ADAPTABILITY OF COWPEA (*Vigna unguiculata*) LINES IN KENYA COASTAL REGION

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ABSTRACT

Cowpea (*Vigna unguiculata* L. Walp.) is one of the most important grain legumes grown in sub-Saharan Africa. About 12.5 million tonnes of cowpea grain are produced worldwide each year with the majority (over 94%) of the production taking place on low input, subsistence farms. This crop is most important in the semi-arid and warm areas of Africa where other crops may fail due to poor adaptation to heat, drought and low soil fertility conditions. The objective of this study is to contribute to increased food production in coastal Kenya through development of high yielding, drought tolerant and farmer acceptable cowpea lines. The experiment was conducted Kenya Agricultural and Livestock Research Organization (KALRO), Mtwapa and its sub-centres at Msabaha and Mariakani. The agroecological zones for the sites are; coastal Lowland 3 for Mtwapa, coastal lowland 4 for Msabaha and coastal lowland 5 for Mariakani. The sites have sandy soils with pH of 5.3 to 6.9. Fifteen cowpea lines were sourced from the KARI Gene bank which included three improved cultivars that have been tested in central and eastern regions of Kenya. These genotypes have varying agronomic traits and were collected from various regions of Kenya. They are; K033057, K033073, K003731, K005169, K026753, K027092, K003962, K046781, K028613, K047079, K047078, K047121, KVU 27-1, M 66 and K 80. The checks were the local variety and improve variety K 80. Planting was done in the short rains season of 2012 and in the long rains season of 2013. Planting was done at a spacing of 60 cm × 30 cm. The trial was randomized complete block design (RCBD) with three replications. The data collected included both qualitative and quantitative traits. At maturity the different lines were harvested, weighed with the pods, then threshed and the grain yield per plot measured. 100 seed weight was also recorded per plot. The net plot was the two middle rows of the plot. The year effects were clearly manifested in the agronomic traits and seed quality of the cowpea evaluated. The superiority of K005169 in all the agroecological zones in high grain yield production is observed making the genotype a candidate for consideration in the breeding with others to introgress the genes for high yield potential. The 16 genotypes attained maturity within 70 to 76 days after planting and can therefore be classified as early maturing type. Of the 16 genotypes tested in the three agroecological zones of the lowland coast region, five have shown outstanding performance across the test environments. They are K005169, KVU 27-1, M66, K003962 and K046781. These genotypes have manifested their adaptability and stability across test

environments and can be recommended for introduction in the region and will contribute to increased production of cowpea.

Keywords: *Genotypes, Adaptation, Agroecological zones, Qualitative, Quantitative, Introgression*

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.) is one of the most important grain legume grown in sub- Saharan Africa (Ehlers and Hall, 1997; Timko and Singh, 2008). About 12.5 million tons of cowpea grain are produced worldwide each year with the majority (over 94%) of the production taking place on low input, subsistence farms in Africa (Langyintuo et al., 2003; FAOSTAT, 2013). This crop is most important in the semi-arid and warm areas of Africa where other crops may fail due to poor adaptation to heat, drought and low soil fertility conditions (Gwathmey and Hall, 1992; Ehlers and Hall, 1997; Singh et al., 1999; Singh and Matsui, 2002; Hall, 2004). Among the major six world producers of cowpea, five are located in Africa and include Nigeria, Niger, Bukina Faso, Senegal and Mali (Fery, 2002; FAOSTAT, 2013). Cowpea is the second most important grain legume in Kenya after beans *(Phaseolus vulgaris)* (Muthamia and Kanampiu, 1996). The area under cowpea in Kenya is estimated at 215,269 ha (FAOSTAT, 2013).

Although 85% of the total area under the crop is in Eastern province, cowpea ranks first among grain legumes in Coast province. The crop is mainly grown under intercropping systems with maize *(Zea mays)* and/or cassava *(Manihot esculenta).* Two characteristics add to its agronomic importance: the plant is generally drought tolerant and interacts with bacterial (Rhizobium sp.) to fix nitrogen in root nodule thereby enhances soil fertility especially when used in rotation with cereal (Eloward and Hall, 1987; Sanginga et al., 2003). It also play an important role in suppression of weeds, while at the same time it is eaten as a vegetable while growing and dry seed after maturity (Kamau and Weru, 2001). It is a deep rooted crop and grows well in sandy soils and is more tolerant to drought than other legumes (Dadson et al., 2003; Lauriault and Kirksey, 2007). The crop can fix about 240 kg ha^{-1} of atmospheric nitrogen and make available about 60-70 kg ha^{-1} for the succeeding crops grown in rotation with it (Kamau and Weru, 2001; CRI, 2006; Aikins and Afuakwa, 2008).

Cowpea is often referred to as ‘’poor man’s meat’’ because it has a high protein content of 20 -25% and good nutritional value (Diouf and Hilu, 2005). The mean crude protein levels for leaves, grains and crop residues are 32-34%, 23-35% and 11-12%, respectively (Imungi and Porter, 1983). The leaves are also a good source of minerals including Iron (Fe), Calcium (Ca), Phosphorous (P) and Zinc (Zn). The crop is highly palatable, very nutritious, and relatively free of anti-nutritive factors (Kay, 1979). The fruits are consumed at all stages of growth (e.g., green pods, fresh or dry seeds) and young leaves are often used for soups and stews (Quaye et al., 2009). In addition to its value as human food, cowpea hay is an important source of animal fodder (Tarawali et al., 2002).

Cowpea is well adapted to arid and semi-arid areas due to its morphological as well as genetic makeup. The deep rooted system and its earliness in maturity are some of the factors that make cowpea very adaptable to hostile environment. Other than being a major source of cheap protein, cowpea is a dependable source of income mainly from sale of leaves as a vegetable. Farmers at the coast of Kenya experience very low grain yields (100 -300 kg ha^{-1}) and this has been attributed to a number of factors including insect pest damage, lack of high yielding cultivars and poor crop management practices (Kega et al., 1994; Otieno et al., 1994). Another problem is lack of appropriate seed varieties at planting.

Justification

Cowpea is the pulse of choice in Coastal Kenya where it yields well compared to other pulses. It is among the staple foods in the region supplying basic energy, protein, vitamins and minerals (iron and calcium). It is an inexpensive source of protein in the diets of most communities at the coast. The varieties the farmers grow are inherently low yielding and it is against this background that new varieties could be introduced to the area by testing their adaptability with the objective of availing to farmers suitable high yielding varieties. The genotypes that show adaptability to the area can also be used in future breeding work for improvement of the local germplasm.

Drought also is increasingly becoming a major yield limiting constraint in coastal region. It is manifested in the form of high variability in rainfall amount and distribution over different agro-ecologies and seasons. Hence, a breeding programme aimed at developing adaptable cultivars needs to be established. Genotype by environment interaction and yield stability of different cowpea genotypes available in the country, need to be investigated in order to identify the adaptable and stable genotypes for different locations in the coastal region of Kenya. There is need to introduce new lines to test their adaptability and stability with the aim of recommending them to the farmers to boost the production of cowpea.

MATERIALS AND METHODS

Experimental Sites

The experiment was conducted at Kenya Agricultural and Livestock Research Organization), Mtwapa (former KARI) (E 039° 44.680'; S 03° 54.954') and its sub-centres at Msabaha (040° 02.327'; S 03° 54.954') and Mariakani (E 039° 28'; S 03° 50'). The agroecological zones (AEZ's) for the sites as described by Jaetzold and Schmidt, (2012) is coastal lowland 3 (CL3) for Mtwapa, coastal lowland 4 (CL4) for Msabaha and coastal lowland 5 (CL5) for Mariakani. The sites have sandy soils with pH of 5.3 to 6.9. The mean annual rainfall for Mtwapa and Msabaha is 1200 and 1000mm, respectively. For Mariakani, the mean annual rainfall is 800mm. In all those sites rainfall is bimodal with the long rains starting in April/May up to August. Short rains start in October and extend to December. However, due to the prevailing global climate change, rainfall is erratic and therefore cannot be predicted with precision like it was previously. The elevation at Mtwapa centre, Msabaha and Mariakani sub-centres is 30m, 15m 185m above sea level (asl), respectively.

Genotypes

Fifteen cowpea lines were sourced from the KARI Gene bank which included three improved cultivars that have been tested in central and eastern regions of Kenya. These genotypes have varying agronomic traits and were collected from various regions of Kenya (Table I).

Table 1: Cowpea genotypes indicating where collected and colour of the seeds

Genotype / Accession	Where collected	Seed colour
K033057	Eastern Province in Embu	Cream
K033073	Eastern Province in Embu	Cream
K003731	Eastern Province in Machakos	Cream.
K005169	Eastern Province in Machakos	Grey dotted
K026753	Eastern Province in Machakos	Black
K027092	Eastern Province in Machakos	Cream
K003962	Eastern Province in Machakos	Red
K046781	Eastern Province in Makueni	Red
K028613	Nyanza Province in Siaya	Cream
K047079	Western Province in Busia	Cream
K047078	Western Province in Busia	Cream
K047121	Western Province in Vihiga	Cream
KVU 27-1	improved cultivar	Dark red
M 66	improved cultivar	Cream
K 80	improved cultivar commonly grown	Cream
Local variety(Mnyeza)		Dark red

K80 is an improved cowpea variety that is well adapted in the coastal region and was one of the check varieties. It is a dual purpose type and can do well in drier regions at 200mm of rainfall. Its grains are creamy brown and its yield potential ranges from 1.8 – 2.0t/ha. The other check is one of the local landraces (mnyeza) in the area where the trials were conducted.

Planting the Trial

After generating enough seeds for the three sites earmarked for the trial, planting was done in the short rains season of 2012 and in the long rains season of 2013. Planting was done at a spacing of 60 cm × 30 cm at the seed rate of 10 kg $ha^{-1.}$ The trial was randomized complete block design (RCBD) with three replications. The location of the sites was at Mtwapa (CL3), Msabaha (CL4) and Mariakani (CL5). In Mtwapa the trial site was previously planted cassava and after ploughing and harrowing, planting was done on 22nd October 2012. In Msabaha the site was on a field where maize was previously planted. Planting was done on 7th November 2012 while at Mariakani the land was under fallow for two years and planting was carried out on 12th November 2012. In April 2013, ploughing and harrowing of the trial sites was carried out in the three locations. Planting of the trial was on 26th April 2013 at Mariakani, 29th April at Mtwapa and 30th April at Msabaha. The number of treatments per trial was sixteen which is the cowpea genotypes being tested that included the local check and the improved check variety (K 80). There were four rows in each plot whose spacing was 60×30 and two seeds were planted per hill. At planting, phosphate fertilizer was applied at a rate of 45kg of P ha^{-1}. Routine spraying as a control measure for biotic stresses was done using insecticides and fungicides. All the agronomic practices required were carried out. Weeding was done three times in all the sites.

Data Collection and Analysis

The data collected included both qualitative and quantitative traits – it was on stand count, days to emergence, days to flowering, days to pod-setting, days to maturity, number of pods per plant and number of seeds in a pod. At maturity the different lines were harvested, weighed with the pods, then threshed and the grain yield per plot measured. 100 seed weight was also recorded per plot. The net plot, or where the data was collected, was from the two middle rows of the plot.

The data was analyzed using the SAS program.

The statistical model was a follows;

$Y_{ijklm} = \mu + Ei + Y_j + R_{k\,(i-j)} + G_l + GE_{il} + GY_{jl} + GYE_{ijl} + \varepsilon_{ijklm}$; Where:

Y_{ijklm} - is the observation of l^{th} treatments (genotypes) in the k^{th} replication in the i^{th} environment.

μ - is general mean.

E_i - is location.

Y_j - is year.

R_k - is k^{th} replication in the i^{th} environment.

G_l - is l^{th} treatment in the k^{th} replicate.

GE_{il} - is the genotype and environment interaction.

GY_{jl} - is the genotype and year interaction.

GYE_{ijl} - is the genotype, year and environment interaction.

ε_{ijklm} - is the random error effect.

RESULTS

The potential of the genotypes were better revealed in 2013. The mean grain yield in the combined analysis was 915.89 and 1644.19 kg ha^{-1} in 2012 and 2013 respectively (Table II). Number of pods per plant, number of seeds per pod, length of seed, width of seed and weight of seed were also significantly higher in 2013 compared to data obtained in 2012. Cowpea planted in 2013 physiologically matured earlier than 2012 by four days (Table II). Pod weight was also significantly higher ($p < 0.05$) in 2013 (2591.63 kg ha^{-1}) compared to 2012 (1477.6 kg ha^{-1}). The mean weight of seed was 13.40 g in 2013, significantly different ($p < 0.05$) in 2012 with 12.19 g. From the combined analysis, the performance of the 16 genotypes in the three across test agro ecological zones (AEZ's) was significantly different ($p < 0.05$) for all traits except in pod weight. The mean grain yield from Mtwapa and Mariakani, 1371.82 and 1385.71kg ha^{-1} respectively were significantly different ($p < 0.05$) from Msabaha's. Flowering at Mtwapa took 46 days and was significantly different from the other two agroecological zones (Table III).

There was no significant difference between 2012 and 2013 for days to 50% flowering in both years at Mariakani (CL 5). However, the year effects were notable for all other variables measured to be significantly different ($p < 0.05$). Mariakani had the highest mean grain yield of 1984.4 kg ha^{-1} in 2013 and the lowest grain yield of 787 kg ha^{-1} in 2012 compared to means at Mtwapa and Msabaha. In 2012, cowpea flowered after 43 days at Mtwapa (CL 3) and flowered latest at Mariakani (CL 5) after 45 days. In the same year, pods were produced and plants matured at CL 3 after 50 and 61 days, respectively. The latest in 2012 to produce 50% of pods was CL 4 at 54 days and the latest to attain physiological maturity was in CL 5 at

79 days (Table IV). Compared with 2013, the number of pods produced per plant was lowest in 2012 across all the agro ecological zones (AEZ's) at 12, 16 and 25 pods in CL 5, CL 3 and CL4 respectively. During short rain season of 2012, the highest number of seeds per pod was produced in CL 4 (18 seeds) and lowest in CL 5 (13 seeds). The highest mean number of internodes per plant was also observed at CL 5 (13) and lowest at CL 3 (5). The lowest mean pod weight and the grain yield in 2012 were observed at CL 5 with 1231 kg ha^{-1} and 787 kg ha^{-1} respectively and the highest pod weight of 1705 kg ha^{-1} was detected at CL 4 and grain yield of 984 kg ha^{-1} at AEZ CL 3. The lowest 100 seed weight recorded that year was 10.16 g at CL 3 while the highest was at CL 4 with 13.47 g.

In the long rains of 2013, cowpea took 43 to flower at CL 4 compared to CL 3 where it took 48. Cowpea took 71 days to mature at CL 4 days in contrast to 80 days observed at CL 3. During this season, Mariakani (CL 5) had the highest pod weight and grain yield of 2927.1 and 1984.4 kg ha^{-1} respectively while the lowest was at Msabaha (CL 4) with 2204.3 and 1189 kg ha^{-1} of pod weight and grain yield respectively (Table IV). Weight of seed varied across the locations. The highest seed weight was at Mariakani (CL 5) (14.24 g) compared to Msabaha (13.49g) and Mtwapa (12.48 g) (Table IV). Genotype K026753, flowered the earliest (42 days) at CL 3 compared to K046781, M66 and K80 which took 49.3, 48.6 and 48.5 days, respectively (Table V). At Msabaha (CL 4), K003731 and K046781 took 42 days to flower compared to the rest of the genotypes. However, it took 46 days for K033073 to flower compared to two check varieties which flowered after 43 and 44 days (Table V).

At Mariakani in CL5, genotypes – K047079 and K047121 flowered significantly earlier at 43 days than others. The improved check (K80) and K033073 took significantly longer to flower than other genotypes at 47 days. Following was K027092 at 46 days. The local check (mnyeza) took 44 days to 50% flowering (Table V). K80 and M66 significantly ($p < 0.05$) took the longest to 50% podding at 56 days while the earliest to 50% podding was K026753 at 50 days in CL 3 (Table V). At CL 4, the earliest podding (52 days) were detected on genotypes K033057 and K047079 while K033073 and K047078 took 55 days to produce pods. The improved check (K80) achieved 50% podding at 53 days while the local check (mnyeza) at 54 days. There were no significant differences for podding days at CL 5 (Table V). At CL 3, K003962, K028613 and K027092 matured the earliest in 68 days, while K047078, K047079 and K046781 took the longest time (74 and 73 days) to mature. Further comparison showed that it took 70 days for local variety to mature (Table VII). At CL 4, it took 77 days for the local check to mature compared to 69 days for K003962. The improved check (K80) took 76 days to mature (Table VII). The variation in period it takes cowpea to mature was further noted at CL 5. In this region, K027092 took 69 days to mature followed by K033073 and KVU 27-1 at 72 days. The improved check (K80) attained physiological maturity at 80 days and the local check (mnyeza) 77 days. In fact, K047079 and K046781 took 81 days to mature. In this study, genotypes evaluated at CL 5 took longer time to mature compared to the other agro ecological zones.

There was variability among cowpea genotypes evaluated across the locations for the number of pods per plant. In AEZ CL 3, genotypes, K046781 and K005169 had significant high ($p < 0.05$) number of pods compared to the rest with 24 pods per plant. The improved check (K80) had 23 pods per plant while the local check had 19 pods per plant. KVU 27-1, one of the improved varieties being tested had significantly low ($p < 0.05$) number of pods with 15 pods / plant (Table V). At CL 4, the local check produced 34 pods per plant, a value that was higher than those observed on other genotypes. In comparison, 21 numbers of pods per plant were observed on K033073 (Table V). At AEZ CL 5, genotypes K047078 and K028613 produced 25 and 23 pods /plant in contrast to improved check (K80) and M66 which produced 21 pods per plant. The lowest number of pods was observed on K005169, K047121 and K003962. The local check had a mean of 19 pods per plant (Table V).

Table 2: Means of agronomic traits and seed quality of 16 cowpea genotype in 3 environments (Mtwapa, Msabaha and Mariakani) in 2012 and 2013.

Year	Days to 50% flowering	Days to 50% podding	Days to physiological maturity	Number of pods/plant	Length of pod (cm)	Number of branches/plant	Height of plant (cm)	Number of seeds/pod	Seed length (mm)	Seed width (mm)	Number of internodes	Pod weight (kg/ha)	Grain yield (kg/ha)	100 seed weight (g)
2012	44.31 a	52.92 b	72.52 b	17.68 b	17.21b	3.90 a	54.04b	15.36 b	7.19 b	5.89b	9.59 a	1477.6b	915.89b	12.19b
2013	45.73 a	54.62 a	76.06 a	25.75 a	18.06a	3.55 b	59.04a	17.30 a	7.24 a	5.96a	9.15 b	2591.6a	1644.19 a	13.40a
Lsd	0.529	0.474	0.768	1.151	0.316	0.134	2.416	0.389	0.073	0.061	0.354	182.00	114.35	0.216

NB: Means followed by same letter are not significantly different

TABLE 3: Means of agronomic traits and seed quality of 16 cowpea genotypes evaluated across 3 environments (Mtwapa, Msabaha and Mariakani)

Environ	Days to 50% flowering	Days to 50% podding	Days to physiological maturity	Number of pods/ plant	Length of pod (cm)	Number of branches/ plant	Height of plant (cm)	Number of seeds/pod	Seed length (mm)	Seed width (mm)	Number of internodes	Pod weight (kg/ha)	Grain yield (kg/ha)	100 seed weight (g)
Mtwapa (CL 3)	45.97a	52.89 c	70.98 c	20.27 b	17.13b	3.23 c	56.78b	15.66 b	6.91 c	5.71c	6.22 c	2069.90a	1371.82a	11.32b
Msabaha (CL 4)l	44.03 c	53.84 b	73.96 b	25.95 a	18.28a	3.52 b	58.79a	17.86 a	7.23 b	5.98b	10.06 b	1954.78a	1082.61b	13.48a
Mariakani (CL 5)	45.04 b	54.58 a	77.90 a	18.94b	17.47b	4.42 a	54.03b	15.46 b	7.51 a	6.07a	11.82 a	2079.28a	1385.71a	13.59a
Lsd	0.648	0.581	1.941	1.410	0.387	0.164	2.959	0.476	0.090	0.075	0.434	222.91	140.05	0.264

NB: Means followed by same letter are not significantly different

Table 4: Means of agronomic traits and seed quality of 16 cowpea genotype across three environments over two years.

Environ	Year	Days to 50% flowering	Days to 50% podding	Days to physiological maturity	Number of pods/ plant	Length of pod (cm)	Number of branches/ plant	Height of plant (cm)	Number of seeds/pod	Seed length (mm)	Seed width (mm)	Number of internodes	Pod weight (kg/ha)	Grain yield (kg/ha)	100 seed weight (g)
Mtwapa	**2012**	43.45 b	50.10 b	61.29 b	15.83 b	16.59b	3.29 a	51.53b	14.18 b	6.80 b	5.67a	4.71 b	1496.2b	984.38b	10.16b
	2013	48.50 a	55.68 a	80.68 a	24.72 a	17.67a	3.18 a	62.04a	17.14 a	7.02 a	5.76a	7.74 a	2643.5a	1759.26a	12.48a
Lsd		**1.292**	**1.099**	**1.041**	**1.656**	**0.472**	**0.220**	**2.283**	**0.657**	**0.120**	**0.106**	**0.474**	**231.99**	**60.605**	**0.330**
Msabaha	**2012**	44.14 b	54.43 a	76.67 a	25.25 b	18.75a	3.81 a	55.07b	18.28 a	7.23 a	6.00a	10.31 a	1705.3b	976.27b	13.47a
	2013	43.91 a	53.25 b	71.27 b	26.64 a	17.81b	3.23 b	62.50a	17.44 b	7.22 a	5.97a	9.80 a	2204.3 a	1188.95a	13.49a
	Lsd	**0.717**	**0.639**	**0.740**	**2.319**	**0.607**	**0.257**	**5.971**	**0.584**	**0.113**	**0.112**	**0.608**	**310.98**	**157.85**	**0.444**
Mariakani	**2012**	45.32a	54.22 b	79.58 a	11.98 b	16.26b	4.59 a	55.51a	13.61 b	7.54 a	6.01b	13.74 a	1231.5 b	787.0b	12.94b
	2013	44.77a	54.93 a	76.22 b	25.89 a	18.68a	4.24 b	52.56a	17.32 a	7.47 b	6.14a	9.90 b	2927.1a	1984.4a	14.24a
Lsd		**0.641**	**0.682**	**1.957**	**2.036**	**0.569**	**0.227**	**3.624**	**0.791**	**0.152**	**0.104**	**0.752**	**394.75**	**260.17**	**0.354**

NB: Means followed by same letter are not significantly different

Table 5: Days to flowering, days to podding, number of pods and length of pods of 16 cowpea genotypes in Mtwapa, Msabaha and Mariakani 2012/13

Germplasm	Days to 50% Flowering			Days to 50% podding			Mean No. of pods /plant			Mean length of pod (cm)		
	MTP	MSA	MRK	MTP	MSA	MRK	MTP	MSA	MRK	MTP	MSA	MRK
K033057	44.3 bc	43.34 cde	44.67 bc	50.8 cde	52.67 d	55.00 a	19.3 bcd	22.06 d	16.84 cde	17.4 bcde	19.11 abc	17.91 bcd
K028613	47.5 ab	44.00 bcde	45.84 ab	53.7 abcd	54.00 abcd	54.84 ab	19.5 bcd	24.72 bcd	23.06 ab	16.0 ef	16.34 f	15.33 fg
K047079	44.7 bc	44.17 bcde	43.84 c	53.8 abc	52.67 d	54.00 ab	18.4 cde	23.22 cd	18.45 abc	16.3 ef	18.98 abcd	18.70 bc
K033073	46.8 ab	46.34 a	47.00 a	53.8 abc	55.50 a	55.67 a	19.2 bcde	21.67 d	20.78 abc	15.8 f	16.81 ef	16.73 def
K005169	45.8 ab	44.17 bcde	44.50 bc	52.2 bcde	54.50 abc	55.17 a	24.5 a	27.67 bcd	16.67 cde	17.3 cde	17.31 def	16.67 def
K047121	46.5 ab	42.50 e	43.84 c	52.8 bcde	53.17 cd	54.17 ab	18.4 cde	25.67 bcd	14.56 de	18.0 abc	18.36 bcde	17.63 cde
K026753	42.2 c	43.17 de	45.50 abc	50.0 e	54.17 abcd	54.50 ab	22.9 abc	26.28 bcd	19.17 bcd	14.1 g	16.35 f	14.52 g
K003731	44.5 bc	42.83 de	44.50 bc	51.2 bcde	53.67 bcd	53.84 ab	20.6 abc	29.22 abc	19.50 abcd	17.4 bcde	18.41 bcde	16.04 efg
K046781	49.3 a	42.34 e	44.67 bc	54.0 ab	54.00 abcd	55.50 a	24.7 a	25.73 bcd	17.78 bcde	18.6 ab	20.36 a	20.35 a
K027092	44.2 bc	45.33 abc	46.00 ab	50.7 de	54.00 abcd	54.17 ab	19.5 bcd	23.39 bcd	18.72 bcd	18.**2** abc	18.74 abcd	19.21 abc
K003962	44.3 bc	43.50 cde	44.67 bc	50.8 cde	53.50 bcd	54.50 ab	14.7 de	24.06 bcd	12.89 e	19.3 a	19.81 ab	19.48 ab
M66	48.7 a	44.34 abcde	45.17 bc	56.5 a	53.33 bcd	54.00 ab	19.7 bc	26.61 bcd	21.17 abc	17.1 cdef	17.69 cdef	16.68 def
K80	48.5 a	44.17 bcde	47.00 a	56.7 a	53.50 bcd	55.00 a	23.5 ab	29.84 ab	21.17 abc	16.4 ef	18.21 bcde	16.73 def
KVU 27-1	45.8 ab	44.67 abcd	44.67 bc	52.2 bcde	53.50 bcd	55.17 a	14.5 e	24.17 bcd	17.73 bcde	18.7 ab	19.76 ab	19.09 abc
K047078	46.2 ab	46.00 ab	44.34 bc	53.2 bcd	55.00 ab	54.84 ab	23.5 ab	26.33 bcd	25.11 a	16.9 cdef	17.76 cdef	16.52 def
LOC (Mnyeza)	46.3 ab	43.67 cde	44.50 bc	54.0 ab	54.33 abcd	53.00 b	18.7 cde	34.61 a	19.50 abcd	16.8 def	18.51 bcde	18.02 bcd
MEAN	**46.0**	**44.03**	**45.04**	**52.9**	**53.84**	**54.58**	**20.1**	**25.95**	**18.94**	**17.1**	**18.28**	**17.48**
CV%	**4.2**	**2.60**	**2.17**	**3.7**	**1.42**	**1.28**	**15.3**	**12.60**	**15.99**	**7.5**	**6.55**	**9.18**

Means with the same letter are not significantly different.

Table 6: Number of seeds, seed length, seed width and number of internodes of 16 cowpea genotypes in Mtwapa, Msabaha and Mariakani 2012/13

Germplasm	Mean No. of seeds per pod			Mean Seed length (mm)			Mean seed width (mm)			Mean No. of internodes/plant		
	MTP	MSA	MRK	MTP	MSA	MRK	MTP	MSA	MRK	MTP	MSA	MRK
K033057	16.6 ab	17.45 bc	17.00 a	6.94 defg	7.38 bc	7.33 efg	5.95 bc	6.22 bcd	6.07 de	5.72 bc	9.00 c	11.39 bcdef
K028613	15.8 abc	17.28 bc	15.00 ab	6.55 i	7.05 def	6.95 gh	5.29 g	5.72 ghij	5.60 gh	6.11 abc	9.50 bc	13.17 abc
K047079	17.4 a	18.50 ab	17.06 a	6.57 hi	6.92 efg	7.60 def	5.74 cdef	6.15 bcd	6.43 bc	6.89 ab	9.33 c	14.83 a
K033073	14.6 cd	17.78 ab	15.11 ab	6.18 j	6.70 gh	6.88 h	4.83 h	5.40 j	5.68 gh	6.11 abc	9.61 abc	12.06 bcde
K005169	15.6 abc	17.28 bc	15.50 ab	7.03 cde	7.57 b	7.37 efg	5.90 c	5.80 efghi	5.82 fgh	5.67 bc	10.17 abc	11.06 cdef
K047121	14.9 bcd	18.33 ab	15.33 ab	6.82 efghi	7.18 cde	7.25 fgh	6.00 bc	6.12 bcde	6.32 cd	5.56 bc	10.17 abc	10.33 ef
K026753	13.3 d	16.11 c	13.89 b	6.58 hi	7.17 cde	7.27 fgh	5.29 g	5.92 defgh	5.77 fgh	6.78 ab	10.06 abc	11.78 bcdef
K003731	14.3 cd	18.06 ab	15.00 ab	6.90 efgh	7.18 cde	7.32 efg	5.79 cde	6.05 cdef	6.05 def	7.17 a	10.00 abc	10.89 def
K046781	16.3 abc	18.00 ab	15.00 ab	7.74 a	7.93 a	8.55 a	6.39 a	6.75 a	6.95 a	6.22 abc	10.28 abc	11.39 bcdef
K027092	15.5 abc	18.83 ab	15.72 ab	7.27 bcd	7.55 b	7.72 cde	5.71 cdef	5.97 defgh	5.87 efg	6.89 ab	10.06 abc	9.78 f
K003962	16.6 ab	19.28 a	15.89 ab	7.50 ab	7.60 b	8.30 ab	6.21 ab	6.03 cdefg	6.50 bc	6.22 abc	11.06 ab	11.56 bcdef
M66	15.2 bcd	17.67 abc	15.89 ab	6.60 ghi	6.53 h	7.05 gh	5.58 efg	5.77 fghi	5.88 efg	7.11 a	9.95 abc	13.50 ab
K80	16.4 ab	17.95 ab	14.94 ab	6.68 fghi	6.83 fgh	7.27 fgh	5.48 fg	5.68 hij	5.75 gh	5.61 bc	11.33 a	12.28 bcde
KVU 27-1	15.3 bc	18.11 ab	15.61 ab	7.35 bc	7.32 bcd	8.03 bc	5.99 bc	6.32 bc	6.63 b	5.39 c	10.33 abc	12.67 bcd
K047078	14.4 cd	17.72 abc	15.00 ab	6.89 efghi	7.17 cde	7.28 fgh	5.51 efg	5.48 ij	5.55 h	5.72 bc	10.11 abc	12.11 bcde
LOC (Mnyeza)	15.9 abc	17.50 bc	15.50 ab	7.02 cdef	7.62 ab	8.00 cd	5.83 cd	6.42 b	6.30 cd	6.44 abc	10.06 abc	10.44 ef
MEAN	**15.5**	**17.86**	**15.47**	**6.91**	**7.23**	**7.51**	**5.7**	**5.99**	**6.07**	**6.2**	**10.06**	**11.83**
CV%	**6.8**	**4.04**	**5.04**	**5.82**	**5.17**	**6.45**	**6.8**	**5.83**	**6.72**	**9.5**	**5.70**	**10.91**

Means with the same letter are not significantly different.

Generally, the mean number of seeds per pod also varied across the three environments. An average number of seeds per pod (17) was detected on K047079 at AEZ CL 3 in contrast to 13 seeds/pod observed on genotype K026753. The local check (mnyeza) and the improved check (K80) had 16 seeds per pod (Table VI). At CL 4, K003962 bore pods that contained an average of 19.27 seeds which was significantly higher ($p < 0.05$) than K026753 (16 seeds per pod). The improved check (K80) had an average of 17 seeds per pod as was the local check (mnyeza). Genotypes K047079 and K033057 produced a mean number of seed per pod of 17 at CL 5. Significantly few ($p < 0.05$) seeds per pod were in variety K026753 with a mean of 13.88 seeds per pod. The local check (mnyeza) and the improved check (K80) had 15 seeds per pod and competed well with other genotypes (Table VI).

The seed weights of genotypes tested at AEZ CL 3 were comparatively lower than those in other agroecological zones (Table VII). An average seed weight of 14.9 g was observed on K046781 in CL 3. The seeds of check variety, K80 and local check weighed 10 g and 11 g respectively. The lowest seed weight of 8.7 g was noted on genotype K033073 in CL 3. Just like in CL 3, the genotype with significantly ($p<0.05$) low 100 seed weight recorded in CL 4 was K033073 with 11.81 g. The one with the significantly high ($p < 0.05$) weight recorded was K046781 with a mean weight of 16.31 g. The local check (mnyeza) and the improved check (K80) had 14.5 g and 12.93 g in CL 4 (Table VII). Comparatively, in CL 5, the highest seed weight of 17.56 g was observed on genotype K046781 and was followed by K003962 (16.37 g) and KVU 27-1 (15.32 g). Seeds from both local check and improved check exhibited an average weight of 14.73 g and 12.47 g respectively. The weight of seed from K028613 and K033073 were among the lowest (Table VII).

At Mtwapa site (CL 3), grain yield also varied among the genotypes and the best yielding genotypes - K005169, produced grain yield of 2025.5 kg ha^{-1} compared to the improved check K80 (1657.4 kg ha^{-1}). These genotypes produced 32% and 17% more than the local check which produced 1377.3 kg ha^{-1}. The lowest significantly different ($p < 0.05$) grain yield was in genotype K047121 with 1159.72 kg ha^{-1}. (Table VII). At CL 4, the highest significantly different ($p <0.05$) grain yield were observed in genotype K005169 with 1439.8 kg ha^{-1}. It was followed by KVU 27-1, K003962, K046781, M66 and K80 at 1395.8, 1331, 1169, 1136.6 and 1092.6 kg ha^{-1} respectively. The local check had yield of 990.7 kg ha^{-1} and had out yielded K027092, K033073, K033057, K003731 and K047079 which had low significantly different ($p < 0.05$) yield (Table 10). In Mariakani, CL 5 the highest significantly different ($p < 0.05$) grain yield were recorded in genotype KVU 27-1 with 1782.4 kg ha^{-1}. It was followed by K005169 and M66 with 1708.3 and 1588 kg ha^{-1} respectively. K80, the improved check and the local check (mnyeza) gave yield of 1527.8 and 1463 kg ha^{-1} respectively. The lowest significantly different yield was 993.1 kg ha^{-1} by K047121 (Table VII).

DISCUSSION

The fact that that there were significant differences ($p < 0.05$) in most of the variables measured due to the effects of the year (season), environment and the year × environment interaction in the combined analysis is evident of the genetic variability of the 16 genotypes under test in three agro ecological environments. The effect of the genotype × year interaction on the 16 genotypes was of no consequence on the seasons. The genotype × environment interaction indicates the effect it had on the expression of the genotypes in various characters studied. This is a pointer that not all genotypes express their potential similarly in different environments. So there is need to select particular genotypes in different environments. This observation supports the earlier reports of Agbogidi and Ofuoko (2005) that plants respond differently to environmental factors based on their genetic makeup and their adaptation capability indicating variability among species.

The potential of the genotypes were better expressed in long rains 2013 compared to short rains 2012 due to favorable weather prevailing in 2013. In the short rains 2012, the rainfall recorded from November 2012 when the cowpea were planted to February 2013 when the crop was harvested was 67.95mm, 59.63mm and 83.95mm in Mtwapa (CL 3), Msabaha (CL 4) and Mariakani (CL 5). In the second planting in the long rains of 2013, from April to July the rainfall recorded in the sites at Mtwapa, Msabaha and Mariakani was 165.85mm, 134.85 and 141.1mm.

Table VII: Mean height of plants (cm), number of days to physiological maturity, grain yield (kg/ha) and 100 seed weight (g) of 16 cowpea genotypes tested at Mtwapa, Msabaha and Mariakani 2012/13

Germplasm	Mean height of plant (cm)			Days to 50% physiological maturity			Mean grain yield (kg/ha)			Mean 100 seed weight (g)		
	MTP	MSA	MRK	MTP	MSA	MRK	MTP	MSA	MRK	MTP	MSA	MRK
K033057	56.17 b	54.16 ab	57.67 abc	70.83 bcdef	74.50 bcd	77.34 abc	1481.9 bc	923.61 c	1391.67 ab	11.67 def	14.56 bc	12.83 de
K028613	48.24 c	56.74 ab	62.11 a	69.50 g	76.00 ab	79.50 a	1277.8 bc	1000.00 abc	1315.28 ab	9.53 hi	12.56 ef	11.83 ef
K047079	56.98 b	60.16 ab	50.28 bc	71.50 ab	71.00 fg	81.17 a	1288.9 bc	908.33 c	1430.56 ab	11.29 def	13.14 de	14.41 c
K033073	56.03 b	70.12 a	53.06 abc	69.83 fg	71.67 fg	72.00 cd	1294.4 bc	923.61 c	1113.89 ab	8.78 i	11.81 ef	11.26 f
K005169	65.31 a	51.84 b	50.34 bc	69.67abcde	73.84 cde	80.84 a	2025.0 a	1438.89 a	1708.33 ab	11.16 efg	13.37 bcde	13.06 d
K047121	56.84 b	61.52 ab	58.61 ab	71.50 bcdef	75.34 abc	79.84 a	1159.7 c	1005.56 abc	993.06 b	12.06 cde	13.31 cde	13.41 d
K026753	44.23 c	56.88 ab	51.00 bc	70.5 bcdefg	72.00 ef	78.67 a	1175.0 c	1048.61 abc	1036.11 b	9.67 hi	12.54 ef	12.05 ef
K003731	59.09 ab	60.60 ab	49.10 bc	70.00 defg	76.00 ab	76.00 abc	1179.2 c	913.89 c	1336.11 ab	11.12 fg	13.37 bcde	13.11 d
K046781	60.81 ab	63.99 ab	51.62 bc	73.13 abc	74.00 bcde	81.00 a	1252.8 bc	1168.06 abc	1583.33 ab	14.90 a	16.32 a	17.57 a
K027092	57.88 b	51.84 b	48.34 c	68.34 g	72.67 def	69.00 d	1295.8 bc	958.33 bc	1208.33 ab	12.15 cd	12.83 ef	13.32 d
K003962	59.50 ab	58.82 ab	53.22 abc	68.00 g	69.67 g	80.84 a	1490.3 bc	1330.56 abc	1284.72 ab	13.38 b	14.62 b	16.37 b
M66	57.94 b	57.69 ab	53.28 abc	72.67 abcd	74.17 bcd	80.17 a	1527.8 bc	1137.50 abc	1587.50 ab	10.23 gh	12.76 ef	12.63 de
K80	61.83 ab	65.62 ab	57.95 abc	72.0 abcdef	76.00 ab	79.83 a	1656.9 ab	1093.06 abc	1527.78 ab	10.27 gh	12.93 def	12.47 de
KVU 27-1	48.89 c	59.00 ab	57.84 abc	69.67 efg	74.67 bcd	72.83 bcd	1290.3 bc	1395.83 ab	1781.94 a	12.77 bc	14.09 bcd	15.33 c
K047078	59.91 ab	50.66 b	53.61 abc	74.67 a	74.67 bcd	79.67 a	1176.4 c	1086.11 abc	1409.72 ab	11.01 fg	13.01 def	13.12 d
LOC (Mnyeza)	59.00 ab	61.06 ab	56.56 abc	70.34 cdefg	77.33 a	77.84 ab	1377.8 bc	990.28 bc	1463.89 ab	11.15 efg	14.46 bc	14.73 c
MEAN	**56.79**	**58.79**	**54.03**	**70.76**	**73.97**	**77.91**	**1371.9**	**1082.64**	**1385.76**	**11.36**	**13.48**	**13.59**
CV%	**9.52**	**8.93**	**7.36**	**2.49**	**2.82**	**4.69**	**16.5**	**15.90**	**16.34**	**3.57**	**8.13**	**12.46**

Means with the same letter are not significantly different.

This explains the superior performance observed in 2013 as opposed to 2012 in the grain yield and other yield components. In the short rains of 2012, in all the agroecological sites where the trials were carried out, it was noted that the days to 50% flowering, to 50% podding and to 50% physiological maturity came much earlier than in the long rains of 2013. This is due to weather condition which triggered the genotypes to mature early for their survival. In the long rains season of 2013, the mean days to 50% flowering was 45.5. The days to physiological maturity were longer with a means of 75.5 days. This is due to the higher rainfall that was well distributed during this season that afforded expression of the genetic potential of the genotypes. In all the agroecological zones, the superiority of genotype K046781 in terms of the highest significant ($p < 0.05$) 100 seed weight is observed across all three agroecological zones. K033073 shows the lowest 100 seed weight across the three AEZ's suggesting its low genetic potential in seed weight.

The superiority of K005169 in all the agroecological zones in grain yield was observed making the genotype a candidate for consideration in breeding to introgress the genes for high yield potential. The 16 genotypes attained maturity within 70 to 76 days after planting. Egbe et al (2010) classified cowpea varieties that matured in ≤ 60 days as extra early, 61 -80 as early and > 80 days as late. Therefore, most of the 16 genotypes could be classified as early maturing. In CL 5, two genotypes took longer to attain physiological maturity at 81 days and could be classified as late maturing in that specific environment.

There seem to be a relationship between the number pods per plant and the grain yield. In all the AEZ's, genotype K026753 recorded the lowest number of pods per plant and is among the lowest grain yielder. K005169 recorded high number of pods in all the AEZ's and it is among the highest grain yielder. The number of seeds per pod follows the same trend. Genotype K026753 recorded significantly low number of seeds per pod in all the agro ecological zones. The genotype having the highest 100 seed weight is K046781 which indicate its genetic potential and is suitable to consider in crossing with other genotypes for introgression of that characteristic. The superiority of the improved cowpea genotypes of KVU 27-1, M66 and K80 is manifested across the three agro ecological environments. Not to be outdone is the local check across the environment too. Other genotypes that performed impressively in specific environment are K003962 and K033057 in AEZ CL 3.

In CL 4, other genotypes that had good performance are K003962 and K046781 while in CL 5 genotypes with promising results apart from the ones with good performance across the environments were K046781, K047079 and K047078. K003962 and K033057 are collections from Machakos and Embu, respectively. K046781 is a collection from Makueni while K047079 and K047078 are from Busia. The climatic condition of all these environments is quite diverse and is indication of cowpea genotypes suitability in wide environments. The improved check (K80) and the local check performance in terms of grain yield was impressive across the three agro ecological zones where the study was carried out. They will be included in the breeding program so that their unique genetic characteristics can be used in development of new varieties.

CONCLUSION

Of the 16 genotypes tested in the three agroecological zones of the lowland coast region, five have shown outstanding performance across the test environments. They competed well and some even out performed K80, the improved check variety that is popular in the region currently. They are K005169, KVU 27-1, M66, K003962 and K046781. These genotypes have manifested their adaptability and stability across test environments and can be recommended for introduction in the region and will contribute to increased production of cowpea. The other genotypes had also some unique qualities which can be exploited for development of new superior genotypes in terms of earliness, drought tolerance, high number of pods, more seeds per pod, etc. All those characteristics contribute to the superiority of the genotype. K026753 and K003731 are early flowering while K027092 and K033073 attain maturity early compared to other genotypes. A cowpea breeding program can be started at KALRO Mtwapa now that some characterizations of those sixteen genotypes have been done. This can be by establishment of a crossing block of all those genotypes where crosses can be done. Meanwhile for the aforementioned five genotypes with superior performance, multiplication of seeds could commence for distribution to farmers in the region.

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