Yield performance of early-maturity cowpea (*Vigna unguiculata*) elite lines under four varied environments

P. Haisirikul[1], T. Sontornkarun[1], W. Burakorn[1], W. Pinta[1], S. Chankaew[1], T. Monkham[1], A. Phapumma[1], S. Laudthong[1] and J. Sanitchon[1,*]

[1] Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen Thailand
* Corresponding author: jirawat@kku.ac.th
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ABSTRACT

Cowpea (*Vigna unguiculata*) is a leguminous crop that can widely adapt to diverse environments, including high temperature and drought–prone areas. Due to its early maturity, the cowpea has been introduced into cropping systems. Cowpeas are utilized as fresh pod, dry grain, fodder and green manure. The cowpea breeding project herein developed cowpea lines through crossing and pure line selection, in which 27 lines were selected. However, performance evaluation is most required prior to their release to the farmer. A total of 29 cowpea lines (27 lines from a breeding program and 2 of check varieties) were evaluated under four environments at the Department of Agronomy, Faculty of Agriculture, Khon Kaen University from 2016 to 2018. The trials were laid out in a randomized complete block design with three replications. The results found the significance of G × E interaction on grain yield. A planting date of November 15, 2017 presented the greatest grain yield (286.6 g/m^2). The higher temperature of April 9, 2017 affected the shortening days to flowering (32.10 days) and days to harvest (50.23 days). According to regression and GGE biplot, CPL33, 305, 39D, and KKM60–2 are great in yield performance and adaptability across four environments. Moreover, they are also early maturity (68–72 days) and suitable for crop rotation.

Keywords: Cropping system, protein, GGE Biplot, breeding, multipurpose cowpea

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INTRODUCTION

The cowpea (*Vigna unguiculata*) is a leguminous crop that can widely adapt to diverse environments, including high temperatures and drought. Cowpea planting worldwide was estimated at 14 million ha in 2000 (Singh *et al*., 2002), with most production occurring in Africa's Sudanian Savanna zone (Hall, 2012). Cowpeas are drought tolerant due to their intense root density, root penetration and leaf shading in which to maintain soil moisture. Cowpeas have been utilized in many aspects, such as green manure for soil improvement, resulting in heightened N availability (37.5–81.25 kg/ha) (Tarawali *et al*., 1997). Fresh cowpea pods and dry grain are also suitable for human consumption, particularly for vegetarians, due to their high protein content (Giami, 2005), which, at 24.8%, is higher than the protein contents of beef (20%), poultry (20%) and pork (12%). In terms of the costs of protein derivatives, the cowpea averaged US$2.13/kg versus $12.2, $9.15 and $9.02/kg for pork, beef and eggs, respectively (Osho and Dashiell, 1997). A short life cycle of cowpea makes it benefit to year-round cropping system (Willey, 1979; Francis, 1981). Southeast

Asia represents the second largest production area of cowpeas, led by India, and followed by Indonesia, Myanmar, Nepal, Sri Lanka, Pakistan, the Philippines, and Thailand. Other far eastern countries also produce the cowpea, however, in less quantity than that of Southeast Asia (Steele and Mehra, 2009). Out of those, the two large production area of Asia belongs to Myanmar and China (119,398 and 5,108 ha) (FAO, 2018).

Thai farmers practice cowpea as a minor crop for rotation with other major field crops such as cassava, rice and corn. Cowpea is thus produced during both rainy and dry season. Cowpea breeding program at Khon Kaen University (KKU) started with crossing and selection and some selected lines with early maturity lines were identified. However, before the lines are released, yield evaluation under different environments is most needed to estimate an interaction between genotype (G) and environment (E) and identify high adaptability and stability cultivars (Becker and Leon, 1988; Huehn, 1990; Cruz and Regazzi, 1994). Success varieties have shown highly predictable performances, even under quite distinct environmental conditions (Cruz and Regazzi, 1994). Moreover, G × E interaction has been utilized in the creation of unbiased estimates of yield stability, capable of withstanding both predictable and unpredictable environmental variations (Kamdi, 2001). The selection of cowpea variety, therefore, presents the most important factor in its production. While some varieties can be obtained through an international research center or gene bank, their adaptability to, and usage, in a specific location must be determined. Many methodologies can be used to explain the behavior of genotypes tested across a range of environments, such as the variance of G × E interaction and simple linear regression (Eberhart and Russell, 1966). The high yield stability of cowpea genotypes has been shown resulting in principal components (PC) that near to zero and high mean–grain yield with a regression coefficient close to one and low deviation from regression, respectively.

In Thailand, the cowpea represents a minor crop, which has been underutilized since the past decade. However, due to its early maturity, it has a high potential for crop rotation within different ecologies. On upland areas, farmers grow cowpeas before the main crops, such as maize. While in the lowland paddy fields, the cowpea is rotated both before and after the rice crop. Most field crop areas in Thailand are rainfed, with unpredictable rainfall area. Therefore, high potential genotypes must be selected to guarantee high yields. The Khon Kaen University Cowpea Breeding Project developed several cowpea breeding lines. The breeding lines, created in the Agronomy Field Crop Station (in the rainy season), delivered high yields and early maturities. However, prior to utilization, an evaluation of these breeding lines with multipurpose grain usage must be performed including yield, yield adaptability and yield potentials in different environments. The objective of this study, therefore, was to evaluate yield and yield potential of the early-maturity cowpea elite lines, in order to identify suitable cowpea lines for Thailand seasons, year-round crop rotation and improving multi-locations trials.

MATERIALS AND METHODS

Plant Materials

Our study 29 genotype comprised of 24 cowpea lines, devided from two crosses (KVC7 × KKU25 and KC402 × KC306–2), together with the 3 lines were obtained from the Red Cowpea 6–1 US (KKM 40–5–2, KKM 60–2 and KKM 60–6–2) through gamma irradiation at 40 and 60 k–rad and 2 check varieties (KKU25 and KVC7) (Table 1). All of 29 genotypes were maintained by pure lines selection method for more than 30 generations. Note that the KKU25 check variety is a non–stake yard–long bean, whereas KVC7 is multipurpose cowpea. All lines were provided by the Cowpea Breeding Project, Khon Kaen University, Khon Kaen, Thailand (Figure 1).

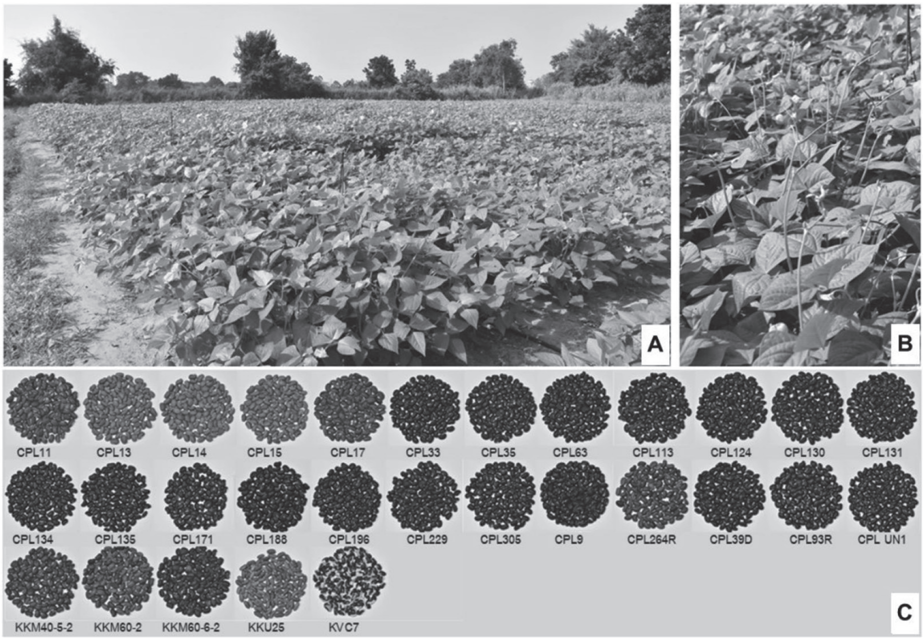

Figure 1 The experiment field (A), cowpea line 305 (B) and seed characteristics of all test lines (C)

Table 1 List of cowpea lines and varieties, sources and seed colors

No.	Lines/Varieties	Sources of lines	Seed color
1	CPL 11	KVC7 × KKU25	Red
2	CPL 13	KVC7 × KKU25	Red
3	CPL 14	KVC7 × KKU25	Red
4	CPL 15	KVC7 × KKU25	Red
5	CPL 17	KVC7 × KKU25	Red
6	CPL 33	KVC7 × KKU25	Black
7	CPL 35	KVC7 × KKU25	Black
8	CPL 63	KVC7 × KKU25	Black
9	CPL 113	KVC7 × KKU25	Black
10	CPL 124	KVC7 × KKU25	Black
11	CPL 130	KVC7 × KKU25	Black
12	CPL 131	KVC7 × KKU25	Black
13	CPL 134	KVC7 × KKU25	Black
14	CPL 135	KVC7 × KKU25	Black

Table 1 Continued.

No.	Lines/Varieties	Sources of lines	Seed color
15	CPL 171	KVC7 × KKU25	Black
16	CPL 188	KVC7 × KKU25	Black
17	CPL 196	KVC7 × KKU25	Black
18	CPL 229	KVC7 × KKU25	Black
19	CPL 305	KVC7 × KKU25	Black
20	CPL 11	KVC7 × KKU25	Black
21	CPL 264R	KC402 × KC 306–2	Red
22	CPL 39D	KVC7 × KKU25	Red
23	CPL 93R	KVC7 × KKU25	Black
24	CLP UN1	Unknown	Black
25	KKM 40–5–2	Red cowpea 6–1 US	Red
26	KKM 60–2	Red cowpea 6–1 US	Red
27	KKM 60–6–2	Red cowpea 6–1 US	Red
28	KKU25 (standard check)	KKU335 × Yardlong bean[a]	Black
29	KVC7 (standard check)	KC402 × KC 306–2	Holstein

Note: a = unknown

Field Experiments

All lines and varieties were evaluated for yield stability in the field. The experimental field was conducted at Khon Kaen University's Agronomy Field Crop Station, in four environments, from 2016 to 2018. Four planting dates, i.e., November 3, 2016 (environment 1), April 9, 2017 (environment 2), November 15, 2017 (environment 3) and August 25, 2018 (environment 4), were determined by the growing season of Thailand. The weather data of four environments were significant across each environment, which affected the cowpea growth and development (Table 2). The experiments were laid out in a randomized complete block design (RCBD) with three replications. Planting was direct seeded, using 3–5 seeds/hill, with subsequent thinning to 2 seedlings/hill. The plot size was 2 × 4 m^2 and consisted of 4 rows, 4 m in length (68 hills/plot). The spacing between row and hill were 50 and 25 cm, respectively. Fertilizer was applied at a rate of 156.25 kg/ha (N, P_2O_5, K_2O) at 20 days after planting and in the flowering stage. Dry season irrigation was supplied via sprinklers.

Table 2 Planting date, temperature, day length and relative humidity in four environments

Environment	Planting date	Temperature (°C)			Day length (h/day)			Average relative humidity (%)
		Min	Max	Average	Min	Max	Average	
1	3 Nov 2016	19.7	31.6	25.7	11.09	11.30	11.16	86.60
2	9 Apr 2017	24.6	34.5	29.5	12.25	12.54	12.42	92.00
3	15 Nov 2017	17.5	30.7	24.1	11.09	11.22	11.12	87.60
4	25 Aug 2018	22.6	33.0	27.8	11.52	12.33	12.12	93.00

Data Collection

The agronomic traits were collected following the International Board for Plant Genetic Resources (IBPGR, 1983). Days to flowering (DTF) was based on the number of days from the day after sowing to roughly 50% flowering within each plot. Days to harvest (DTH) was determined when 90% of the total pod had matured. Pod yield was determined at the harvesting dates from samples taken from 4 hills (8 plants) from the middle rows, which were then air–dried to approximately 14–18% moisture content. Both grain yields and 100–seed weights were gathered after pod threshing. Weather factors within our four environments consisted of minimum, maximum and average temperatures, day–length and relative humidity which were recorded throughout the experiment.

Data Analysis

The analysis of all parameters was based on a randomized complete block design for individual environment. Combined analyses over season were also performed for homogeneity environments, according to Bartlett's test (Gomez and Gomez, 1984). Stability and performance analysis on the genotype means were used to determine the genotypic consistency over environments. To investigate yield stability, additive main effects and multiplicative interaction (AMMI analysis) was performed based on grain yield over environments (Gollob, 1968; Onofri and Ciricifolo, 2007). Principal component analysis (PCA) and GGE (genotype and genotype by environment) biplot graph were subsequently constructed to determine G × E interaction. The interpretation of biplot graph depicts the adaptability and phenotypic stability of genotypes was used to determine yield stability of the genotypes across environment by the PCA scores biplot. The yield stability of the cowpea lines was also studied through regression analysis (Eberhart and Russell, 1966). The statistical analyses were performed by the R–language (R Development Core Team, 2012). Regression coefficient (b) and variance of the regression deviations (S^2di) were estimated using the following formulas:

$$b_i = 1 + \frac{\sum_i (Xij - \bar{x}i. - \bar{x}.j + \bar{x}..)(\bar{x}.j - \bar{x}..)}{\sum_j (\bar{x}.j - \bar{x}..)^2}$$

$$s^2_{di} = \frac{1}{E-2}\left[\sum_i \left(x_{ij} - \bar{x}i. - \bar{x}.j + \bar{x}..) - (b_i - 1\right)^2 \sum_i (\bar{x}.j - \bar{x}^2_{..}\right]$$

Where X_{ij} is yield of genotype *i* in environment *j*, $\bar{x}i$ is the mean yield of genotype i, $\bar{x}.j$ is the mean yield of environment j, $\bar{x}$. is the grand mean,(S^2_{di}) is standard deviation of the regression coefficients and *E* is the number of environments (Eberhart and Russell, 1966)

RESULTS AND DISCUSSION

Grain Yields and Agronomic Traits

The grain yields and agronomic traits of the cowpea lines and varieties in each environment were evaluated. The G × E interaction affected significantly on all traits except DTH and pod number per plants (Table 3). These results indicated that cowpea lines responded differently to various environmental conditions. A similar result was reported by El-Shaieny *et al*. (2015). Besides, the environmental variance was greater than the genotype except for pod number per plant (Table 4). The same proportion was found in Rocha *et al*. (2017). Furthermore, the environment 3 was shown the greatest favorable condition to produce the grain yield (Table 3). A significance of G × E interaction revealed the difference in suitable varieties for a particular environment. The CPL 93R was the highest grain in environment 1, meanwhile, CPL 63, CPL 13 and CPL 9 were superior for environments 2, 3 and 4, respectively (Table 5). All the top varieties were greater in yield than KU25 and KVC7, check varieties. Among the four environments, environment 3 was the most variable for grain yield with the grain yield 286.80 g/m^2 compared with 160.0, 248.26 and 268.87 g/m^2 of environment 1, 2 and 4 (Table 3).

Table 3 Days to flowering, day to harvest, pod per plant, 100–seed weight, plant dry weight, harvest index and grain yield in each environment

Environment	Days to flowering	Days to harvest	Pod per plant	100–seed weight (g)	Plant dry weight (g)	Harvest index	Grain yield (g/m^2)
1	45.37[b]	78.37[a]	8	19.08[c]	278.69[a]	0.22[d]	160.00[c]
2	32.10[d]	50.23[c]	8	18.65[c]	144.93[c]	0.42[c]	248.26[b]
3	52.02[a]	76.83[ab]	7	24.07[a]	107.24[d]	0.46[b]	286.80[a]
4	40.71[c]	75.63[b]	8	21.68[b]	182.73[b]	0.58[a]	268.87[ab]
P–value							
Genotypes (G)	<0.001	0.031	<0.001	<0.001	<0.001	<0.001	<0.001
Environment (E)	<0.001	<0.001	0.258	<0.001	<0.001	<0.001	<0.001
G × E	<0.001	0.109	0.065	<0.001	0.003	<0.001	<0.001
CV (%), E	4.40	8.59	38.17	6.96	23.84	32.78	35.43
CV (%), G × E	4.47	10.67	26.09	7.83	26.76	28.32	20.19

Note: CV = Coefficient of variation, different letter in a column indicate significant difference at 95%, Mean comparison based on least significant difference

Days to Flowering and Days to Harvest

The cowpea genotype showed significant difference for days to flowering and days to harvest in environments 1, 2 and 4 (Table 5) in which the DTF and DTH were shortest in environment 2, with 32.10 and 50.23 days, respectively (Table 3). Comparatively, the DTH in four environments ranged from 54–89, 43–58, 59–84 and 73–77 days respectively. The environment 2 also experienced the highest temperatures (24.6–34.5°C) with average temperature 29.5°C and had long day length duration (12.25–12.54 h/day) with average 12.42 h/day (Table 2) which is also thought to have affected the cowpea genotype's DTF and DTH at 32 and 50 days, respectively, that was shorter than other environments (Table 3). This suggests that some genotypes respond to high temperature and the long duration of day length, in term of early flowering and harvest, while maintaining a high yield especially, CPL 11, CPL 13 and CPL 14 with short DTH of 44.7, 44.0 and 44.0 days on higher temperature 29.5°C (environment 2) but stay longer DTH under the low temperature of 24.1°C (environment 3) as shown in Table 2. Furthermore, early maturing cowpea varieties have proven capable of surviving under dry environments, due to their ability to escape drought (Singh, 1994). The cowpea's short maturity has proven beneficial for crop rotation and intercropping systems in drought–prone areas (Mortimore *et al.*, 1997).

Yield Performance

Yield stability based on Eberhart and Russell (1966) demonstrated that the most promising lines CPL 13, CPL 33, CPL 305, CPL 39D and KKM 60–2 were great in stability with grain yields of 307.0, 258.8, 250.1, 244.9, and 243.2 g/m^2 with regression coefficients of 1.24, 1.03, 0.99, 0.93 and 0.80, respectively (Table 6).

Table 4 Mean square of days to flowering, days to harvest agronomic traits and grain yield of cowpea genotypes in four environments

Source of variance	df	Days to flowering	Days to harvest	Peduncle length (cm)	Pod per plant	100–seed weight (g)	Plant dry weight (g)	Harvest index	Grain yield (g/m^2)
Genotype (G)	28	23.29**	90.60*	123.10**	17.27**	145.10**	9,972.00**	4,857.00**	36,900.00**
Environment (E)	3	6,095.33**	15,422.40**	1,336.34**	14.71^{ns}	549.85**	47,1552.00**	202,335.00**	704,358.00**
G × E	84	9.16**	69.70^{ns}	57.88*	5.49^{ns}	5.31**	3,635.00**	1,809.00**	13,811.00**
CV (%), E × R		4.40	8.59	23.64	38.17	6.96	23.84	32.78	35.43
CV (%), G × E × R		4.47	10.67	15.94	26.09	7.83	26.76	28.32	20.19

Note: CV = Coefficient of variation, ** Significant difference at 99%, * Significant difference at 95%, ns = Not significant

Table 5 Days to harvest and grain yields of the cowpea lines and varieties in the four environments

No.	Lines/Varieties	Days to harvest				Grain yield (g/m^2)			
		E1	E2	E3	E4	E1	E2	E3	E4
1	CPL 11	79.3	44.7	78.7	74.0	159.6	237.9	251.5	225.8
2	CPL 13	71.0	44.0	75.7	74.7	210.4	307.4	374.9	335.2
3	CPL 14	71.7	44.0	74.7	74.0	169.7	282.4	342.0	390.2
4	CPL 15	74.3	47.7	78.0	75.3	158.2	230.8	267.2	221.2
5	CPL 17	81.0	51.0	78.0	77.3	256.0	274.1	349.8	196.8
6	CPL 33	86.7	54.7	70.7	76.7	184.4	233.2	323.4	294.0
7	CPL 35	82.3	51.0	70.7	76.3	228.2	246.0	333.4	284.7
8	CPL 63	81.7	53.7	82.0	76.0	168.7	346.7	276.0	293.0
9	CPL 113	86.7	55.0	82.0	76.0	71.9	235.0	350.3	204.6
10	CPL 124	78.7	56.3	80.0	75.3	120.5	252.8	231.0	266.6
11	CPL 130	75.3	57.7	72.7	76.0	100.8	242.8	256.6	255.8
12	CPL 131	76.7	50.3	82.7	74.0	162.3	236.4	245.4	221.0
13	CPL 134	89.0	50.3	70.7	76.0	90.5	203.9	220.0	264.7
14	CPL 135	82.0	52.3	82.0	77.0	148.3	194.9	226.0	201.9
15	CPL 171	79.3	53.7	82.0	76.3	131.7	158.4	317.2	287.5
16	CPL 188	74.0	45.7	65.3	74.0	150.0	187.5	244.9	219.0
17	CPL 196	77.7	47.0	78.0	76.0	171.5	329.7	270.6	255.8
18	CPL 229	78.0	48.7	82.0	76.0	163.5	243.1	346.8	357.9
19	CPL 305	78.3	50.3	82.0	75.3	176.9	245.5	322.8	255.3
20	CPL 9	86.0	51.0	80.0	75.7	186.2	253.4	325.6	478.9
21	CPL 264R	81.7	50.0	83.0	75.3	106.9	245.2	276.2	195.8
22	CPL 39D	77.0	51.0	70.7	77.0	161.6	279.8	273.6	264.5
23	CPL 93R	81.7	42.7	59.3	76.0	276.7	244.3	298.2	276.7
24	CPL UN1	81.3	53.0	70.7	75.7	162.1	250.5	193.3	193.0
25	KKM 40–5–2	80.0	48.0	65.3	73.3	152.0	199.4	255.8	290.4
26	KKM 60–2	76.7	50.7	83.0	75.7	168.8	273.5	251.1	279.4
27	KKM 60–6–2	53.7	52.3	82.0	74.7	132.6	227.8	301.7	181.6
28	KKU25 (standard check)	78.0	48.0	82.7	78.0	101.5	270.6	278.3	250.0
29	KVC7 (standard check)	73.0	52.0	83.7	75.7	168.7	266.6	313.2	355.7
	Mean	78.4	50.2	76.8	75.6	160.0	248.3	286.8	268.9
	LSD	13.6	6.3	–	1.4	78.4	77.6	91.6	77.4
	F–test	*	**	ns	**	**	**	**	**
	CV (%)	10.6	7.7	15.4	1.1	30.0	17.4	19.3	17.6

Note: E1 = Environment 1, E2 = Environment 2, E3 = Environment 3, E4 = Environment 4, LSD = Least significant difference, CV = Coefficient of variation, ** Significant difference at 99%, * Significant difference at 95%, ns = Not significant

The yield stability by GGE biplot was identified superior genotypes CPL 33, 35, 63, 305, 39D, and KKM60–2 which represented by entry number 6, 7, 8, 19, 22 and 24 in Figure 2. Environment 3 was also defined as high yield and stability since it is the most right side of yield and close to zero in PC1 (Figure 2). In addition, the criteria for high stability is the closeness to the origin point. This illustrated that genotype number 6, 8, 17, 19, 22 and 24 (CPL 33, CPL 63, CPL 196, CPL 305, CPL 39D and KKM 60–2) were high in yield stability as shown in Figure 2.

The first (PC1) and second principal components (PC2) were about 54.6% and 20.7%, therefore accounted for 75.3% in total through both G × E interaction (Figure 3). Additionally, all cowpea genotypes were superior to those check varieties (KKU25 and KVC7) (Table 5). The combination of both methods of performance analysis encourages us to recommend to farmers the CPL 33, CPL 305, CPL 39D, and KKM 60–2 genotypes which demonstrated the highest grain yields and performance in all environments. According to G × E interaction, it is necessary to estimate the different responses of genotypes to a wide range of conditions (Becker and Leon, 1988; Simmonds, 1991; Cruz and Regazzi, 1994). The DTH of the four recommended genotypes were not longer than 90 days (Table 2), These genotypes were high performance in yield. They are thus, fit in the cropping system.

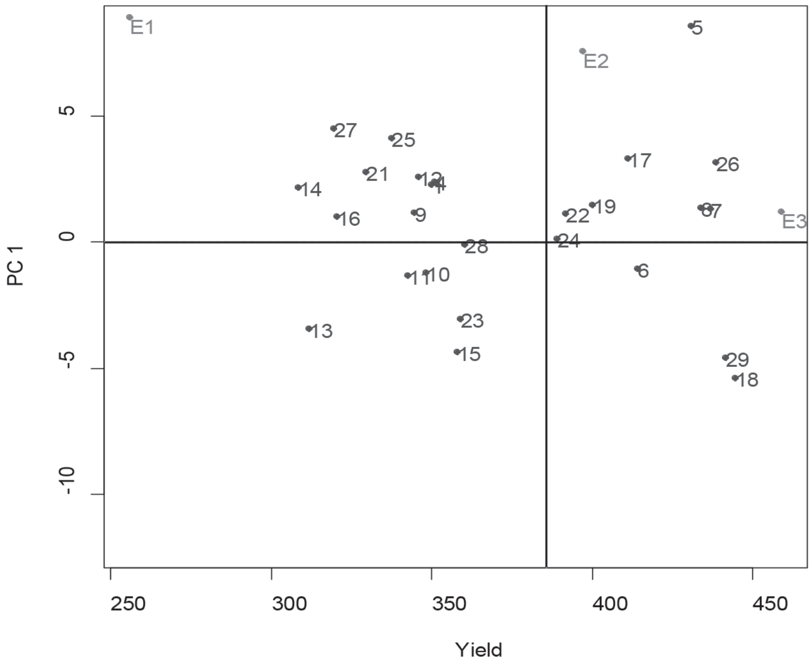

Figure 2 Yield stability of 29 cowpea genotypes derived from GGE biplot analysis across four environments, E1 = Environment 1, E2 = Environment 2, E3 = Environment 3 and E4 = Environment 4

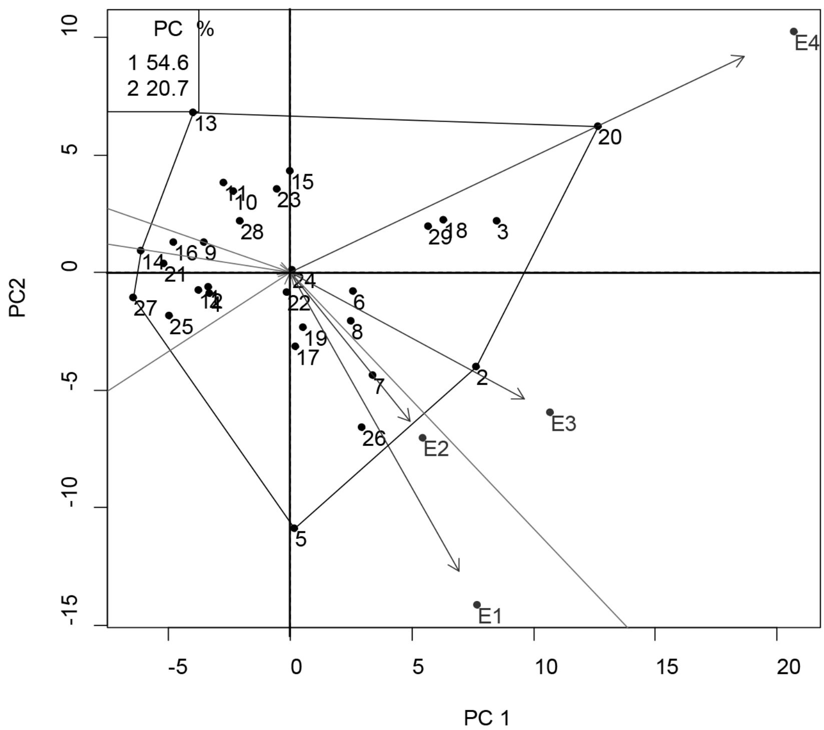

Figure 3 Principal component analyses of the yield stabilities of 29 cowpea genotypes across four environments, E1 = Environment 1, E2 = Environment 2, E3 = Environment 3 and E4 = Environment 4

Table 6 Grain yield and yield stability of cowpea lines and cowpea genotypes in four environments using the Eberhart and Russell model (1966)

No.	Lines/Varieties	Grain yield (g/m²)	b	S^2_{di}
1	CPL 11	218.7^{fghi}	0.70	0.14
2	CPL 13	307.0^{ab}	1.24	0.12
3	CPL 14	296.1^{abc}	1.57	0.45
4	CPL 15	219.4^{fghi}	0.77	0.17
5	CPL 17	269.2^{bcd}	0.29	0.77
6	CPL 33	258.8^{cde}	1.03	0.28
7	CPL 35	273.1^{abcd}	0.69	0.33
8	CPL 63	271.1^{bcd}	1.02	0.60
9	CPL 113	215.5^{ghi}	1.86	0.58

Table 6 Continued.

No.	Lines/Varieties	Grain yield (g/m²)	b	S^2_{di}
10	CPL 124	217.7[ghi]	1.06	0.36
11	CPL 130	214.0[ghi]	1.32	0.20
12	CPL 131	216.3[ghi]	0.63	0.15
13	CPL 134	194.8[i]	1.23	0.35
14	CPL 135	192.8[i]	0.57**	0.07
15	CPL 171	223.7[efghi]	1.37	0.63
16	CPL 188	200.4[i]	0.69	0.17
17	CPL 196	256.9[def]	0.85	0.56
18	CPL 229	277.8[abcd]	1.52	0.43
19	CPL 305	250.1[defg]	0.99	0.27
20	CPL 9	311.0[a]	1.58	1.11
21	CPL 264R	206.0[hi]	1.18	0.40
22	CPL 39D	244.9[defgh]	0.93	0.24
23	CPL 93R	274.0[abcd]	0.08	0.27
24	CPL UN1	199.7[abcd]	1.32	0.38
25	KKM 40–5–2	224.4[efghi]	0.95	0.38
26	KKM 60–2	243.2[defgh]	0.80	0.30
27	KKM 60–6–2	210.9[hi]	1.03	0.53
28	KKU25 (standard check)	225.1[i]	0.31	0.41
29	KVC7 (standard check)	276.1[efghi]	1.42	0.30
	Mean	241.00		
	CV (%)	20.19		

Note: CV = Coefficient of variation, ** = Significant difference at 99%, b = Regression coefficients, S^2_{di} = Standard deviation of the regression coefficients, different letter in a column indicate significant difference at 95%, Mean comparison based on least significant difference

CONCLUSIONS

The G × E interaction affected significantly on cowpea yield rather than the genotypic effect. Consequently, among environments, different lines showed high potential in yield. However, stability evaluation could identify 4 consensus lines CPL 33, CPL 305, CPL 39D and KKM60–2 with high yield and short maturity. These lines are suitable for year-round cropping system.

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