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Article *in* Plant Breeding and Biotechnology · March 2019

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Plant Breed. Biotech. 2019 (March) 7(1):12~23
https://doi.org/10.9787/PBB.2019.7.1.12
Online ISSN: 2287-9366
Print ISSN: 2287-9358

RESEARCH ARTICLE

Evaluation of Advanced Breeding Lines of Cowpea (*Vigna unguiculata* L. Walp) for High Seed Yield under Farmers' Field Conditions

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ABSTRACT Climate change has imposed greater challenge on cowpea production in the savannah ecology of West Africa sub-region in the recent time, however, development of varieties that combined resilience (stability) and precocity with high seed yield would be a sustainable approach to mitigate this problem. To this end, nine advanced breeding lines were evaluated along with two commercial varieties across three locations in guinea savannah ecology, using a randomized complete block design of three replications. Results obtained for seed yield and yield components indicate that the eleven cowpeas exhibited substantial variability for all plant traits studied and implications discussed. Additive Main Effect and Multiplicative Interaction (AMMI) analysis however revealed that the variations recorded were substantially attributable to genotypic component (70-80%) and less of environment (0.7-7.0%), a measure of phenotypic stability of these cowpea lines. However, seed yield and yield components vary significantly across the three locations, which further emphasize the important role of soil and climatic variables to cowpea production. In this study, two varieties (IT07K-299-6 and IT11K-61-82) consistently combined high seed yield (> 2 tons/ha) with precocity across the three locations, and could be multiplied for distribution to farmers as short-term intervention for yield increase. Reduced seed viability of these varieties reflects seed storage challenge in cowpea farming. In addition to significant contributions of some yield components to seed yield, there was evidence of strong association between precocity and high yield, and its implication for cowpea improvement discussed.

Keywords Cowpea breeding, Genetic variability, Guinea savannah ecology, Seed yield & Yield components, Varietal development

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.), remains one of the main staple food legume and cheap source of protein for millions of poor inhabitants of low-land humid and dry savannah regions of Africa. Timko *et al*. (2007) opined that cowpea plays a critical role in the lives of millions of people of Africa and other parts of developing world, where it is used to supplement cereal- and tuber- based diets that are of low protein content. Cowpea recipes could also substitute for animal proteins in vegetarian diets because of its rich protein and amino acids (Alghali 1991; Boukar *et al*. 2011). In addition to its rich nutritional value, cowpea has become a valuable component of farming system in many countries across West Africa sub-region because of its ability to restore soil fertility through nitrogen fixation (Carsky *et al*. 2002; Tarawali *et al*. 2002; Sanginga *et al*. 2003). Hay produced from cowpea plant residues also play major role in the feeding of ruminant animals during the dry season in many northern parts of West Africa (Tarawali *et al*. 2002).

Nigeria is a major producer of cowpea as it accounts for about 61% of total seed production in Africa (http://www.iita.org/crops/cowpea; last visited in 24th September, 2018), with production of about 3.6 million metric tons in

Received October 13, 2018; Revised December 22, 2018; Accepted December 22, 2018; Published March 1, 2019
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2016 (www.fao.org/faostat/en/#data/QC; last visited in 23rd July, 2018). This high volume of production demonstrates the importance of cowpea cultivation as a component of Nigerian farming system, with cultivation expanding beyond northern region traditionally known for the crop in recent time (Nwofia *et al*. 2006; Akande *et al*. 2012). However, in spite of the enormous economic, nutritional and ecological/environmental benefits offered by cowpea as food and commodity crops for people of sub-Sahara Africa, its production has been seriously affected by low seed yield. Available statistics indicate significant low yield across years (http://faostat.fao.org/site/339/default.aspx.), with yield at farm-gate far below the optimum. Studies have shown that low yield of below 500 kg/ha are prevalent in the sub-Sahara region (Adipala *et al*. 1997; Oyekanmi and Sangodoyin 2007). Mortimore *et al*. (1997) had also reported cowpea yield of 110 kg/ha on farmers' fields in the northern guinea savannah of Nigeria, an area considered as heart of cowpea production in West and Central Africa. Generally, farmers-traditional cultivars are known to be well adapted to the low input conditions, but often exhibit very poor yield with indeterminate/late plant maturity and highly susceptible to drought and major diseases and pests. And concerted efforts made by national and regional breeding programs to address these production constraints have yielded limited success because of the diverse ecological space and poor extension services in West Africa sub-region. Thus, in order to achieve significant cowpea yield improvement in farmers' fields there is an urgent need to compliment national and regional efforts through adoption of Researcher-Farmers' participatory model that is agro-ecologically focused. Evidently, yield is known to be a complex phenotypic trait in plants with many interwoven physiological and developmental traits controlled by different arrays of genes. And understanding interrelationship among yield component constituents (Oladejo *et al*. 2011) and the environment (Nwofia 2012) is vital to developing varieties that will produce high and stable seed yield, but above all adapted to different agro-ecological environments. Okeleye *et al*. (1999) had advocated for development of varieties that are adaptable to guinea savannah ecology, often characterized by high rate of crop failure, because of unreliable total amount, distribution and duration of rainfall. Such improved varieties are not readily available to farmers in this region today. As a strategy to bridge this gap, 21 cowpea breeding lines from International Institute of Tropical of Agriculture (IITA), Ibadan, Nigeria were initially evaluated for three years to select promising high yielding and adaptable cowpea varieties for guinea savannah agroecology. And that study led to identification of nine lines with potential for high yield (Aliyu and Makinde 2016). Meanwhile, Oyekanmi and Sangodoyin (2007) had opined that such promising lines should be evaluated across multiple locations for grain-seed yield before introduction to national seed system and final release to farmers. Thus, this study set to evaluate these selected nine advanced cowpea breeding lines with potentials for high grain-seed yield along with two commercial varieties on farmer's fields across three locations in Kwara State located in the guinea savannah agro-ecology.

MATERIALS AND METHODS

Eleven cowpea genotypes which include nine advanced breeding lines and two commercial varieties as checks were evaluated across three locations during the 2017 cropping season. The nine breeding lines (IT07K-299-6, 1T08K-126-19, IT08K-150-12, IT08K-150-24, IT10K-125-100, 1T10K-815-5, IT10K-837-1 and IT11K-61-82) were selected from previous pre-breeding evaluation study (Aliyu and Makinde 2016). Seeds of these advanced breeding lines were sourced from IITA, Ibadan and the commercial varieties (Ife Brown and TVX 3236) were sourced from National Seed Service. Three farming communities known for cowpea cultivation were selected viz., Eleyoka from Ifelodun Local Government Area, Malete and Shao from Moro Local Government Area, all in Kwara State and the climatic attributes of these selected locations presented (Fig. 1). Kwara State is demographically an agrarian state with a total land area of 36,852 km^2 and is located in the guinea savannah ecology of Nigeria. It is bordered in the south and north by the tropical forest and Sudan savannah ecologies, respectively. Soil samples were collected from each farm site in 4 replicates for physical

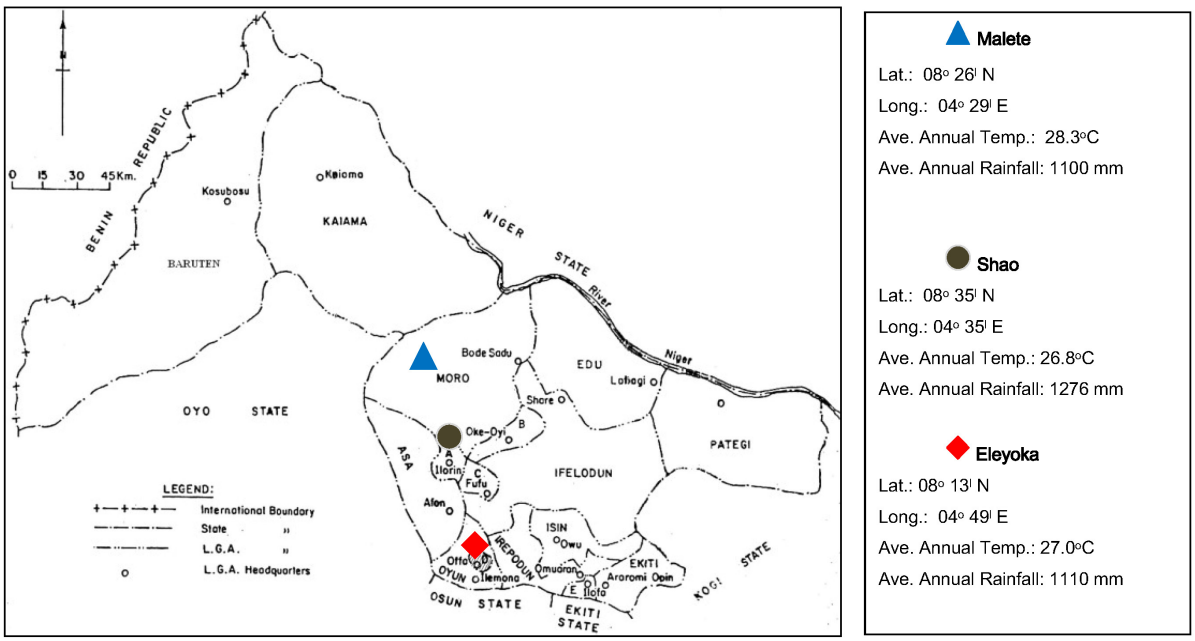


Fig. 1. Map of Kwara State showing the three experimental locations (farms) and their climatic characteristics.

and chemical analyses to have an overview of the nutrient status of the soils and their implication on cowpea yield. Processed soil samples were analyzed at IITA laboratory and results of physical and chemical parameters of the soils are presented in Supplementary Tables S1 and S2, respectively. Each field trial, consisting of 11 varietal treatments was laid out in a randomized complete block design (RCBD) and replicated thrice. And each treatment plot consists of two rows of 10 m length with 1.0 m of alley between plots. Two seeds were planted per hole at spacing of 0.3 × 0.6 m and thinned down to one after 2 weeks of germination, thus, giving effective plant population of about 55,555 plant/ha. Planting was done during 2017 cropping season (July-October 2017) with sowing done across the three locations within 48 hours to minimize variation in volume of precipitation. The experimental plots were manually weeded thrice and field pests were managed with fortnight spraying of cypermethrin™ and pendimethaline at the rate of 20 g a.i/ha, until pod maturity. Plant data were collected on survival count (%) (SVC), pod maturity (PDM), pod seed fill (POF), pod length (cm) (POL), pods per plant (PPP), seeds per pod (SPO), seeds per plant (SPP), 100-seed weight (g) (HSW), seed weight per plant (SWP), and seed-grain yield per hectare (kg) (YPH). Pod maturity was ranked into 1.00 (95% pod maturity less than 45 days after sowing), 3.00 (95% pod maturity at 45-60 days after sowing) and 5.00 (95% pod maturity later than 60 days after sowing). All data were summarized and statistically analyzed for analysis of variance and Additive Main Effect and Multiplicative Interaction (AMMI) analysis using GENSTAT softwares (13.0 version) by VSN International (www.vsni.co.uk/software/genstat).

RESULTS

Results of analysis of variance indicate that the 11 cowpea varieties exhibited significant different ($P < 0.01$) for plant survival count and all the seed yield component traits evaluated (Table 1). Similarly, locations and its interaction with variety (L × V) recorded significant differences ($P < 0.05$ and $P < 0.01$) for all the plant traits studied. The results also showed that yield components such as yield per hectare, and seed per plant recorded very high coefficients of variation and contrastingly, moderately low variation for pod length, pods per peduncle, seeds per pod and individual (hundred) seed weight (Table

Table 1. Level of variability of yield and yield components traits in 11 cowpea varieties across three locations.

Source of variation	Degree of freedom	SVC[z]	PDM[y]	POF[x]	POL[w]	PPP[v]	SPO[u]	SPP[t]	HSW[s]	SWP[r]	YPH[q]
Replication	2	12.28	0.04	0.00	0.78	0.00	0.87	3384.00	1.07	91.00	280866.00
Variety	10	528.90**	21.01**	0.32**	95.15**	2.07**	104.50**	74946.00**	45.59**	1478.73**	4563890.00**
Location	2	166.25**	1.73**	0.02	29.62**	0.35**	49.76**	3922.00	3.05*	104.61*	322862.00*
Variety x Location	20	38.27**	0.53*	0.18	2.93*	0.09**	4.92*	8576.00**	1.75	125.09**	386079.00**
Error	44	10.92	0.22	0.01	1.57	0.02	2.27	1986.00	0.98	36.51	112671.00
Mean		19.34	3.10	0.97	14.77	2.36	14.06	164.85	14.00	22.87	1270.68
Range		4.00-39.00	1.00-5.00	0.54-1.39	9.65-26.65	1.80-4.20	7.50-27.80	24.89-530.64	7.94-18.77	3.07-69.41	170.66-3855.92
Coefficient of variation (%)		43.77	49.94	21.79	23.42	21.23	23.42	63.23	17.05	62.20	62.20

*, ** and *** stand for significant at the 0.5, 0.1 and 0.01 probability level, respectively.
[z]Plant survival count, [y]Pod maturity, [x]Pod-seed filling, [w]Pod length (cm), [v]Pods per peduncle, [u]Seeds per pods, [t]Seeds per plant, [s]Hundred seed weight (g), [r]Seed weight per plant (g), [q]Seed yield per hectare (kg).

1). Grand mean values of these data (Table 1) indicate that this group of cowpeas had about 55% plant survival rate, predominantly medium maturing with pod-seed fill of 97%, pod length of 15 cm, two pods per peduncle, 14 seeds per pod and 165 seeds per plant. These varieties are predominantly medium seed size (0.14 g/seed), with average seed yield of 1.2 tons/ha (Table 1). Summarized data across the 3 experimental locations indicate that cowpea plants performed comparably better in Malete with Shao being the least (Table 2). However, among the 11 varieties, IT07K-299-6 and IT11K-61-82 recorded significant better performance by combining high plant survival rate with early maturity (precocity) and high seed yield of more than 2 tons/hectare. TVX-3236 was the most viable among the lots, which is about three times better than the poorest variety (IT10K-817-7). Five varieties (46%) among these cowpeas are late maturing and while three (27%) each exhibited early and medium maturities, respectively (Table 2). In time of pod size, IT10K-837-1 is characterized by very long pods, which is about twice length of TVX-3236 and Ife Brown pods. High number of pods per peduncle was mostly recorded for IT11K-61-82, TVX-3236, and IT07K-299-6; with about 41%, 33%, and 14% above the group mean (Table 2). Comparably, IT07K-299-6 and IT08K-150-12 exhibited efficient seed development than other nine varieties, with about 120% in pod-seed fill. Production of large seeds differentiates IT10K-837-1 from the rest of the varieties.

For brevity, G × E data of plant characters and seed yield components were analyzed with AMMI statistical procedure, summarized and presented as biplots of principal components (Fig. 2a-j). And overview of this AMMI analysis shows that variation in cowpea attributes is more of genotype (variety) than environment (location) (Fig. 2a-j), with between 70% and 89% variability due to varietal effect, and 0.7% and 7% to environment (data not shown). TVX-3236, IT11K-61-82 and IT07K-299-6 were best three varieties in terms of plant survival rate across the 3 locations, with performance in Malete being exceptionally higher than other locations (Fig. 2a). In terms of pod maturity, IT11K-61-82, IT10K-815 and IT07K-299-6 are the most precocious varieties (Fig. 2b). For pod-seed fill efficiency, IT08K-126-19, IT07K-299-6, IT08-150-12 and IT11K-

Table 2. Mean values of 11 cowpea varieties and performance in three locations.

	SVC[z)]	PDM[y)]	POF[x)]	POL[w)]	PPP[v)]	SPO[u)]	SPP[t)]	HSW[s)]	SWP[r)]	YHP[q)]
Location										
Shao	50.06	3.36	0.94	14.18	2.28	13.04	153.40	14.06	20.96	1164.00
Malete	62.43	2.94	0.99	15.86	2.48	15.43	175.20	13.67	24.48	1360.00
Eleyoka	53.34	3.00	0.97	14.27	2.31	13.73	165.90	14.27	23.18	1288.00
LSD (0.05)	4.68	0.23	0.04	0.62	0.07	0.74	22.11	0.49	2.99	166.50
Variety										
IT07K-299-6	83.49	1.00	1.19	17.66	2.68	21.07	360.00	14.10	50.53	2807.00
IT08K-126-19	58.40	3.00	1.14	14.81	2.14	16.69	223.00	15.26	33.76	1876.00
IT08K-150-12	42.23	3.00	1.21	12.75	2.09	15.42	96.40	14.88	14.03	779.00
1T08K-150-24	50.80	4.33	0.83	13.72	2.00	11.31	135.70	15.06	20.90	1161.00
ITK10K-125-100	43.49	3.00	0.75	15.68	2.00	11.73	64.20	14.34	9.40	522.00
IT10K-815-5	48.26	1.00	1.13	14.27	2.42	16.08	170.50	15.05	25.29	1405.00
IT10K-817-7	23.80	5.00	0.84	13.98	2.01	11.42	88.50	15.21	13.43	746.00
IT10K837-1	38.40	3.66	0.67	22.80	2.08	15.24	130.30	17.19	22.00	1222.00
IT11K-61-82	87.63	1.00	1.06	14.40	3.32	15.22	285.00	12.91	36.56	2031.00
Ife Brown	42.54	5.00	0.98	11.66	2.06	11.38	163.20	9.22	15.29	849.00
TVX-3236	88.89	4.11	0.85	10.74	3.13	9.14	96.60	10.78	10.40	578.00
LSD (0.05)	7.20	0.19	0.13	1.25	0.11	1.06	44.96	0.88	5.14	285.80
Mean	55.26	3.10	0.97	14.77	2.36	14.06	164.90	14.00	22.87	1271.00

[z)]Plant survival count, [y)]Pod maturity, [x)]Pod-seed filling, [w)]Pod length (cm), [v)]Pods per peduncle, [u)]Seeds per pods, [t)]Seeds per plant, [s)]Hundred seed weight (g), [r)]Seed weight per plant (g), [q)]Seed yield per hectare (kg).

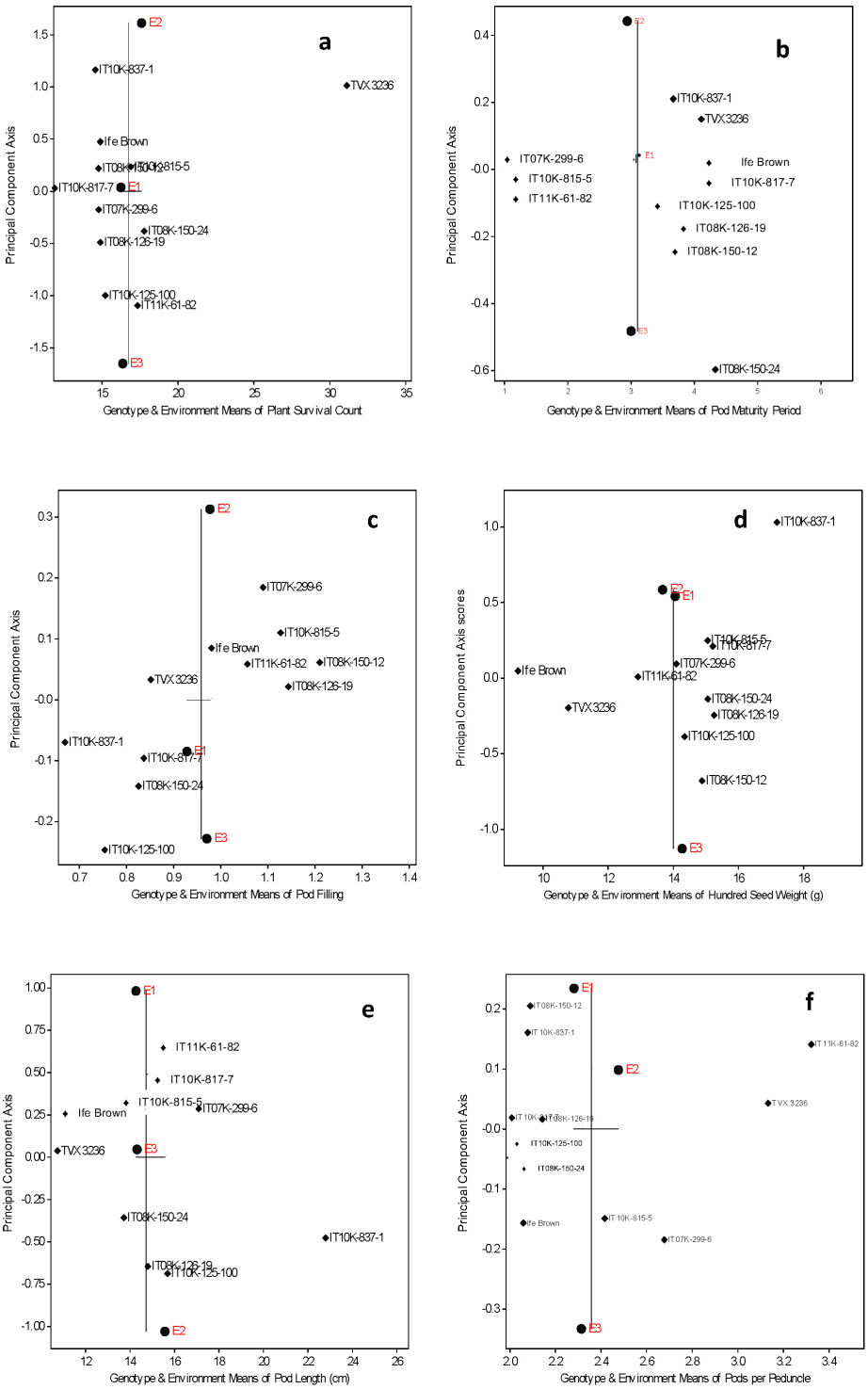


Fig. 2. Additive Main Effect and Multiplicative Interaction (AMMI) analysis biplots of Genotype x Environment Means of (a) Plant Survival Count (rate), (b) Pod Maturity Period, (c) Pod-seed filling efficiency, (d) Hundred seed weight, (e) Pod length (cm), (f) Pods per peduncle, (g) Seeds per pod, (h) Seeds per plant, (i) Seed weight per plant and (j) estimated total seed yield per hectare of data from 11 cowpea varieties across three experimental locations. Locations are indicated in AMMI biplots as E1: Shao, E2: Malete, and E3: Eleyoka.

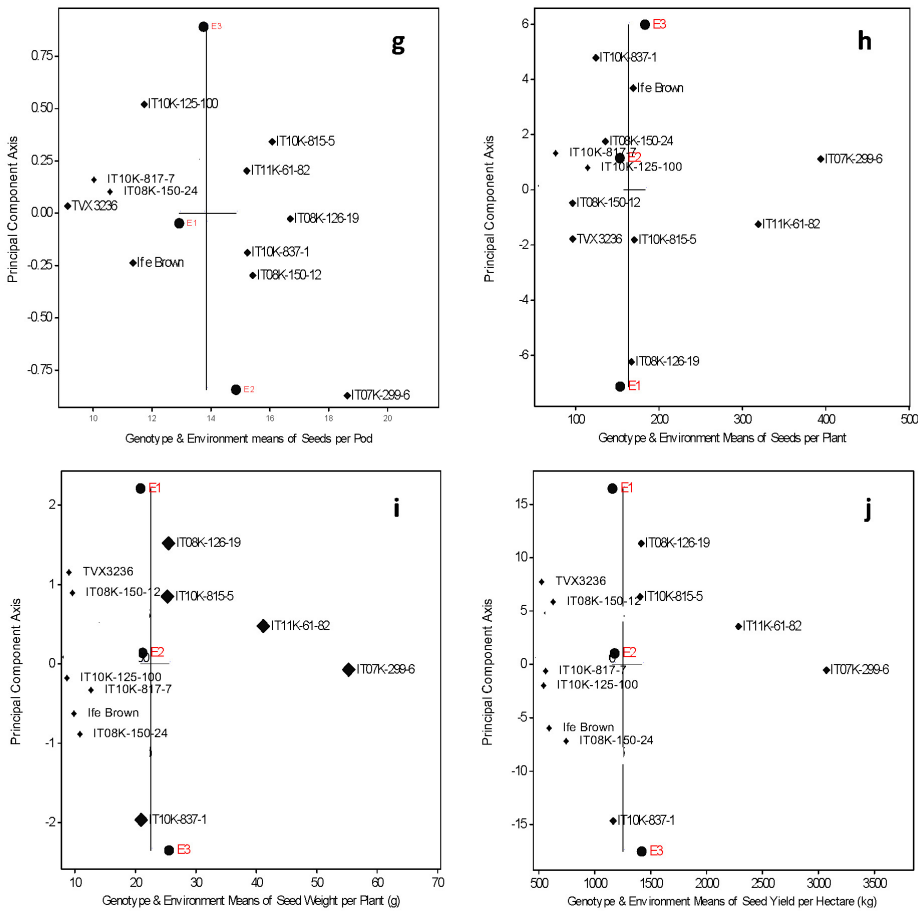


Fig. 2. Continued.

61-82 had more than 100% seed fill with Malete being most favorable (Fig. 2c). However, IT10K-837-1 with largest seed weight produced the longest pods across the three locations, with Malete being the most favorable for these yield components (Fig. 2d, e). AMMI biplot for pod clustering (pods/peduncle) identifies IT11K-61-82, TVX-3236 and IT07K-299-6 to be outstanding with Malete being distinct from two others (Fig. 2f). G × E biplots of seeds per pod and seeds per plant identify IT07K-299-6, IT08K-126-19 and IT10K-815-5 as best varieties and Malete performance being distinct from other (Fig. 2g, h). Biplots of seed weight per plant (g) and total seed yield per hectare (kg) though indicate significant variation across the three locations, had IT07k-299-6, IT11K-61-82 and IT08K-126-19 as outstanding varieties, also with plants grown in Malete being the most prolific (Fig. 2i, j).

Correlation coefficient analysis of plant characters and seed yield components is presented in Table 3. Plant survival rate recorded significant positive correlations with pod-seed fill, peduncle per plant, seeds per pod, seeds per plant, seed weight per plant, and seed yield per hectare. However, it recorded negative significant correlations with pod maturity and seed weight. Correlations between pod maturity and pod-seed fill, pod length, pods per peduncle, seeds per pod, seeds per plant, and seed yield per hectare are negatively significant ($P < 0.001$; r (97) = 0.254). Pod-seed fill recorded positive significant correlations with pods per peduncle, seeds per pod, seeds per plant, seed weight per plant, and seed yield per hectare. It however recorded a significant negative correlation with pod length. Correlations between pods length and seeds per pod, seed weight, seed weight per plant, and seed yield per hectare are

Table 3. Correlation analysis of seed yield and yield components of cowpea.

	SVC[z)]	PDM[y)]	POF[x)]	POL[w)]	PPP[v)]	SPO[u)]	SPP[t)]	HSW[s)]	SWP[r)]	YHP[q)]
SVC[z)]	1.00									
PDM[y)]	–0.44**	1.00								
POF[x)]	0.27**	–0.49**	1.00							
POL[w)]	–0.08ns	–0.23*	–0.32**	1.00						
PPP[v)]	0.73**	–0.46**	0.22*	–0.12ns	1.00					
SPO[u)]	0.26*	–0.65**	0.63**	0.51**	0.16ns	1.00				
SPP[t)]	0.44**	–0.54**	0.42**	0.19ns	0.39**	0.59**	1.00			
HSW[s)]	–0.30**	–0.16ns	–0.11ns	0.56**	–0.32**	0.30**	–0.08ns	1.00		
SWP[r)]	0.39**	–0.59**	0.41**	0.32**	0.33**	0.68**	0.97**	0.14ns	1.00	
YPH[q)]	0.39**	–0.59**	0.41**	0.32**	0.33**	0.68**	0.97**	0.14ns	0.99**	1.00

*$r(97) = 0.195$, $P < 0.05$; **$r(97) = 0.254$, $P < 0.01$. ns: not significant.
[z)]Plant survival count, [y)]Pod maturity, [x)]Pod-seed filling, [w)]Pod length (cm), [v)]Pods per peduncle, [u)]Seeds per pods, [t)]Seeds per plant, [s)]Hundred seed weight (g), [r)]Seed weight per plant (g), [q)]Seed yield per hectare (kg).

significantly positive. Pods per peduncle showed positive and significant correlations with seeds per plant, seed weight per plant, and seed yield per hectare, but had significant negative relationship with seed size (individual seed weight). Seeds per pod and seeds per plant recorded significant positive correlations with seed weight per plant, and seed yield per hectare. Correlations between seed weight, and seed yield per hectare are significantly positive (Table 3).

DISCUSSION

Development and selection of improved genotypes is a major sustainable strategy to combat problem of low yield in dry savannah regions of sub-Sahara Africa. And one of the most sustainable breeding strategies is the continuous expansion of germplasm and evaluation of promising genotypes for adaptation and yield stability. Breeding for stable yield would also involve evaluation of crop varieties across diverse environments within or without regions to identify superior genotypes with broad or specific adaptation due to G × E interaction. Kaya *et al*. (2002) opined that varietal adaptation could be differs significantly across environments. In this study, nine advance breeding cowpea lines were evaluated along with two commercial varieties (as checks) across three locations (microenvironments) in the guinea savannah ecology (Kwara State, Nigeria) to select and develop improved cowpeas with high seed yield for farmers in this dry savannah region in the country.

Govindaraj *et al*. (2015) emphasized the importance of genetic variability as a life-blood of crop improvement and, Meena *et al*. (2017) opined that success in the development of high yielding varieties is consequence upon level of genetic variability and diversity of the breeding population. The eleven cowpea varieties used in this study however exhibited wide range of phenotypic variability for total seed yield and some yield component traits like pod maturity period and seeds per plants. Thus, wide variability extant of this nature could be attributed to inherent genetic properties of cowpea varieties and/or environmental influence, which could be exploited for improvement through selection and/or hybridization of individuals with desired

quality characteristics. Wide genetic variability in cowpea has been reported in other studies (Grisih *et al*. 2006; Idahosa *et al*. 2010; Nwofia *et al*. 2014; Shanko *et al*. 2014). Owusu *et al*. (2018) advocated the need to develop cowpeas that combine earliness with high yield in Ghana. In terms of pod maturity (phenology), six of the advanced breeding lines expressed early to medium pod maturity period and comparatively better than the existing commercial varieties (Ife Brown and TVX 3236) that are late maturing. Matured pods were ready for harvest 2-3 weeks earlier in these six cowpeas compared to the late maturing genotypes. These set of individuals with early (IT07K-299-6, IT10K-815-5 and IT11K-61-82), and medium (IT08K-126-19, IT08K-150-12, and IT10K-125-100) maturing habit could be genetically exploited to develop varieties amenable to two cropping cycles in the guinea savannah region with limited range of rainfalls. Precocity in cowpea would not only makes it possible to perform two to three planting cycles per year (de Moura Oliveira *et al*. 2016), but could reduce losses and/or stabilize the production in regions with long periods of droughts (Machado *et al*. 2008; Ayo-Vaughan *et al*. 2011). Cowpeas with short period of maturity also allow farmers to cultivate the crop as second harvest after main crops like maize (corn), soybean or rice. Interestingly, two varieties (IT07K-299-6 and IT11K-61-82) from six individual identified with early maturity combine earliness with high seed yield and could be selected as improved varieties to meet short-term need of farmers in this region. Genetic studies on earliness (precocity) in cowpea reported that the trait is controlled by polygenes and could be greatly influenced by environment (Adeyanju and Ishiyaku 2007; Ayo-Vaughan *et al*. 2011; Neto *et al*. 2017). Perhaps polygenic nature of this trait could explain variation in pod maturity of the same cowpea variety across locations in this study.

The choice of AMMI analysis for this G × E data was because of its robustness (Thillainathan and Fernadez 2001) and synteny with other statistical tool like GGE biplot as recently reported (Aliyu *et al*. 2014). Significant variation recorded in seed yield and yield components across the three locations within the same ecology underscores the complex interplay between genes (genotypes) and environment and the need to incorporate genotype by microenvironment (G × mE) interaction in the breeding scheme during varietal development program. Aliyu and Abdulkareem (unpublished data) observed significant variations in seed yield and yield components of cowpea from two locations within 5 kilometers radius. Sreelakshmi *et al* (2010) opined that G × E interaction and its components have a direct bearing on the environmental adaptation of the varieties to be recommended for commercial cultivation. Among the three locations where field trials were conducted, cowpeas from Malete performed fairly better than the two other locations. In other words, seed yield from Malete and Eleyoka were 7.00% and 1.40% above mean seed yield, respectively. On the contrast, seed yield from Shao was 8.42% below the mean seed yield. Variation in seed yield and yield components across farm locations as observed in this study could be attributed to soil nutrient composition and climatic variables. Soil pH (below 6.8 and above 7.5) has been reported to significantly affect cowpea yield (Joe and Allen 1980; Goenaga *et al*. 2013), while change in temperature of 1°C below and above optimum could speed up leaf senescence, and high soil precipitation (volume of rainfall) reduces root nodulation and consequently reduce seed yield in cowpea (Bagnall and King 1987; Ajetomobi and Abiodun 2010). However, the best three cowpea varieties (IT07K-299-6, IT11K-61-82 and IT08K-126-19) for Malete and Shao, and (IT07K-299-6, IT11K-61-82 and IT08K-150-24) for Eleyoka have potentials to produce about 2.72 tons/ha, 2.17 tons/ha and 1.93 ton/ha of grain-seed yield, respectively. These genotypes could be selected for farmers use in the short-term. It is important to note that the best three varieties in Malete also ranked best three in Shao (08° 35' N 04° 35' E), which has a congruity with Malete (08° 26' N 04° 29' E) compared to Eleyoka (08° 13' N 04° 49' E). Indeed, climatic variables like amount of rainfall and temperature in Malete and Shao are relatively close compared to Eleyoka (Fig. 1).

Importantly, two cowpeas (IT07K-299-6 and IT11K-61-82) consistently produced high seed yield across the three experimental locations. This stable expression of high yield suggest that these two cowpea varieties probably possessed inherent resilience mechanisms for stability of yield component compensation, stress tolerance and

capacity to recover rapidly from stress (Nath *et al*. 2013).

Significant positive correlation between plant survival rate and yield components further underscore the importance of high-quality seeds to cowpea seed yield. Seeds with germination (viability) below 85% are not advisable for field planting as there was significant reduction in seed yield in varieties with lower survival percentage. Results obtained in this study disagree with Adetumbi *et al*. (2011) that reported no significant difference in seed yields of old and new seed of two varieties of cowpea. Two varieties of Ife Brown were used in that study and Ife Brown varieties are characterized by late maturity. Sample size, type of genotype and environmental condition could account for variation between the two studies. While there is general opinion that effect of seed ageing would have been removed once seedlings have become established in the field, effect of poor-quality seeds (dying embryo) would be more consequential on plant vigor and seed yield of early maturing varieties than late maturing genotypes. Baysah (2013) observed significant effect on early stage of growth (2-3 weeks) cowpea. Akhter *et al*. (1992) reported increased frequency of abnormal cells with seed age.

Furthermore, significant positive correlation between yield components (pods per peduncle, seeds per pod, seeds per plant, and seed weight per plant) and seed yield recorded in this study is consistent with previous studies (Drabo *et al*. 1984, 1985; Ogunbodede 1989; Aliyu and Makinde 2016), which suggest plausible faster genetic improvement of seed yield in these cowpea varieties. Relationships between plant maturity and seed yield components were however negative and significant, indicating early maturing varieties from this study produce higher seed yield compare to late maturing types. This is a positive selection index for cowpea improvement in this location. This result is consistent with previous data (Aliyu and Makinde 2016) but contrast to Owusu *et al*. (2018) that reported positive association between high grain yield and late maturity in northern Ghana. Variations between the two studies could be attributed to climatic variables, genotypes, and breeding history of the plant materials (Molosiwa *et al*. 2016). Perhaps, overgeneralization of inference from correlation and/or genetic linkage studies between cowpea plant maturity and seed yield components could sometimes be misleading, therefore inferences and conclusions should be drawn on biotypes and/or regions data-specific basis.

Data reported in this study has further shed light on the significant role of environment on phenotypic and genotypic stability of cowpea seed yield and yield components especially in the savannah ecology in West Africa sub-region and its implication on overall cowpea production. However, this multi-locational on-farm varietal trial has led to identification and selection of two cowpea genotypes (IT07K-299-6 and IT11K-61-82) that combined precocity with stable high seed yield across the three trial locations. These varieties could be multiplied for immediate release to farmers through formal seed distribution system to salvage declining cowpea production in the area.

ACKNOWLEDGEMENTS

We acknowledged the technical supports of Mr. Omotayo Jimoh and Mr. Muhammed Usman, both Laboratory Technicians in the College of Agriculture, Kwara State University, Malete for this project. We also appreciated our undergraduate students and farmers that participated in this study.

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