

Genotype variability and stability in seed and forage yields of cowpea under Gezira conditions

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ABSTRACT

An experiment was conducted for three consecutive seasons (summer, autumn and winter) in 2006 at Gezira University Farm, Wad Medani, Sudan, to estimate stability and genetic variability of seed and forage yields and their components in 15 cowpea (*Vigna unguiculata* (L.) Walp) genotypes. Plant height, days to first flowering, days to 50% flowering, days to pod maturity, number of pods per plant, pod weight, 100-seed weight, seed yield, fresh forage yield and harvest index were measured in autumn, while only seed and forage yields were measured in summer and winter. Analysis of autumn season only showed significant differences among genotypes for all studied characters. High broad sense heritability estimates (>80%) were recorded for plant height, days to first flowering, number of pods per plant, pod weight, fresh forage yield and harvest index. Autumn was the best of the three seasons in terms of seed yield, suggesting that most of the genotypes responded relatively better under rainfed conditions than irrigated, whereas summer was the best in terms of fresh forage yield. Seed yield stability estimates revealed that IT98K-412-13 and IT98K-131-2 were the most stable genotypes for seed yield, while, IT89KD-288 and IT95K-52-34 were the most stable genotypes for forage yield. Two genotypes, IT95K-52-34 and IT98K-311-8-2, were identified as dual purpose (forage and seed) genotypes. These two genotypes would fit well in the Sudanese agricultural system where cowpea is being grown both for food and animal feed.

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp] is an important food and fodder legume that originated in Africa (Steele, 1972). It is an important legume in the tropics and has many uses. In fresh form, the young leaves and immature pods are used as vegetables. The crop is also an important source of livestock feed and, therefore, of great value to farmers (Singh *et al.*, 1997).

It is estimated that globally, cowpea is cultivated on about 14.5 million hectares with an annual production of over 4.5 million tons. However, the bulk of cowpea production comes from the drier regions of northern Nigeria, north east Brazil and Niger Republic growing 2.3, 1.9 and 0.4 million hectares, respectively (Singh *et al.*, 2002). Cowpea is shade-tolerant and, therefore, considered as a compatible intercropping crop with many cereals and root crops. Subsistence farmers in sub-Saharan Africa usually intercrop cowpea with maize, sorghum, millet and cassava (Singh *et al.*, 1997).

In the Sudan, cowpea is grown mainly for its seeds in small-irrigated farms along the Nile banks. It is grown under rainfed conditions as sole and/or intercropped with pearl millet in western Sudan or intercropped with maize, sorghum and cassava in southern Sudan. In the Gezira scheme, cowpea is grown along the irrigation canals mainly for forage. This situation provides a good ground for developing a cutting edge variety to suit both production environments. Therefore, the objective of this study was to evaluate 14 introduced cowpea genotypes as compared to a local check under irrigated and rainfed condition.

MATERIALS AND METHODS

An experiment was conducted in three consecutive growing seasons (summer, autumn and winter) in 2006 at Gezira University Farm, Wad Medani, Sudan (latitude 14° 25' N, longitude 33° 29' E). Fourteen cowpea genotypes, IT97K-819-18, IT99K-1122, IT98K-412-8, IT98K-391-2, IT97K-461-4, IT95K-52-34, IT99K-1060, IT98K-1399, IT98K-131-2, IT96D-733, IT98K-412-13, IT98K-311-8-2, IT89KD-288, and IT99K7-212-2, kindly provided by the International Institute of Tropical Agriculture (IITA) in Nigeria, plus a local check (Belade) were evaluated

Land was prepared by disk harrowing and then ridging. The experiment was arranged in a randomized complete block design with three replications. Each entry was planted on a plot consisting of four ridges of 4 m long with intra- and inter-row spacings of 0.25 m and 0.80 m, respectively. Two seeds were sown per hole. Trials were planted on the 20th of April, 20th of July and 25th of October of 2006 for the summer, autumn and winter seasons, respectively. In summer and winter, the experiment was under irrigation, while in autumn it was under rainfed conditions.

During the autumn season, data were collected on days to first flowering and 50% flowering as the number of days from emergence to the appearance of at least one flower and 50% of plants in a plot had flowered, respectively. Days to pod maturity were counted as the number of days from emergence to the time when 75% of pods reached full maturity. Plant height (cm) was measured at pod maturity as the distance from ground level to the base of the first branch. Numbers of pods per plant were counted as the average of numbers in three plants in a plot. Pod weight (g) and 100-seed weight (g) were measured as the average weight of 5 pods and weight of 100 seeds counted from three randomly selected plants in a plot, respectively. Fresh forage yield was measured as weight of freshly harvested vegetative parts at 50% flowering. Seed yield was determined in kg ha⁻¹. Harvest index was calculated

as the ratio of seed yield to biological yield. However, during winter and summer seasons, only seed and fresh forage yields were measured.

The analysis of variance was done to test the differences among genotypes within each season separately and then combined to test genotypic differences, seasonality and genotype x environment interaction effects. Duncan's Multiple Range Test was used for mean separation. In autumn, broad sense heritability estimate was calculated for each of the studied characters. Genotypic and phenotypic coefficient of variation and genetic advance were also computed. Combined analysis of data generated from the three seasons was carried out for the estimation of stability parameters only for seed and forage yields following Eberhardt and Russell (1966) procedures.

RESULTS AND DISCUSSION

Performance of genotypes

Significant differences were observed among the 15 cowpea genotypes for most of the studied characters in autumn season. A wide range of variability was found in most of the characters measured (Table 1), indicating the presence of genetic variability and diversity in the cowpea genotypes used in this study. The existence of high variability for different characters among cowpea varieties has been reported earlier (Ramachandran *et al.*, 1980; Ntare, 1992; Ahmed, 2003).

Table 1. Phenotypic variability of some characters measured in 15 cowpea genotypes tested at Gezira research farm in the autumn season of 2006.

Character	Mean	SE±	C.V.(%)	F value
Plant height (cm)	18.8	0.4	3.3	53.6***
Days to first flowering	44.4	0.8	6.1	8.6***
Days to 50% flowering	58.3	0.5	1.6	34.5***
Days to pod maturity	62.6	0.4	3.2	4.1***
Number of pods plant ⁻¹	12.4	0.3	11.5	5.6***
Pod weight (g)	2.4	0.1	9.5	14.2***
100-seed weight (g)	21.8	0.8	1.4	872.7***
Seed yield (kg ha ⁻¹)	503.8	34.2	14.3	29.7***
Fresh forage weight (kg ha ⁻¹)	7233.3	251.4	10.7	12.0***
Harvest index	19.4	1.5	13.2	45.9***

*** Significant at 0.001 probability level.

Variability, heritability and genetic advance

Phenotypic coefficient of variability was high for harvest index followed by seed yield and low for number of pods per plant. Genotypic component of variability followed a similar trend as that of phenotypic variability (Table 2). High coefficients of genotypic variations for seed yield and harvest index in cowpea were earlier reported by Omoigui *et al.* (2006).

Plant height, days to first flowering, number of pods per plant, pod weight and harvest index showed relatively high broad sense heritability estimates (Table 2). The highest value of genotypic coefficient of variability and genetic advance as percentage of the mean was recorded by harvest index followed by seed yield and 100-seed weight, indicating that their improvement can be achieved by mass selection.

Results of heritability estimates showed that days to first flowering had the highest broad sense heritability followed by harvest index, pod weight, plant height, and fresh forage yield (Table 2).

However, traits of economic importance such as seed yield had low heritability estimates, suggesting that their improvement should be effective through progeny test. Harvest index, pod weight, and 100-seed weight combined high heritability estimates with high genetic advance and genotypic coefficient of variability, suggesting that cowpea improvement programs should focus on selection of genotypes with high number of pods, 100-seed weight, and harvest index. Similar results were reported by several workers (Sobha, 1994; Umaharan *et al.*; 1997; Vidya and Oommen, 2002). In this study, some characters including harvest index, fresh forage yield and pod weight that combined high heritability estimates with high genetic advance can be effectively selected for in early generations, while selection for characters like seed yield with relatively low heritability can be delayed for later generations.

Table 2. Estimates of genotypic (σ^2_g) and phenotypic (σ^2_p) variances, genotypic (GCV) and phenotypic (PCV) coefficient of variability, broad sense heritability (h^2_b) estimates, and genetic advance as percentage of mean (GA %).

Character	σ^2_g	σ^2_p	h^2_b	GCV	PCV	GA (%)
Plant height (cm)	5.8	6.9	83.9	12.9	14.0	24.2
Days to first flowering	18.8	21.3	88.3	9.8	10.4	18.9
Days to 50% flowering	8.1	10.4	77.8	4.9	5.5	8.8
Days to maturity	4.3	5.7	75.9	10.3	14.3	6.0
Number of pods plant ⁻¹	3.1	3.8	82.0	14.2	15.7	26.4
Pod weight (g)	0.2	0.2	86.0	19.7	20.6	38.9
100-seed weight (g)	20.1	27.6	73.0	20.6	24.1	36.3
Seed yield (kg ha ⁻¹)	30629.4	51359.1	59.6	34.7	45.0	55.3
Fresh forage yield (kg ha)	2004881.0	2415873.0	83.0	19.6	20.3	36.7
Harvest index	80.4	99.5	87.8	46.3	51.5	85.6

Stability and genotype x environment interaction for seed and forage yields

In the combined analysis of variance, genotypes interacted significantly with seasons for seed and fresh forage yield (Tables 4, 5). These results depict instability within the genotypes for seed and fresh forage yields in cowpea over the three seasons (autumn, summer and winter). Similar results were obtained by Okeleye *et al.* (2002) and Aremu *et al.* (2007). The slope of linear regression of genotype mean in a given environment on the mean yield of all genotypes describes the adaptation of individual genotype to a range of changing environments.

The mean performance of seed yield in 15 cowpea genotypes tested in this study ranged from 619.8 kg ha⁻¹ for IT98K-311-8-2 to 214.3 kg ha⁻¹ for IT99K-1122 with an overall mean of 403.4 kg ha⁻¹. Seven out of 15 genotypes including the local check, Belade (466.6 kg ha⁻¹), had seed yield relatively higher than the overall mean. Although IT98K-311-8-2 had the highest seed yield, with a regression slope of $b = 1$, its deviation (Sd) was significantly different from zero (Table 3), indicating that it is only adaptable to favourable environments (summer). Genotype IT98K-412-13 had a regression slope of 0.1 with the least value of deviation from the regression (Sd) and, therefore, considered as the most stable genotype across the three seasons. According to Eberhardt and Russell (1966), a genotype is considered stable when it has relatively high average yield across environments, a slope of regression

line close to unity ($b = 1$) and a minimum deviation of regression coefficient from zero ($Sd = 0$). Based on these criteria, only a few cowpea genotypes used in this study were relatively stable.

Table 3. Mean yield and estimates of stability parameters for seed and fresh forage yield in 15 cowpea genotypes tested for three seasons in 2006.

Genotype	Seed yield (kg ha ⁻¹)				Forage yield (kg ha ⁻¹)			
	Mean	bi	Sd	Ri	Mean	bi	Sd	Ri
IT97K-819-18	319.5	0.8	12693	0.62	3984.0	0.4	5380714	0.35
IT99K-1122	214.3	0.3	21069	0.12	3645.2	0.8	139327	0.96
IT98K-412-8	409.7	0.1	1318	0.23	6721.7	1.1	1257233	0.96
IT98K-391-2	367.1	0.8	24113	0.98	7677.1	1.6	475602	0.94
IT97K-461-4	519.7	2.1	163045	0.94	2985.4	0.2	2866692	0.17
IT95K-52-34	469.6	2.1	358097	0.43	8530.9	1.3	3035977	0.92
IT99K-1060	329.0	0.6	12734	0.97	3636.1	1.3	4804386	0.74
IT98K-1399	292.2	0.3	3770	0.92	4748.7	0.8	10517925	0.57
IT98K-131-2	609.0	1.9	162265	0.78	5576.7	1.0	2210504	0.91
IT96D-733	272.6	0.3	5733	0.46	7283.8	2.7	157099727	0.88
IT98K-412-13	398.0	1.7	138770	0.73	4753.0	0.5	678374	0.89
IT98K-311-8-2	619.8	1.0	555678	0.07	8154.3	1.6	8402310	0.87
IT89KD-288	350.1	0.5	14636	0.83	8577.0	1.9	77711746	0.89
IT99K7-212-2	413.8	0.7	17176	0.97	6578.1	1.4	33627	0.78
BELADE (check)	466.6	1.9	173118	0.80	4826.9	0.6	1403296	0.86

bi = regression slope.

Sd = deviation from regression.

Ri = coefficient of determination.

The check variety, Belade, had significantly lower mean seed yield than those of IT98K-311-8-2 and IT98K-131-2, its regression slope was more than one, that deviated significantly from regression and differed from zero (Tables 3, 4). From these results, it is apparent that IT98K-311-8-2 and IT98K-131-2 are high yielders but under specific environment and, in our case, under summer and winter environmental conditions of the Gezira, while the local check, Belade, appears to have combined yield stability with relatively high seed yield in autumn season of the Sudan Gezira (Table 4). The most stable genotype that had consistent seed yield across seasons in the Sudan Gezira was IT98K-412-13.

Table 4. Mean seed yield (kg ha⁻¹) and rank of 15 cowpea genotypes tested during winter, summer and autumn at Gezira University farm in 2006.

Genotype	Winter		Summer		Autumn	
	Mean	Rank	Mean	Rank	Mean	Rank
IT97K-819-18	220.0abc	12	272.7cd	13	465.7cd	7
IT99K-1122	193.3bc	14	122.7e	15	327.0ef	12
IT98K-412-8	390.3a	1	443.3cd	4	395.3cde	9
IT98K-391-2	247.3abc	7	391.0cde	9	463.0cd	8
IT97K-461-4	220.3abc	11	549.7c	3	789.0b	2
IT95K-52-34	229.0abc	8	184.0de	14	995.7a	1
IT99K-1060	224.3abc	9	442.0cd	5	320.7ef	13
IT98K-1399	247.3abc	6	295.3cde	12	334.0def	11
IT98K-131-2	296.3abc	4	853.0b	2	677.0b	4
IT96D-733	220.3abc	10	345.7cd	11	251.7f	14
IT98K-412-13	141.3abc	15	385.0cde	10	667.0b	5
IT98K-311-8-2	353.7ab	2	1263.0a	1	242.7f	15
IT89KD-288	263.0abc	5	434.0cd	6	353.3def	10
IT99K7-212-2	313.0abc	3	433.0cd	7	495.3cd	6
BELADE (check)	195.3bc	13	425.0cd	8	799.3b	3
Mean	403.4					
Analysis of variance						
Season (S)	71.79***					
Genotype (G)	10.91***					
Sx G	12.10***					
CV%	26.4					

The mean fresh forage yield of all genotypes ranged from 8577 kg ha⁻¹ for IT89KD-288 to 8530 kg ha⁻¹ for IT95K-52-34, with an overall mean of 5845.3 kg ha⁻¹. The local check, Belade, had a mean yield of 4826.9 kg ha⁻¹, which was significantly lower than the top two genotypes, IT89KD-288 and IT95K-52-34 (Table 5).

Table 5. Mean and rank for fresh forage yield (kg ha⁻¹) of 15 cowpea genotypes tested during winter, summer and autumn at Gezira University farm in 2006.

Genotype	Winter		Summer		Autumn	
	Mean	Rank	Mean	Rank	Mean	Rank
IT97K-819-18	2332bcd	7	3370d	14	6250d	11
IT99K-1122	8170e	15	5702cd	9	4417e	15
IT98K-412-8	2644abc	3	10104abc	6	7417bcd	8
IT98K-391-2	1823bcde	10	11875ab	5	9333a	1
IT97K-461-4	2159bcde	8	2297d	15	4500e	14
IT95K-52-34	3859a	1	12734ab	3	9000a	2
IT99K-1060	1210de	14	3615d	13	6083d	13
IT98K-1399	1305cde	12	4608cd	12	8333abc	5
IT98K-131-2	1647bcde	11	7000bcd	8	8083abc	7
IT96D-733	2560bcd	4	12291ab	4	7000cd	9
IT98K-412-13	2735ab	2	5441cd	11	6083d	12
IT98K-311-8-2	2473bcd	5	13823a	2	8167abc	6
IT89KD-288	1846bcde	9	15052a	1	8833ab	3
IT99K7-212-2	1214de	13	10104abc	7	8417abc	4
BELADE (check)	2351bcd	6	5546cd	10	6583d	10
Mean	6008.6					
Analysis of variance						
Season (S)	1.06*					
Genotype (G)	6.85***					
SxG	2.46***					
CV%	35.6					

The regression coefficient (bi) for fresh forage yield among the genotypes ranged from 0.16 for IT97K-461-2 to 2.7 for IT96K-733, and the deviation from regression ranged from 33627 for IT99K7-212-2 to 157099727 for IT96D-733. These results indicated that IT97K-461-4 was the most adapted genotype to unfavourable environments, while IT96D-733 was the most adapted to favourable environments (Tables 3, 5). Genotypes with regression coefficients nearly to 1 and combined stability with relative high seed yield were IT95K-52-34, IT98K-412-8 and IT99K-1060. About 74 to 96% (% Ri values) of the total variation in fresh forage yield of the three stable genotypes was accounted for by the deviation in environmental index, suggesting that the regression coefficients had considerable predictive value for genotypes.

These results suggest that IT89KD-288 and IT95K-52-34 are high yielders but, only under specific environments, in our case under summer and winter conditions. Although Belade had low yield potential, it appears to be stable across the three seasons at Gezira (Table 5). Two genotypes, IT95K-52-34 and IT98K-311-8-2 had relative high seed and fresh forage yields across the 3 seasons, suggesting that they can be recommended for dual purpose that can promote integrated farming system (livestock and human feed) in the Sudan.

CONCLUSION

This study has revealed significant genetic diversity within the 15 cowpea genotypes tested across winter, summer and autumn. The 5 top genotypes for seed yield were IT97K-461-4, IT98K-131-2, IT95K-52-34, Belade and IT99K-212-2, while IT89KD-288, IT95K-52-34, IT98K-412-8 and IT96D-733 were the best for fresh forage production. However, most of the high yielding genotypes were unstable across the seasons. Genotypes with stable seed yield were IT98K-311-8-2, IT98K-291 and IT98K-412-8; whereas IT98K-311-8-2, IT95K-52-34, IT98K-412-8, and IT99K-1060 had consistent fresh forage yield across the three seasons. Two genotypes, IT98K-311-8-2 and IT95K-52-34 were identified as dual purpose. These two genotypes can fit well in the Sudanese agricultural system where cowpea is being grown for both food and animal feed.

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تحليل ثبات الأداء والتباين لإنتاج البذور والعلف لمحصول اللوبيا الحلو تحت الظروف المناخية لمنطقة الجزيرة (*Vigna unguiculata* (L.) Walp)

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الخلاصة

أجريت التجربة لثلاثة مواسم متتالية (صيف، خريف و شتاء 2006) في مزرعة جامعة الجزيرة، وادمدي، السودان، لتحديد مقدار الثبات والاختلاف الوراثي لإنتاج البذور والعلف ومكوناتهما في 15 سلالة لوبيا حلو. استخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات. تم قياس صفتي إنتاج البذور و العلف في المواسم الثلاثة وفي الخريف فقط تم قياس صفات ارتفاع النبات، الأيام حتى بداية الأزهار، الأيام حتى 50% أزهار، الأيام حتى نضج القرون، عدد القرون في النبات الواحد، وزن القرون، وزن ال100 حبه ودليل الحصاد. أظهرت النتائج اختلافا كبيرا بين السلالات في معظم الصفات المدروسة. أعلى نسبة لدرجة التوريث على النطاق العريض (أكثر من 80%) سجلت لطول النبات، الأيام حتى الأزهار، عدد القرون في النبات الواحد، وزن القرن، إنتاجية البذور والأعلاف الخضراء ودليل الحصاد. كان التفاعل بين السلالات والبيئة معنوياً لكل من إنتاجية البذور والعلف. أظهرت الدراسة بان السلالتين IT98K-311-8-2, IT95K-52-34 يمكن أن يستخدموا لإنتاج العلف و البذور وكانت أعلى السلالات إنتاجاً للبذور-IT98K-311-8-2, IT95K-52-34, IT97K-461-4, IT99K-7-212-2 و 619.79 كجم/هـ وان أعلى السلالات إنتاجاً للعلف الأخضر كانت IT98K-311-8-2, IT95K-52-34, IT89K-288, IT96D-733, IT98K-412-8 والتي تتراوح إنتاجيتها بين 7612.7 و 8577.0 كجم/هـ.