. At harvesting, data was obtained for mature pod color, seed shape, testa texture, seed color, eye color and 100 seed weight.

Data Analysis

The data was recorded in data sheets in the field and thereafter entered in an excel sheet and analyzed on GENSTAT program version 14 platform. Qualitative data was used to assess the distribution of the accessions in different traits of the respective characteristics expressed as a percentage of the total number of accessions; number of accessions possessing a certain attribute divided by the total number of accessions multiplied by 100. Quantitative data was subjected to ANOVA to determine the variation in the respective traits. The contribution of the respective characters to the variation of the different traits was assessed by Principal Component Analysis. The accessions were grouped using cluster analysis and correlation among traits was determined using Pearson correlation analysis. Unweighted ranking of the characters positively associated with productivity was done by ranking five traits; pod length, number of pods per plant, number of seeds per plant and number of branches per plant, individually and summing up the ranks for each accession. The sum of ranks was used to obtain accessions with the potential of greatest performance and least performance.

Results

Variation in the cowpea accessions

Qualitative Characters

The distribution of accessions among the traits of 15 qualitative morphological characters is presented in Table 2. Distribution of accessions among the traits were evenly distributed for immature pod color, leaf color, seed shape and twining tendency and skewed for terminal leaflet shape, raceme position, pod attachment, pod curvature, mature pod color, flower color, testa texture and eye color.

Table 2. Distribution of accessions among respective traits of the evaluated characters.

Characteristic	Percentage distribution of the accessions in respective traits
1. Growth Habit	Acute erect 23 Semi erect 73 Intermediate 5
2. Growth pattern	Determinate 27 Indeterminate 73
3. Twinning tendency	None 6 slight 39 Intermediate 42 Pronounced 13
4. Pigmentation	None 44 very slight 36 Moderate 5 Intermediate 1 Extensive 4
5. Terminal leaflet shape	Globose 99 Hastate 1
6. Raceme position	Above canopy 24 upper canopy 56 Throughout 20
7. Pod attachment	Pedant 81 30-90^{o} 16 Erect 3
8. Immature pod color	None 31 pigmented valves green sutures 34 splashes of pigment 28 uniformly pigmented 1 pigmented tip 6

Characteristic	Percentage distribution of the accessions in respective traits
9. Pod curvature	Straight 12 Slightly curved 88
10. Mature pod color	Straw 65 Dark brown 34 Black/dark purple 2
11. Flower color	White 1 white purple 4 purple 95
12. Leaf color	Pale green 1 intermediate green 55 Dark green 45
13. Seed shape	Kidney 2 ovoid 47 Globose 1 Rhomboid 50
14. Eye color	Absent 81 Brown splashes 2 Tan brown 3 Blue to black 4 speckled 10
15. Testa texture	Smooth 89 Smooth to rough 7 Rough to wrinkled 4

The accessions could be placed into three groups based on growth habit: acute erect, semi erect and intermediate. Over half of the accessions (73%) were semi erect, acute erect (23%) and 5% intermediate. Two classes of growth habits were observed; determinate (27%) and indeterminate (73%). It was also observed that the accessions had three distinct groups based on the raceme position; above canopy (24%), upper canopy (56%) and throughout the plant (20%). Based on pod color, both mature and immature pods showed a wide range of variation. There were accessions that had no pigmentation (green) on immature pods to those with uniform pigmentation; 31% of the accessions did not have pigmented pods, 34% of the lines had pigmented valves and green sutures, splashes of pigment were observed in 28% of the accessions and 6% of the lines had pigmented tips. Only 1% of the accessions had uniformly pigmented immature pods. The mature dried pods also showed uneven distribution of accessions; straw (65%), dark brown (34%), dark purple (1%). The accessions also showed uneven distribution for flower color and terminal leaflet shape. The observed flower colors included; white (1%), white-purple (4%), purple (95%) and terminal leaflet shape: Globose (99%) and hastate (1%). 88% of the lines under study produced slightly curved pods while the remaining 12% had straight pods.

Twining tendency of the accessions showed even distribution with 6% of the accessions with no twining, 39%, 42% and13% of the accessions were observed to show slight, intermediate and pronounced twining respectively.

Variation in Quantitative Characters

Variations among the quantitative traits are presented in Table 3. The accessions were significantly different for Number of days to 50% emergence, Pod length, Number of pods per plant and number of seeds per pod. There were no significant differences among the accessions for one hundred seed weight, number of branches per plant, number of days to 50% flowering, terminal leaflet length and terminal leaflet width (Table 3).

Table 3. Variation within quantitative morphological traits of cowpea.

Trait	*P*	Mean	Range	SD	CV (%)
100SW(g)	0.398	8.8±2.05	5.9-11.4	1.21	23.2
No. of branches per plant	0.155	4.38±0.69	3.4-5.2	0.42	15.7
Emergence - 50%(days)	‹*0.001*	6.06±1.24	4.3-8.3	0.966	20.4
Flowering-50%(days)	0.28	70.87±3.27	65-75.7	1.952	4.6
Pod length(cm)	0.006	11.56±1.51	9.01-13.96	1.051	13.1
No. of pods per plant	‹*0.001*	21.95±5.31	6.67-30	4.54	24.2
No. of seeds per pod	0.005	8.36±1.92	5.07-11.07	1.34	22.9
Terminal leaflet length(cm)	0.487	4.39±0.83	3.4-5.8	0.486	19
Terminal leaflet width(cm)	0.42	2.81±0.72	1.8-4.11	0.428	25.6

Analysis of Variance for the quantitative traits of cowpea accessions. p=0.05 probability level; Mean is the average of the character measured for 110 accessions; Range gave the highest and lowest values of a character; CV is coefficient of variation.

Table 4. Mean values of 20 highest and 20 lowest accessions based on quantitative traits.

SN	ACC	PL	SPP	100SW	PPP	BP	Ranks
1	GBK 003662	11.8	10.9	8.7	26.3	4.7	1
2	GBK 003663	12.6	10.2	6.7	27.0	4.1	2
3	GBK 003676	10.5	8.1	8.7	26.7	4.3	3
4	GBK 003723	11.9	8.6	11.2	23.0	4.2	4
5	GBK 003650	12.9	9.6	9.5	26.7	5.1	5
6	GBK 003642	9.9	6.2	9.3	10.7	4.3	6
7	GBK 003669	11.4	10.8	9.8	22.0	4.7	7
8	GBK 003668 D	13.0	9.5	8.3	25.3	4.3	8
9	GBK 003780	12.9	9.1	7.1	19.7	5.1	9
10	GBK 003709	10.3	7.8	6.2	7.0	4.9	10
11	GBK 003685	12.0	8.5	8.3	26.0	3.9	11
12	KAB 1	11.9	9.3	10.8	22.3	4.8	12
13	GBK 003985	12.6	9.5	10.2	23.0	5.2	13
14	GBK 003796	11.5	6.3	9.1	23.3	4.1	14
15	GBK 003645	11.5	6.5	8.9	27.0	4.1	15
16	GBK 003676	11.7	9.6	9.3	20.7	4.2	16
17	GBK 003676 B	11.0	7.0	11.4	20.7	4.4	17
18	GBK 003687	11.6	6.3	6.9	25.0	4.0	18
19	GBK 003654	9.5	5.1	10.0	19.7	4.8	19
20	K80	13.0	10.9	8.4	28.3	4.5	20
21	Kenkunde	12.7	8.2	8.9	21.3	4.1	91
22	GBK 003698	12.3	9.3	9.2	30.0	4.5	92
23	GBK 003694	12.5	10.3	8.5	21.3	3.9	93
24	GBK 003711	11.0	9.2	9.7	22.7	3.8	94
25	KOL 8	12.0	8.0	8.0	19.0	4.3	95
26	KOL 2	11.3	8.6	8.3	18.3	4.5	96
27	KAT 1	11.9	9.4	8.1	21.7	4.2	97
28	MBL	10.6	7.8	11.4	18.7	3.9	98
29	MAC 1	12.3	7.1	9.4	24.3	4.3	99
30	GBK 003682	13.2	10.2	10.0	25.3	4.5	100
31	GBK 003687 B	10.1	8.5	10.0	24.7	4.7	101
32	MAR.5	12.6	6.7	10.1	10	4.9	102
33	MAR.3	11.2	7.0	7.8	7.0	4.6	103
34	M66	13.1	10.4	9.7	19.7	4.1	104
35	MAC 3	11.9	8.5	9.6	18.0	4.3	105
36	KATT	10.1	7.5	11.4	25.3	4.7	106
37	GBK 005173 B	10.4	7.7	6.9	26.7	4.5	107
38	KIP 2	11.3	6.9	9.3	24.7	4.3	108
39	GBK 027089	11.2	10.9	7.8	19.3	5.1	109
40	GBK 034722	11.1	7.8	8.7	23.0	4.9	110

ACC=accession number PL=Pod length SPP=Number of seeds per pod 100SW=a hundred seed weight PPP= number of pods per plant BP=Number of main branches per plant.

The accessions that showed high potential (top 20) and least potential (bottom 20) in productivity based on overall unweighted ranking among characters positively associated with productivity are presented in Table 4. These results indicate that the top 5% of the lines that showed high productivity potential are GBK 003662, GBK 003663, GBK 003676, GBK 003723, GBK 003650, GBK 003642 which superseded the registered varieties. K80 was ranked number 20 whereas Kenkunde and M66 were ranked 91 and 104 respectively.

Pair wise correlation among the traits is presented in Table 5. Significant correlation among the traits was established for number of days to 50% emergence and terminal leaflet length, number of days to 50% emergence and terminal leaflet width, terminal leaflet length and terminal leaflet width, number of days to 50% emergence and number of days to 50% flowering, number of pods per plant and number of days to 50% emergence and pod length and number of seeds per pod. Inverse correlation was observed for number of days to 50% emergence and number of days to 50% flowering (r=-0.21) and number of days to 50% emergence and number of pods per plant were (r=-0.53). On the other hand, number of days to 50% emergence and terminal leaflet length, number of days to 50% emergence and terminal leaflet width were both positively correlated at (r=0.188) and (r=0.204) respectively. Pod length was highly correlated to the number of seeds per pod (r=0.547). It was also observed that the terminal leaflet length and the terminal leaflet width were highly correlated (r=0.523).

Table 5. Pearson's correlation among quantitative traits recorded on cowpea.

Character	E (50%)	BP	TLL	TLW	F (50%)	PPP	PL	SPP	100SW
E (50%)	1								
BP	-0.0273	1							
TLL	**0.1881***	-0.0242	1						
TLW	**0.2042***	0.0880	**0.5230****	1					
F (50%)	**-0.2131***	0.0510	-0.0787	0.0890	1				
PPP	**-0.5258****	-0.1200	-0.0611	0.0742	0.1376	1			
PL	0.0510	-0.1324	-0.0221	-0.0328	-0.1147	0.0986	1		
SPP	0.0749	0.0789	-0.0091	0.0560	-0.0295	0.1742	**0.5470****	1	
100SW	0.0085	0.0392	0.0424	0.0140	0.0782	0.1053	0.0411	0.0429	1

The table shows coefficient of correlation (r) between the agronomic traits measured.

Classification of the Cowpea Accessions

The quantitative characters evaluated were reduced to five major principal components that accounted for 19.8, 18.0, 15.91, 12.4 and 11.2 respectively accounting for 77% of the total variation (Table 6). PC1 was attributed mainly to number of days to 50%, emergence, number of pods per plant, terminal leaflet length and terminal leaflet width. PC 2 was attributed to pod length and seeds per pod. PC 3 was associated with number of days to 50% emergence, number of days to 50% flowering, number of pods per plant, terminal leaflet length and terminal leaflet width (Table 6).

Table 6. Eigen vectors and values for five Principal Component.

	PC 1	PC 2	PC 3	PC 4	PC 5
Eigen value	1.782	1.620	1.431	1.116	1.010
% variance	19.80	18.00	15.91	12.40	11.22
Cumulative Variance	19.80	37.80	53.71	66.11	77.33
Vector Loadings					
%100Seed Weight	0.05686	0.05984	0.01451	**0.54445**	**0.73494**
No. of Branches/Plant	-0.07734	-0.10131	0.07847	**-0.65861**	**0.60621**
Emergence_50%	**-0.57700**	0.09694	**-0.29519**	0.00341	0.02544
Flowering_50%	0.21671	-0.14965	**0.38164**	**-0.37066**	-0.12195
Pod Length	0.07599	**0.65918**	-0.17454	-0.08388	-0.16279
No. of Pods/Plant	**0.46836**	0.21126	**0.44474**	0.20598	0.00878
No. of Seeds/Pod	0.06598	**0.66252**	-0.03755	-0.24503	0.16710
Terminal Leaflet Length	**-0.46927**	0.11945	**0.44362**	0.15119	-0.13919
Terminal Leaflet Width	**-0.40149**	0.14837	**0.57826**	0.00644	0.05451

Quantitative data for nine characters evaluated were subjected to multivariate cluster analysis (Hammer *et al.,* 2001) generating a dendrogram showing similarity among the accessions. Fig. 1 shows the relationship among the 110 accessions that were evaluated based on quantitative characters. The accessions are initially divided into two major clusters (1 and 2), 61% similarity level. Cluster 1 is subdivided into two sub-clusters A and B. Sub-cluster A had five accessions while sub-cluster B had two accessions. Cluster 1 is comprised of seven accessions (Table 7) obtained from Machakos except one, KIP2, from Baringo. Cluster 2 had 82 accessions obtained from Machakos.

Table 7. Distribution of accessions within clusters based on similarity among quantitative traits.

Cluster	Similarity of coefficient	No. of accessions	Name of accessions
Cluster 1	0.61		
A	0.64	5	KOL 5, GBK 003645, GBK 003694, KIP 2, GBK 003714
B	0.64	2	GBK 003651, GBK 003687
Cluster 2	0.61		
C I	0.64	84	GBK 003688, GBK 003780, GBK 027089, GBK 003699, GBK 003816, KOL 6, GBK 003709, KOL 2, KAR 1, GBK 003654, GBK 003670, GBK 003695, GBK 003687, GBK 003718, GBK 003670, GBK 003675, GBK 036582, GBK 003680, GBK 003685, GBK 026941 B, GBK 026958, GBK 003642, GBK 034722, GBK 003720, GBK 003705, GBK 003820, GBK 003727, GBK 003796, GBK 003669, LAM4,KVU-27-1, KAT 1, GBK 003676, GBK 003707, GBK 003700, K80, GBK 003674, GBK 003724, GBK 026941, GBK 003717, KOL 2, GBK 003916, GBK 026958,KOL 8, GBK 003689, MAC 2, MAR.3, GBK 003650, GBK 003682, GBK 003701, GBK 003985, GBK 003696, GBK 003723, KAB 1, KAT 3, MAR.2, GBK 003660, GBK 003693, GBK 003666, GBK 005173, GBK 027036, MAC 3, GBK 003662, GBK 003698, GBK 003663, GBK 003668, GBK 003685, GBK 027079, GBK 003697, GBK 003876, GBK 003701, KAB 3, GBK 003706, GBK 003717, MAC 1, GBK 003711,GBK 00394, GBK 003711, GBK 003713, GBK 003804, GBK 003726, KENKUNDE, M66, MAR.5
C II	0.70	3	KIP 1, MBL,GBK 003642
DIII	0.67	8	GBK 003657, GBK 003676, GBK 005173, GBK 003690, GBK 034722, KOL 1, GBK 003816, GBK 003814
DIV	0.71	8	GBK 003642, GBK 046540, GBK 003658, GBK 003888, KOL 9B, GBK 003667, KOL 9, GBK 003676

Cluster 2 also had two sub-clusters C and D which are divided further into four groups; I, II, III and IV respectively. Sub-cluster C group I had 84 accessions while sub cluster C group II had 3 accessions. Sub-cluster D group III and sub-cluster D group IV each had 8 accessions. The commercial varieties were observed to have been grouped in one cluster; Cluster 2 sub-cluster C group I. Collections from the National Gene Bank of Kenya procured from Machakos were found in all clusters with majority in Cluster 2, sub-cluster C I (Fig. 1).

Collections obtained directly from farmers in Kola in Machakos were also observed to be evenly distributed across all clusters with Cluster 1 A having one accession, cluster C I has four accessions, cluster D III has one accession and cluster D IV having two accessions. Accessions from Makueni were distributed into two groups; cluster 2 C I had two accessions and cluster 2 D IV had one accession. Accessions from Kitui were grouped into one cluster; Cluster 2 C I except one accession that was grouped in Cluster 2 D IV (Fig. 1). Accessions that were sourced from the central Rift Valley; Baringo county were spread out throughout the clusters; cluster 1 A(1), cluster 2 C I (6) and 2 C II (2).

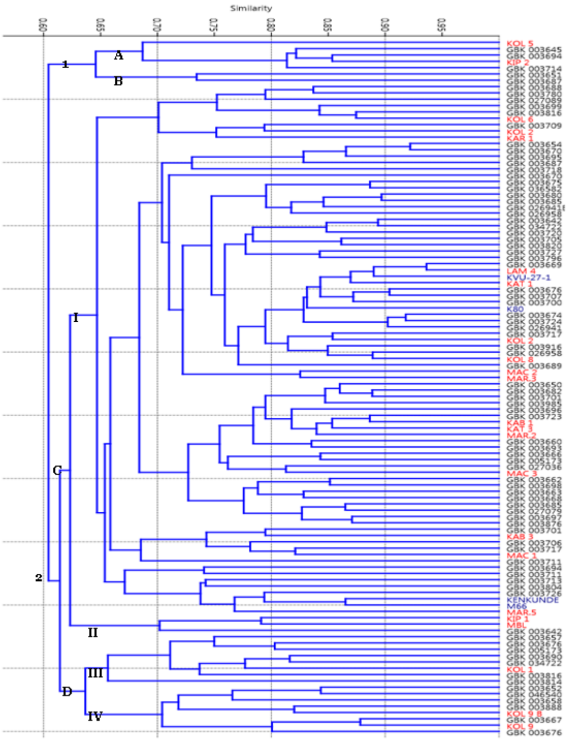

Fig. 1. Clustering of accessions based on quantitative traits.

Discussion

Genetic diversity is an important aspect in improvement of crops during plant breeding programmes. It informs on whether progress can be made in selection for desirable attributes from a population. It also provides an indication of richness and distribution of the alleles available in the population. The accessions under study comprises of landraces from the gene bank were collected from lower eastern region of the country, collection from farmers in central Rift Valley and Lower eastern region and commercial lines registered by the Registrar of plant varieties (KEPHIS). Skewed or uneven distribution of accessions among the characters was observed for terminal leaflet shape, raceme position, pod attachment, pod curvature, mature pod colour, flower colour and eye colour. The low occurrence of accessions in some of the traits of the respective characters, indicate that that some of the alleles are rare in the population or are recessive. Even distribution of accessions in traits was observed for immature pod colour, leaf colour, seed shape and testa texture. Such even distribution of the accessions among the various traits of a characteristic could be attributed to non-selective pressure among such characters.

In this study, 95% of the accessions produced purple flowers which corroborated Doumbia *et al.* (2013), who similarly established that most accessions produced purple flowers, followed by white flowers and the least were white-purple flowered accessions. In a similar study, Cobbinah and Asante (2011) also found that majority of accessions gave purple flowers. Unlike Cobbinah and Asante (2011) and Doumbia *et al.* (2013), this study showed that the accessions with white flowers were less than the white-purple flowered accessions. This could be attributed to ecological and climatic conditions or the farmers' preferences that may not favor accessions with white flowers. In another study, Gibbon and Pain (1985) showed that there were additional flower colours of cowpea such as pale-blue, yellow and pink though they were not observed in this study (Doumbia, 2015). Sangwan and Lodhi (1998) indicated that purple flower colour is dominant over white which has a monogenic recessive nature of inheritance.

All classes of immature pod pigmentation (IBPGR, 1983) were found in the accessions under study. In spite of the various immature pod pigments, 65% of the accessions had straw color and 34% were dark brown mature pods (Table 2).

Raceme position plays a very important role in the harvesting of mature pods. When racemes are on the same level as the canopy or within the canopy, harvesting becomes difficult as most pods are hidden. Pandey and Ngarm (1985) and Bennett-Lartey and Ofori (1999) indicated that accessions which bear racemes above the canopy are easier and cheaper to harvest compared to racemes borne throughout the canopy (Doumbia, 2015). Above canopy receme accessions encourage use of mechanical harvesting. This study showed that 56% of the accessions had upper canopy raceme, 24% of the accessions had a raceme position above canopy and 20% had raceme throughout the canopy. Grain cowpea farmers prefer cowpea which has raceme position above the canopy.

Nkoiannessi (2005) showed that seed testa texture ranged from rough to wrinkled. On the other hand, Adewale *et al.*, (2011) reported accessions with smooth to rough seed texture. This study showed that 89% of the accessions had smooth textured seeds, 7% smooth to rough textured seeds and 4% rough to wrinkled textured seeds. Smooth seed coat texture is preferred in Eastern Africa, unlike in West Africa where preference for rough seed coat allows for easy removal of the seed coat that is important for indigenous food preparations (Singh and Ishiyaku, 2000).

Commercial lines; K80, Kenkunde, M66, Kvu-27-1 and KAR 1 (Table 6) were classified together in group 2. This could be attributed to breeding and selection of these varieties for the region where they have been supplied as government interventions following drought as a mitigation measure (Recha *et al.*, 2012). Accessions obtained from farmers in Kola of Machakos County were evenly distributed in all groupings of the accessions. The even distribution of accessions across groups was also observed for materials sourced from Baringo and those from Machakos. The even distribution is an indication of sharing and exchange of seed among the farmers. Therefore, there is no clear pattern in distribution of the accessions associated with areas of origin. The farmers also seem to have similar preferences in the attributes of the cowpea.

Conclusion

The accessions used in the trial were variable in the characters that were evaluated. Accessions were similarly distributed across the traits of the various characteristics, an indication of a wide range of alleles in the accessions used in the study. In assessing the potential of accessions based on yield associated attributes; GBK 003662, GBK 003663, GBK 003676, GBK 003723, GBK 003650 and GBK 003642 were among the top 5% accessions in the trial whose ranking was even better than the registered lines. These superior accessions could be recommended for evaluation to determine their productivity or adoption. Since most of the accessions showed similarity to the registered varieties, it demonstrates the importance of Kenya's breeding programme in identifying cowpea varieties with similar characteristics as the famers' landraces.

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