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Full Length Article

Grain Yield, Nutritional Composition and Anti-Nutritional Factors of Cowpea Genotypes in Dry Environments of Saudi Arabia

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Abstract

In this 2-year field study, seven cowpea genotypes were evaluated for their grain yield, chemical constitutes and anti-nutritional factors at three different locations in Saudi Arabia. The indeterminate genotypes (Yemeni, Daijiarh Baladi, Daijiarh Hassawi and YG 30119) had prostrate growth pattern and produced higher biomass, and thus can be used as fodder and cover crop. However, the determinate genotypes (Kafr El-Sheikh, Lupia Jizani and Lupia Baladi) produced higher grain yield. The phenotypic expression of yield and other quantitative traits varied due to genotypic differences, locations and genotype by environment interactions. Grains of genotype Daijiarh Baladi had the highest potassium, magnesium, calcium, total phenolics, flavonoids and antioxidant activity, and lowest tannin and phytic acid. Variable amount of 18 amino acids was noted in seven cowpea genotypes. Cowpea produced better yield in western region. The determinate genotypes Kafr El-Sheikh and Lupia Jizani produced more yield; the genotype Kafr El Sheikh yielded better in the centre whereas Lupia Jizani yielded better both in the eastern and western regions. The genotype Lupia Baladi with high zinc, iron and antioxidants, and had high protein and essential amino acids showing that these traits can be improved simultaneously, and this genotype can be used in future breeding programs.

Keywords: Cowpea; Yield; Proximate composition; Anti-nutrient; Antioxidant; Morphology

Introduction

The cowpea (*Vigna unguiculata* (L.) Walp.) is one of the most ancient grain crops grown in the arid and semi-arid zones of the world (Xiong *et al.,* 2018). Its grain is rich in protein (25–30%) and carbohydrates (50–60%), and serve as major source of dietary protein in the developing countries where 83% of total dietary protein comes from the plant sources (Carvalho *et al.,* 2017). The haulms of cowpea are considered as a valuable source of protein for livestock (Ortiz, 1998).

Cowpea can grow well in marginal dry lands characterized by low fertility because of its beneficial role in improving the mechanical properties of the soil owing to its taproot system and its ability to fix the atmospheric nitrogen into the soil (Owolade *et al.,* 2006). It is also a climate resilient legume crop (Xu *et al.,* 2017) with the potential to fix 70 to 240 kg of N/ha/year (Langyintuo *et al.,* 2003). When included in rotation with cereals and other crops, it helps increase the yield of following crop (Bell *et al.,* 2017).

Cowpea grain contains fair amount of lysine, low amount of sulphur-containing amino acids (as cysteine and methionine), minerals and vitamins (folic acid and vitamin B), and fractions of anti-nutritional factors such as pectins, non-starch polysaccharides, protease inhibitors, tannin, and alkaloids (Baptista *et al.,* 2017). However, the relative proportion of these nutrients and anti-nutrient factors determine the dietary significance of cowpea grains. Nonetheless, the composition of cowpea grains is strongly associated with environmental conditions (Wang and Daun, 2004). The soil properties and crop husbandry practices also affect the chemical content of legume grains (Khattab *et al*., 2007; Haider *et al*., 2018) including the cowpea. The grain composition and nutritional profile varies considerably among genotypes (Rangel *et al.,* 2004; Giami, 2005).

In the Kingdom of Saudi Arabia, the growers have been raising the landraces since long. In this regard, studies on of the genetic variability of cowpea landraces and introduced varieties are needed to evaluate their adaptability to different ecological regions of the country. Collection, characterisation and evaluation of available cowpea germplasm may facilitate identification of genetic variability to enable the breeders to select traits of interest for a cowpea improvement programme (Souza and Sorrells, 1991).

Effective utilization of cowpea genetic resources demands their evaluation for nutritional composition and

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anti-nutritional factors (Giami, 2005). Information of the dietary profile, of cowpea landraces, can help exploit them in future breeding programs (Xiong *et al.*, 2018). In Mediterranean Basin, the use of modern legume crops varieties is less common and diversity in local landraces and modern varieties has neither been reported in detail. Thus, the documentation, characterization and exploitation of traditional local landraces can contribute to their conservation and utilization as sources of desirable characteristics (Lazaridi *et al.*, 2017). However, to the best of our knowledge, no study has been carried out to compare the morphological/yield parameters, proximate profile, mineral contents, phenolics and anti-nutritional factors and amino acids profile of different cowpea genotypes under diverse climatic conditions of Saudi Arabia. Therefore, this study was conducted to evaluate the morphological and yield parameters, mineral contents, phenolics and anti-nutritional factors and amino acids profile of different cowpea genotypes used in Saudi Arabia under diverse climatic conditions.

Materials and Methods

Plant Material and Experimental Site

Seven cowpea genotypes, including five landraces from Saudi Arabia (Yemeni, Daijiarh Baladi, Daijiarh Hassawi, Lupia Jizani, and Lupia Baladi) and one improved variety each from Yemen (YG 30119) and Egypt (Kafr El Sheikh) were used in this study. These genotypes were evaluated in field experiments conducted at the Dirab Agriculture Research Station (24°25′49.2″N & 46°22′12.5″E), Riyadh, Palms and Dates Research Centre (25°17′59.7″N & 49°22′36.8″E), Al-Ahsa and a private farm (20°16′24.2″N & 41°41′36.2″E) at Al-Baha, representing the central, eastern, and western regions of Kingdom of Saudi Arabia, respectively during the two consecutive growing seasons of 2015 and 2016.

Crop Husbandry

The seeds of all tested genotypes were sown during the first week of June in 4 m long plots having 70 cm spaced six rows maintaining a distance of 50 cm between hills. The experiments, during both growing seasons and at all three locations, were conducted in a randomized complete block design with three replications. Weeds were controlled by hand weeding done twice. At all three locations, during both years, fertilizers were applied at 100:100:50 kg NPK ha^{-1} using di-ammonium phosphate, urea and potassium sulfate as sources, respectively. Whole of the P was applied at sowing. However, N and K were applied in three equal doses at monthly intervals starting three weeks from seedling emergence. Water was applied when required.

Qualitative Characteristics Measurement

The qualitative characters were only scored for the plants grown at the Dirab Agriculture Research Station based on the descriptions provided by International Plant Genetic Resource Institute (IPGRI, 1982).

Agronomic and Yield-related Traits

Ten plants from each plot were tagged to record the data regarding agronomic and yield related traits. Days to flowering was recorded as time needed to complete 50% flowering by visual observation. Just before the harvesting, plant height was measured with a meter rod. Number of pods per plant was counted from the tagged plants. The tagged plants from each plot, were harvested and threshed to separate grains from the straw to record number of grains per pod, number of grains per plant, grain yield per plant. Grain samples, of hundred grains were taken from each plot and weighed to record seed index.

Grain analyses

Grains of the seven cowpea genotypes were analysed for proximate composition, mineral content, amino acids profile, antioxidant potential and anti-nutritional factors.

Storage substances and mineral composition: Grain crude protein, moisture, total ash, fat and carbohydrate contents following the method of AOAC (1990). Dried grains were ground to powder and digested in concentrated hydrochloric acid. Grain magnesium (Mg), sodium (Na), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and calcium (Ca) were determined following the protocol of AOAC (2005).

Antioxidants: For the estimation of antioxidants, ground grains (1 g) were extracted in a capped centrifuge tube with 10 mL of 80% methanol. The mixture was shaken on an orbital shaker (for 3 h) at 300 rpm at ambient temperature. That extract was centrifuged at 3000 × *g* for 10 min and the supernatants were transferred into new tubes. Total phenolics were estimated following the method of Folin-Ciocalteu (Xu and Chang, 2007) and were expressed as mg gallic acid equivalents (GAE g^{-1}). Total flavonoids were determined by the colorimetric aluminum chloride method (Xu and Chang, 2007) and were expressed as mg quercetin equilibrium (QE) g^{-1}. The ability of samples to scavenge di (phenyl)-(2, 4, 6-trinitrophenyl) iminoazanium (DPPH) radicals was determined following the protocol of Llorach *et al.* (2008) and was expressed as µM trolox equivalents (TE) g^{-1} of grain.

Anti-nutritional factors: The trypsin antitryptic activity of cowpea grains was determined using benzoyl-D, L-arginine-*p*-nitroanilide as a synthetic substrate following the method of Kakade *et al.* (1969). Phytate was extracted using the procedure described by Mohammed *et al.* (1986). The tannins content was determined by Vanillin HCl method (Price *et al.,* 1978).

Amino acids: Amino acidscomposition in the grains of different cowpea genotypes was estimated by high-performance liquid chromatography (HPLC). The ground grains samples (100 μg) were completely hydrolysed at 110°C for 24 h. Samples were cooled at room temperature, centrifuged and dried in a lyophiliser to remove any traces of liquid. The dried residues were dissolved using 0.1 N HCl (100 μL) and were transferred to HPLC glass insert vials. Amino acid standards, *o*-phthalaldehyde, 3-mercaptopropanoic acid, and sodium tetra borate were obtained from Sigma-Aldrich Co., Ltd. (Dorset, England). The amino acid composition was estimated using the auto-injector HPLC (LC-10AT vp; Shimadzu Co., Kyoto, Japan) (Gnanou *et al.,* 2004). Sulphur containing amino acids and trypotophan were estimated following Shahidi *et al.* (1992). The data were processed using Integrator model Chromatopack-CR7-A (Shimadzu Corporation, Japan).

Statistical Analysis

Data of qualitative characters of the seven genotypes are shown as the mean of three replications. The grain yield and its components, as well as nutrition values of the genotypes from each location, were separately analysed, and confirmation of error compatibility across the locations and/or years was performed using Fisher's analysis of variance. As year effect and interactions of years with genotypes and locations were not significant for grain composition, data of both growing seasons were pooled. The least significance difference test was used for the mean separation at probability level 0.05 (Steel *et al.,* 1997) by using MSTAT-C statistical package software. For grain composition, genotypes were separated for each location using the least significance difference test.

Results

Qualitative Characteristics

High morphological variations were detected among the tested cowpea genotypes (Table 1). The plant height ranged from 44 cm (in genotype Kafr El Sheikh) to 169 cm (in genotype Daijiarh Baladi), whereas the days from sowing to flowering ranged from 30 days (Kafr El Sheikh) to 46 days (Yemeni). The tested genotypes had two growth patterns; determinate growth was noted in genotypes Lupia Jizani, Lupia Baladi, and Kafr El Sheikh, which showed erect plants, whereas indeterminate growth was noted in the other genotypes with prostrate plant stature. The tested genotypes had white flowers except the genotype YG 30119, which had light violet coloured flowers. Two types of angles for pod attachment to peduncle (pendant and 30–90° down from erect) were noted in the tested genotypes. The genotypes Lupia Jizani, Lupia Baladi and Kafr El Sheikh had pendant angle whereas other genotypes had 30–90° down from erect (Table 1). The pods of the tested genotypes were light in colour with straight curvature except for the genotypes Daijiarh Baladi and YG 30119, which had slightly curved dark colour pods (Table 1). The pods were large (Lupia Jizani, Lupia Baladi and Kafr El Sheikh), medium (Yemeni) or small (Daijiarh, Baladi, Daijiarh Hassawi and YG 30119) with length ranging from 13 cm (Daijiarh Baladi) to 19 cm (Kafr El Sheikh) and number of grains per pod ranged from 10 (Lupia Baladi to 16 (Yemeni). The grain shape was rhomboid (Yemeni and Daijiarh Baladi, Daijiarh Hassawi), kidney (Lupia Jizani, Lupia Baladi Kafr El Sheikh) or ovoid (YG 30119). The grain eye colour was black in all the tested genotypes except the genotypes Daijiarh Hassawi and Kafr El Sheikh, which had brown grain eye colour and genotype YG 30119, which had grey grain eye colour (Table 1).

Agronomic and Yield-related Traits

Tested cowpea genotypes significantly differed for grain yield and yield contributing traits. The locations also differed significantly for the studied parameters except number of grains/pod. However, difference between the years was only significant for plant height, pods per plant and grain yield. Interaction of years and genotypes (Y × G), location and genotypes (L × G) was significant for all of studied parameters except seed index, which was not significant (Table 2). However, interaction of year and location (Y × L) was not significant for all studied traits. Likewise, interaction of year, location and genotype (Y× L× G) was only significant for grain yield (Table 2).

Genotype Lupia Baladi took minimum days to complete 50% flowering, which was followed by the genotypes Lupia Jizani, Kafr El Sheikh and Daijiarh Hassawi when grown in the central part of the Saudi Arabia. However, genotype Yemeni took maximum days for 50% flowering when raised in east; however, that was followed by the same genotype when grown in the centre or the west of Saudi Arabia (Table 3). Plant height was the highest for the genotype Yemeni grown in west and Daijiarh Baladi grown in central or western region (Table 3). The lowest plant height was noted in the genotype Kafr El Sheikh grown in the east, which was similar to the same genotype gown in the centre or west, the genotype Lupia Baladi grown at all locations and genotype Lupia Jizani grown in central or eastern of Saudi Arabia. Highest numbers of pods per plant were noted in the genotype Kafr El Sheikh grown in the centre; whereas, lowest number of pods per plant were recorded in the genotype Yemeni grown in the east, which was similar to the same genotype in the centre (Table 3). Highest number of grains/pod were noted in the genotype Yemeni grown in the east, which was followed by the same genotype grown in the centre and the genotype YG 30119 grown in the central Saudi Arabia. The lowest number of grains per pod was noted in the genotype Lupia Jizani grown in the central Saudi Arabia, which was similar to the same genotype grown in the east of Saudi Arabia (Table 3). Highest number of grains per plant was observed in the genotype Kafr El Sheikh

Table 1: Description and characterization of the cowpea genotypes used in the study

Genotypes	Plant height (cm)	Growth pattern	Growth habit	Flower color	Days to flowering	Pod color	Angle of pod attachment to peduncle	Pod curvature	Pod length (cm)	Grains per pod	Grain size	Grain shape	Eye color
Yemeni	165	Indeterminate	Prostrate	White	46	Light	30–90° down from erect	Straight	18	16	Medium	Rhomboid	Black
Daijiarh Baladi	169	Indeterminate	Prostrate	White	40	Dark	30–90° down from erect	Slightly curved	13	14	Small	Rhomboid	Black
Daijiarh Hassawi	155	Indeterminate	Prostrate	White	31	Light	30–90° down from erect	Straight	16	15	Small	Rhomboid	Brown
Lupia Jizani	55	Determinate	Erect	White	31	Light	Pendant	Straight	18	11	Large	Kidney	Black
Lupia Baladi	53	Determinate	Erect	White	30	Light	Pendant	Straight	16	10	Large	Kidney	Black
Kafr El Sheikh	44	Determinate	Erect	White	30	Light	Pendant	Straight	19	14	Large	Kidney	Brown
YG 30119	119	Indeterminate	Prostrate	Light Violet	32	Dark	30–90° down from erect	Slightly curved	15	15	Small	Ovoid	Gray

Table 2: Analysis of variance for the days to flowering, plant height and yield related traits of cowpea genotypes across locations and years

SOV	DF	Mean Sum of Squares						
		Days to flowering	Plant height	Pods/plant	Grains/plant	Grains/pod	Seed index	Grain yield/plant
Year (Y)	1	34.6ns	734.9**	27.6**	214.2ns	15.9ns	6.7ns	24.5*
Location (L)	2	377.7**	588.4**	15.2**	4075.7**	2.2ns	115.8**	249.5**
Y × L	2	10.2ns	19.5ns	0.9ns	71.4ns	0.2ns	7.3ns	13.5ns
Error	12	12.9	16.4	3.4	461.6	1.9	12.07	4.7
Genotype (G)	6	220.8**	58565.8**	156.8**	21821.0**	21.9**	228.9**	1251.2**
Y × G	6	43.1**	330.8**	10.2**	1202.2*	14.2*	1.4ns	26.7**
L × G	12	31.1**	146.9**	4.0**	1935.1**	18.7**	7.5ns	64.9**
Y× L× G	12	14.5ns	30.9ns	1.4ns	400.2ns	6.8ns	6.7ns	11.9*
Error	72	9.9	28.284	1.215	491.421	5.1	11.7	5.2
CV%		7.6	5.0	15.3	24.2	17.2	20.8	15.8

SOV = Source of variation; DF = Degree of freedom; ns = Non-significant; * = significant at $P \leq 0.05$; **= significant at $P \leq 0.01$

Table 3: Days to flowering, plant height and yield related traits of cowpea genotypes at three locations in Saudi Arabia

Genotypes	Days to flowering				Plant height (cm)			
	Centre	East	West	Mean	Centre	East	West	Mean
Yemeni	47.0 ab	49.3 a	46.2 a-d	47.5A	162.7 ab	160.0 bc	168.8 a	163.8 A
Daijiarh Baladi	42.7 d-h	44.0 b-f	41.9 e-h	42.9 B	168.2 a	155.0 cd	167.4 a	163.5 A
Daijiarh Hassawi	35.2 jk	41.5 fgh	41.3 fgh	39.3CD	158.0 bc	149.3 d	154.3 cd	153.9 B
Lupia Jizani	34.5 jk	41.7 fgh	39.8 ghi	38.7 DE	49.7 hi	48.4 hi	51.5 h	49.9 D
Lupia Baladi	33.5 k	37.7 ij	39.1 hi	36.8E	47.2 hi	48.3 hi	46.0 hi	47.1 DE
Kafr El Sheikh	35.2 jk	45.5 b-e	46.5 abc	42.4 B	46.7 hi	44.8 i	46.2 hi	45.9 E
YG 30119	36.5 ijk	43.5 b-f	43.2 c-g	41.1 BC	121.2 f	115.0 g	138.3e	124.8 C
	No. of pods/ plant				No. of grains /pod			
Yemeni	3.5 kl	3.0 l	4.6 jk	3.7F	15.0 ab	15.6 a	12.0 d-h	14.2 A
Daijiarh Baladi	4.8 j	4.9 j	5.4 ij	5.0 E	13.5 a-f	12.5 b-g	12.8 b-g	12.9 AB
Daijiarh Hassawi	6.3 hi	7.2 fgh	6.9 gh	6.8 D	14.7 abc	14.7 abc	10.8 gh	13.4 A
Lupia Jizani	11.1 b	8.6 de	10.7 bc	10.2 B	9.5 h	11.1 e-h	13.8 a-d	11.5 B
Lupia Baladi	8.3 ef	7.5 e-h	8.1 efg	8.0 C	11.0 fgh	10.5 gh	13.7 a-e	11.7 B
Kafr El Sheikh	13.5 a	9.9 cd	12.07 b	11.8 A	14.2 a-d	13.5 a-f	14.7 abc	14.1 A
YG 30119	5.5 ij	4.7 jk	5.0 j	5.1 E	15.0 ab	14.0 a-d	12.1 c-g	13.7 A
	No. of grains / plant				Seed index (g)			
Yemeni	54.0 ij	46.5 j	54.1 ij	51.5 E	13.2	12.9	16.7	14.3 CD
Daijiarh Baladi	64.9 g-j	61.0 hij	73.0 f-i	66.3 D	9.2	8.2	12.3	9.9 E
Daijiarh Hassawi	92.8 def	93.0 def	76.5 f-i	87.4 C	10.6	10.9	15.3	12.2 D
Lupia Jizani	103.4 cde	94.0 def	150.2 b	115.9 B	19.6	19.1	22.0	20.2 A
Lupia Baladi	90.3 d-g	80.6 e-h	111.3 cd	94.1 C	15.5	16.2	17.5	16.4 BC
Kafr El Sheikh	188.2 a	120.2 c	155.2 b	154.5 A	18.9	17.8	18.2	18.3 AB
YG 30119	84.6e-h	65.1g-j	60.9 hij	70.2D	10.9	13.3	16.3	13.5D

Means sharing the same case letter, for a parameter, do not differ significantly at $P \leq 0.05$

grown in the central Saudi Arabia. However, lowest numbers of grains per plant were noted in the genotype Yemeni grown in the east. Highest seed index was recorded in the genotype Lupia Jizani, which was followed by the genotype Kafr El Sheikh. However, the minimum seed index was noted in the genotype Daijiarh Baladi (Table 3).

The highest grain yield per plant was noted in the genotypes Lupia Jizani and Kafr El Sheikh grown in the western and central Saudi Arabia during both study years (Table 4). However, the lowest grain yield was noted in the genotype Daijiarh Baladi grown in the east during 2016, which was followed by the same genotype grown in the central Saudi Arabia during 2015 (Table 4).

Grain Analyses

Storage substances and mineral composition: Highly significant differences were found among cowpea genotypes for the grain composition at different locations. The ash percentage ranged between 4.0 to 5.9%. Highest ash percentage was observed for Daijiarh Hassawi, while lowest ash contents were recorded for Lupia Jizaniacross all three locations. The crude protein contents only differed significantly when grown in the western part of Saudi Arabia. The protein contents were highest in genotype Lupia Baladi and were lowest in the genotype YG 30119. The crude fat contents differed significantly among genotypes at all locations, and ranged from 1.7 to 3.2% (Table 5). Genotype YG 30119 had the lowest crude fat contents, whereas highest crude fat contents were noted in the genotypes Daijiarh Hassawi and Lupia Baladiacross the three locations. The cowpea genotypes significantly differed for grain carbohydrate contents when grown in the central and eastern parts of Saudi Arabia. In the centre, highest carbohydrate contents were noted in genotype Lupia Jizani while in the east highest carbohydrate contents were noted in genotype YG 30119. However, lowest carbohydrate contents, at both locations, were noted in genotype Daijiarh Hassawi (Table 5).

Cowpea genotypes varied greatly for grain mineral composition (Table 6). Sodium concentration ranged from 2.3–4.5 mg 100 g^{-1}. In this regard, highest Na concentration was observed in genotypes Yameni, Daijiarh Baladi, YG 30119 and Lupia Baladi, while lowest grain Na was observed in genotye Daijiarh Hassawi (Table 6). Magnesium and K concentration ranged from 14.4 to 25.9 mg 100 g^{-1} and 57.5 to 95.6 mg 100 g^{-1}, respectively. The maximum K concentrations were recorded in genotype Daijiarh Baladi across all three locations and in genotype Yemeni when grown at centre part of Saudi Arabia, while lowest K concentration was recorded in genotypes Lupia Baladi and Kafr El Sheikh. Magnesium concentration was lowest in the genotype Kafr EL Sheikh while the highest was recorded noted in the genotype Daijiarh Baladi, irrespective of location (Table 6). Grain Ca concentration, in cowpea genotypes, ranged from 8.5–14.0 mg100 g^{-1}. Highest Ca concentration was recorded in genotype Daijiarh Baladi while lowest was noted in genotype Kafr El Sheikh (Table 6).

The highest grain Mn concentration was recorded in genotype Daijiarh Baladi across three locations while the lowest grain Mn concentration was noted in genotype Lupia Baladi when grown in the central part of Saudi Arabia (Table 6). Grain Fe and Zn concentration ranged from 0.50 to 0.87 mg100 g^{-1} and 0.43 to 0.68 mg 100 g^{-1}, respectively. The highest Fe concentration were noted in the genotypes Daijiarh Baladi, Lupia Baladi and YG 30119 across three locations while lowest grain Fe concentration were noted in the genotype Daijiarh Hassawi in the central region. Highest grain Zn concentration was noted in genotypes Lupia Baladi and Daijiarh Baladi. while the lowest grain Zn concentration was recorded in genotype Lupia Jizani across three locations. Highest grain Cu concentration was noted in genotype Daijiarh Baladi grown in the eastern region while the lowest grain Cu concentration was noted in the genotype YG 30119 in the same region (Table 6).

Antioxidants

Total phenolic contents significantly varied amongst cowpea genotypes at all three locations. The highest total phenolic contents were noted in the genotype Daijiarh Hassawi in the central region, which was followed by the genotype Daijiarh Baladi at all three locations. The lowest total phenolic contents were recorded in the genotype Lupia Jizaniat all three locations (Table 7). The total flavonoids in grain extracts also differed significantly at all three locations. The highest values were observed in the genotypes Daijiarh Baladi and Kafr El Sheikh at all three locations, which was similar to that of genotypes Daijiarh Baladi and Yemeni in the central and eastern parts of Saudi Arabia. On the other hand, the lowest total flavonoids were recorded in the genotype YG 30119 at all three locations (Table 7). The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity also varied amongst cowpea genotypes and locations. The highest DPPH radical scavenging activity was noted in the genotypes Daijiarh Baladi grown in the central and eastern parts of Saudi Arabia and the genotype Daijiarh Hassawi grown in the west. The lowest DPPH radical scavenging activity was noted in the genotype Lupia Jizani at all three locations (Table 7).

Anti-nutritional Factors

All the tested genotypes significantly differed for trypsin activity inhibition capacity, tannins and phytic acid at the three locations. In the central Saudi Arabia, all the tested cowpea genotypes had the similar trypsin activity inhibition capacity except the genotype Yemeni, which had lower trypsin activity inhibition capacity. In the eastern region, all the tested cowpea genotypes had the similar trypsin activity inhibition capacity except the genotypes Yemeni and YG 30119, which had lower values than the rest of the genotypes.

In the western part, the genotype Yemeni had the lowest trypsin activity inhibition capacity, which was followed by the genotype Daijiarh Hassawi. Rest of all genotypes had similar and higher value of trypsin activity inhibition capacity (Table 7). The lowest tannin contents were recorded in the genotype Daijiarh Baladi while the highest contents were recorded in the grain of genotype Kafr

Table 4: Grain yield/plant (g) of cowpea genotypes across locations and years

Genotypes	Centre		East		West	
	2015	2016	2015	2016	2015	2016
Yemeni	7.7m-r	6.4n-s	5.8p-s	6.2o-s	9.3l-p	7.7m-r
Daijiarh Baladi	5.0 rs	5.5 qrs	5.4 qrs	3.8 s	11.2 j-m	6.7 n-s
Daijiarh Hassawi	8.6 l-r	9.8 k-o	8.3 l-r	13.4 ijk	8.4 l-r	17.3 fgh
Lupia Jizani	22.3 de	17.1 gh	19.1 efg	22.9 cd	32.3 a	32.4 a
Lupia Baladi	13.6 hij	18.6 efg	13.2 ijk	16.7 ghi	20.3 d-g	18.9 efg
Kafr El Sheikh	33.2 a	32.2 a	19.3 d-g	20.8 def	28.1 b	26.5 bc
YG 30119	6.9 n-s	8.4 l-r	7.3 n-s	10.0 j-n	8.9 l-q	11.6 jkl

Means sharing the same letter do not differ significantly at $P \leq 0.05$

Table 5: Grain ash, crude protein, fat and carbohydrates of different cowpea genotypes at three locations in Saudi Arabia

Genotypes	Ash (%)				Crude protein (%)				Fat (%)				Carbohydrate (%)			
	Centre	East	West	Mean	Centre	East	West	Mean	Centre	East	West	Mean	Centre	East	West	Mean
Yemeni	4.5bc	4.3b	4.4bc	4.4B	27.3	27.3	27.3b	27.3B	2.3a	2.1ab	2.2a	2.2A	65.9d	66.3d	66.1	66.1D
Daijiarh Baladi	4.1cd	4.2b	4.2c	4.2BC	25.9	25.6	25.8b	25.8BC	2.0ab	2.0ab	2.0ab	2.0A	68.1c	68.2c	68.2	68.2C
Daijiarh Hassawi	5.9a	5.8a	5.9a	5.9A	32.0	32.3	32.2a	32.2A	3.2a	3.0a	3.1a	3.2A	59.0g	59.0g	59.0	59.0G
Lupia Jizani	4.0d	4.1bc	4.1cd	4.1BC	24.2	25.2	24.7bc	24.7C	1.9ab	1.8ab	1.9ab	1.9A	69.9a	68.8b	69.4	69.4B
Lupia Baladi	5.2b	5.3a	5.3b	5.3A	31.6	30.9	31.3a	31.3A	3.0a	3.1a	3.1a	3.1A	60.3f	60.7f	60.5	60.5F
Kafr El Sheikh	4.8b	4.9ab	4.9b	4.9AB	27.0	27.3	27.2b	27.2B	2.1a	2.3a	2.2a	2.2A	66.1d	65.6e	65.9	65.9E
YG 30119	4.1cd	4.3c	4.2c	4.2BC	24.7	23.9	24.3bc	24.3C	1.7ab	1.8ab	1.8ab	1.8AB	69.5b	70.0a	69.8	69.8A
LSD (P 0.05)	0.4	0.6	0.5	0.6	Ns	ns	3.1	2.7	1.1	0.8	1.0	1.3	0.2	0.3	ns	0.1

Means sharing the same case letter, for a parameter, do not differ significantly at $P \leq 0.05$

Table 6: Minerals contents in the grains of different cowpea genotypes at three locations in Saudi Arabia

Genotypes	Na (mg 100 g^{-1})				Mg (mg 100 g^{-1})				K (mg 100 g^{-1})				Ca (mg 100 g^{-1})			
	Centre	East	West	Mean	Centre	East	West	Mean	Centre	East	West	Mean	Centre	East	West	Mean
Yemeni	4.0a	5.0a	4.5a	4.5A	22.4a	24.1a	23.3a	22.4A	83.1a	87.1b	85.1b	85.3B	10.3b	12.5a	11.4b	11.4B
Daijiarh Baladi	4.2a	4.8a	4.5a	4.5A	25.9a	26.8a	26.4a	25.9A	92.0a	99.2a	95.6a	95.6A	14.5a	13.4a	14.0a	14.0A
Daijiarh Hassawi	2.4b	2.2b	2.3b	2.3B	22.0a	21.0ab	21.5a	22.0A	66.8c	70.3c	68.6c	68.5C	9.3b	12.5a	10.9b	10.9BC
Lupia Jizani	2.6b	3.0ab	2.8ab	2.8AB	16.0c	16.4b	16.2ab	16.0B	58.3cd	56.4d	57.4d	57.5D	10.8b	9.2b	10.0bc	10.0BC
Lupia Baladi	4.4a	4.3a	4.4a	4.4A	19.8ab	21.0ab	20.4ab	19.8AB	70.4c	68.3c	69.4c	69.5C	10.8b	12.9a	11.9b	11.9B
Kafr El Sheikh	2.5b	2.5ab	2.5b	2.5AB	14.4c	15.3bc	14.9b	14.4BC	57.5cd	65.0c	61.3cd	61.3D	8.6b	8.3b	8.5c	8.5CD
YG 30119	3.3ab	4.5a	3.9a	3.9A	16.4c	16.8b	16.6ab	16.4AB	58.2cd	55.3d	56.8d	56.8CD	8.3bc	9.8b	9.1c	9.1C
LSD (P 0.05)	1.1	1.5	0.9	1.2	3.1	4.0	5.4	3.9	10.0	7.4	9.7	8.4	2.2	1.9	1.5	1.8
	Mn (mg 100 g^{-1})				Fe (mg 100 g^{-1})				Cu (mg 100 g^{-1})				Zn (mg 100 g^{-1})			
Yemeni	0.19b	0.18b	0.19b	0.19B	0.59b	0.59ab	0.59a	0.59AB	0.11e	0.12d	0.12ab	0.12B	0.54ab	0.52b	0.53b	0.53C
Daijiarh Baladi	0.25a	0.29a	0.27a	0.27A	0.81a	0.87a	0.84a	0.81A	0.21b	0.27a	0.24a	0.24A	0.67a	0.61a	0.64a	0.64A
Daijiarh Hassawi	0.14d	0.12cd	0.13d	0.13D	0.50bc	0.53b	0.52ab	0.50AB	0.09ef	0.12d	0.11ab	0.11B	0.58a	0.59ab	0.59ab	0.59B
Lupia Jizani	0.17c	0.14c	0.16c	0.16BC	0.55b	0.52b	0.54a	0.55AB	0.14c	0.17c	0.16a	0.16B	0.45b	0.43c	0.44d	0.44E
Lupia Baladi	0.11e	0.15bc	0.13d	0.13D	0.75a	0.77a	0.76a	0.75A	0.22a	0.21b	0.22a	0.22A	0.62a	0.68a	0.65a	0.65A
Kafr El Sheikh	0.19b	0.18b	0.19b	0.19B	0.51b	0.55b	0.53a	0.51AB	0.13d	0.10e	0.12ab	0.12B	0.46b	0.47bc	0.47d	0.47D
YG 30119	0.19b	0.17b	0.18b	0.18B	0.81a	0.82a	0.82a	0.81A	0.10e	0.09e	0.10ab	0.10BC	0.51ab	0.52b	0.52bc	0.52C
LSD (P 0.05)	0.10	0.20	0.20	0.21	0.14	0.20	0.31	0.2	0.01	0.01	0.08	0.05	0.10	0.08	0.05	0.10

Means sharing the same case letter, for a parameter, do not differ significantly at $P \leq 0.05$

El Sheikh across the three locations (Table 7). In the central part of Saudi Arabia, minimum phytic acid contents were noted in the genotype Daijiarh Baladi (Table 7). In the east and west parts, the genotypes Daijiarh Baladi and Kafr El Sheikh had the lowest phytic acid contents whereas all other genotypes had higher and similar phytic acid contents (Table 7).

Amino Acids

The cowpea genotypes significantly varied for grain amino acids across the three locations. The lowest alanine contents, in the central region, were noted in the genotype Daijiarh Hassawi, which was followed by the genotypes Yemeni and YG 30119 whereas the other genotypes had higher and similar alanine contents. In the east, the lowest alanine contents were noted in the genotype YG 30119 whereas the highest alanine contents were recorded in the genotype Kafr El Sheikh. In the west, the highest alanine contents were recorded in the genotype Daijiarh Baladi whereas the lowest alanine contents were noted in the genotype YG 30119 (Table 8). At all three locations, highest glycine contents were recorded in the genotype Daijiarh Hassawi whereas lowest glycine contents were noted in the genotype Yemeni. At all three locations, the lowest leucine contents were recorded in the genotypes Daijiarh Hassawi and Daijiarh Baladi whereas the highest leucine contents were recorded in the

Table 7: Antioxidants and anti-nutritional factors in grains of different cowpea genotypes at three locations in Saudi Arabia

Genotypes	Total phenolics (mg g^{-1})				Total flavonoids (mg g^{-1})				DPPH radical scavenging activity (%)			
	Centre	East	West	Mean	Centre	East	West	Mean	Centre	East	West	Mean
Yemeni	0.60c	0.68a	0.66a	0.65A	2.8a	3.3a	3.7ab	3.3A	47.8c	53.1a	50.5b	50.5B
Daijiarh Baladi	0.82a	0.78a	0.82a	0.81A	3.4a	4.0a	4.8a	4.1A	62.2a	55.2a	48.2b	55.2A
Daijiarh Hassawi	0.86a	0.53ab	0.71a	0.70A	3.3a	3.0a	2.7ab	3.0A	62.8a	47.2b	55.0a	55.0A
Lupia Jizani	0.39d	0.24c	0.33b	0.32C	1.6ab	1.3b	0.6c	1.2B	21.7e	25.7cd	23.8c	23.7C
Lupia Baladi	0.73ab	0.27c	0.52ab	0.51AB	1.9ab	1.4b	0.9c	1.4B	27.0c	30.2c	29.0c	28.7C
Kafr El Sheikh	0.73ab	0.23c	0.50ab	0.49AB	3.5a	3.5a	3.9a	3.6A	50.4b	50.0ab	51.0b	50.5B
YG 30119	0.43d	0.30c	0.39b	0.37BC	1.5b	0.6b	0.1c	0.7B	24.4d	28.2c	26.3c	26.3C
LSD (P 0.05)	0.12	0.22	0.24	0.21	1.2	1.3	1.0	1.1	2.5	3.1	3.9	3.2
	Trypsin inhibitor units (mg g^{-1})				Tannins (mg 100 g^{-1})				Phytic acid (mg g^{-1})			
Yemeni	1.90ab	2.10c	2.20b	2.07B	0.30ab	0.32ab	0.31b	0.31AB	3.10a	3.20a	2.90ab	3.07A
Daijiarh Baladi	3.10a	3.20a	3.10a	3.13A	0.19b	0.20bc	0.18c	0.19BC	2.50ab	2.10b	2.40b	2.33B
Daijiarh Hassawi	2.40a	2.40a	2.60ab	2.47AB	0.21ab	0.25b	0.23c	0.23B	3.30a	3.10a	3.10a	3.17A
Lupia Jizani	2.90a	3.30a	3.20a	3.13A	0.37a	0.38a	0.34b	0.36A	3.10a	3.30a	3.10a	3.17A
Lupia Baladi	2.90a	3.30a	3.20a	3.13A	0.37a	0.38a	0.34b	0.36A	3.10a	3.30a	3.10a	3.17A
Kafr El Sheikh	2.90a	3.10a	3.30a	3.10A	0.42a	0.43a	0.45a	0.43A	2.70a	2.20b	2.50b	2.47B
YG 30119	2.50a	2.60b	2.80a	2.63A	0.39a	0.38a	0.41a	0.39A	3.20a	3.10a	3.50a	3.27A
LSD (P 0.05)	0.71	0.25	0.52	0.71	0.11	0.07	0.06	0.10	0.51	0.45	0.59	0.42

Means sharing the same case letter, for a parameter, do not differ significantly at $P \leq 0.05$
DPPH = 2,2-diphenyl-1-picrylhydrazyl

genotypes Lupia Jizani, Lupia Baladi and YG 30119 (Table 8). At all three locations, the lowest tyrosine contents were noted in the genotype Yemeni whereas the highest leucine contents were recorded in the genotypes Lupia Jizani and Lupia Baladi. Highest isoleucine contents were noted in the genotypes Lupia Jizani and Lupia Baladi at all three locations; whereas the lowest isoleucine contents were recorded in the genotypes Yemeni and Kafr El Sheikh at all three locations. At all three locations, the lowest phenylalanine contents were noted in the genotype Yemeni whereas the highest phenylalanine contents were recorded in the genotype Daijiarh Baladi (Table 8).

The lowest tryptophan contents were recorded in the genotype YG 30119 whereas the highest tryptophan contents, in the central region, were recorded in the genotypes Lupia Jizani and Lupia Baladi. In the east, the highest tryptophan contents were recorded in the genotype Yemeni whereas in the west that were recorded in genotype Daijiarh Baladi (Table 8). The highest valine contents, in the centre and the east, were noted in the genotypes Lupia Jizani and Lupia Baladi whereas in the west, the highest valine contents were noted in the genotype Daijiarh Hassawi. The lowest valine contents, in the east and west, were noted in the genotype Yemeni whereas in the centre, the lowest valine contents were recorded in the genotype YG 30119 (Table 8).

At all three locations, the lowest proline contents were noted in the genotypes Lupia Jizani and Lupia Baladi whereas the highest proline contents, in the central and western parts of Saudi Arabia, were recorded in the genotypes Daijiarh Hassawi and genotype Kafr El Sheikh in the east (Table 8). At all three locations, the highest serine contents were noted in the genotypes Daijiarh Hassawi and Kafr El Sheikh whereas the lowest serine contents were recorded in the genotypes Lupia Jizani and Lupia Baladi, which was similar to genotype YG 30119 in the east and west parts of Saudi Arabia (Table 8). The highest threonine contents, at all three locations, were noted in the genotype YG 30119 whereas the lowest threonine contents were recorded in the genotypes Kafr El Sheikh, Daijiarh Baladi and Yemeni in the central, eastern and western parts of Saudi Arabia, respectively (Table 8). The highest glutamic acid contents, in all locations, were recorded in the genotype YG 30119 whereas the lowest contents were noted in the genotype Yemeni. Likewise, the highest aspartic acid contents, in all locations, were recorded in the genotype YG 30119 whereas the lowest contents were noted in the genotype Daijiarh Baladi. The highest histidine contents, at all three locations, were noted in the genotypes Lupia Jizani and Lupia Baladi whereas the lowest contents were noted in the genotype Kafr El Sheikh in the centre and east, and in the genotype Daijiarh Baladi in the west. The highest cysteine contents, at all three locations, were noted in the genotypes Daijiarh Hassawi and YG 30119 whereas the minimum cysteine contents were noted in the genotype Yemeni. At all three locations, the highest methionine contents were noted in the genotype Daijiarh Baladi whereas the minimum methionine contents were noted in the genotype Daijiarh Hassawi (Table 8). The highest lysine contents, at all three locations, were noted in the genotypes Daijiarh Baladi, Lupia Jizani and Lupia Baladi whereas the lowest lysine contents were noted in genotype Yemeni (Table 8). The lowest arginine contents, at all locations, were recorded in the genotype Daijiarh Baladi whereas the highest arginine contents were recorded in the genotypes Lupia Jizani and Lupia Baladi (Table 8).

Discussion

The phenotypic expression of yield and other quantitative

Table 8: Amino acids content in grains of different cowpea genotypes at three locations in Saudi Arabia

Genotypes	Alanine (g 100 g^{-1})				Glycine (g 100 g^{-1})				Leucine (g 100 g^{-1})			
	Centre	East	West	Mean	Centre	East	West	Mean	Centre	East	West	Mean
Yemeni	3.40b	3.10c	3.60ab	3.37B	5.10c	5.40d	5.20d	5.23D	7.10b	7.30a	7.80a	7.40B
Daijiarh Baladi	4.20a	4.10b	4.30a	4.20A	6.30b	6.60b	6.90b	6.60B	6.30d	6.40c	6.30c	6.33D
Daijiarh Hassawi	2.90c	3.20c	3.20c	3.10B	7.80a	7.80a	7.30a	7.63A	5.90e	6.10d	6.30c	6.10D
Lupia Jizani	4.20a	3.90b	4.10a	4.06A	3.10d	3.50e	3.70e	3.43E	7.50a	7.30a	7.80a	7.53A
Lupia Baladi	4.20a	3.90b	4.10a	4.06A	3.10d	3.50e	3.70e	3.43E	7.50a	7.30a	7.80a	7.53A
Kafr El Sheikh	4.10a	4.70a	3.90a	4.23A	6.10b	5.90c	6.20c	6.07C	6.80c	6.90b	6.70b	6.80C
YG 30119	3.40b	2.90cd	2.70d	3.00B	6.50b	6.60b	6.30c	6.47B	7.50a	7.30a	7.80a	7.53A
LSD (P 0.05)	0.32	0.27	0.38	0.31	0.41	0.49	0.38	0.29	0.26	0.24	0.31	0.33
	Tyrosine (g 100 g^{-1})				Isoleucine (g 100 g^{-1})				Phenylalanine (g 100 g^{-1})			
Yemeni	3.40d	3.20d	3.10e	3.23D	3.50c	3.80c	3.30d	3.53D	4.90f	5.10c	5.20c	5.07D
Daijiarh Baladi	3.80c	3.20d	3.40d	3.46C	4.20a	4.10ab	4.50a	4.27A	6.70a	6.70a	6.80a	6.73A
Daijiarh Hassawi	4.30b	4.60b	4.20c	4.37B	3.90b	4.20a	3.70c	3.93C	6.10c	6.50a	6.20b	6.27B
Lupia Jizani	5.20a	5.50a	5.20a	5.30A	4.30a	4.30a	4.60a	4.40A	5.90d	5.70b	5.80b	5.80C
Lupia Baladi	5.20a	5.50a	5.20a	5.30A	4.30a	4.30a	4.60a	4.40A	5.90d	5.70b	5.80b	5.80C
Kafr El Sheikh	4.30b	4.60b	4.10c	4.33B	3.50c	3.40d	3.70c	3.53D	5.60e	5.80b	6.20b	5.87C
YG 30119	3.90c	4.10c	4.40b	4.13B	4.20a	4.30a	3.90b	4.13AB	6.30b	5.80b	6.10b	6.07B
LSD (P 0.05)	0.24	0.18	0.19	0.21	0.14	0.12	0.18	0.17	0.19	0.21	0.41	0.37
	Tryptophan (g 100 g^{-1})				Valine (g 100 g^{-1})				Proline (g 100 g^{-1})			
Yemeni	1.20b	1.50a	1.30b	1.33B	4.50d	4.60d	4.20d	4.43C	4.12b	4.30b	4.20b	4.21B
Daijiarh Baladi	1.50a	1.30b	1.50a	1.43A	5.20c	5.70ab	4.90bc	5.27B	3.90bc	3.80c	4.10b	3.93C
Daijiarh Hassawi	0.91c	1.10bc	1.20b	1.07C	6.20b	5.90a	6.10a	6.07A	4.80a	4.30b	4.90a	4.67A
Lupia Jizani	1.60a	1.20b	1.00c	1.27B	6.50a	6.10a	5.30b	5.97A	3.20d	3.50c	3.40d	3.37E
Lupia Baladi	1.60a	1.20b	1.00c	1.27B	6.50a	6.10a	5.30b	5.97A	3.20d	3.50c	3.40d	3.37E
Kafr El Sheikh	1.30b	1.30b	1.20b	1.27B	5.20c	5.30c	5.20b	5.23B	4.20b	4.80a	4.70a	4.57A
YG 30119	0.90c	0.80d	0.80d	0.83D	4.30d	4.70d	4.80bc	4.60C	3.40d	3.70c	3.80c	3.63D
LSD (P 0.05)	0.11	0.16	0.17	0.12	0.24	0.21	0.31	0.34	0.23	0.25	0.22	0.21
	Serine (g 100 g^{-1})				Threonine (g 100 g^{-1})				Glutamic acid (g 100 g^{-1})			
Yemeni	7.30c	7.70b	7.20b	7.40B	3.50cd	3.10c	2.80d	3.13D	10.30d	10.50e	10.40e	10.40D
Daijiarh Baladi	7.80ab	7.50b	7.20b	7.50B	3.70c	2.90cd	3.50b	3.37C	12.30c	12.40d	12.50c	12.40C
Daijiarh Hassawi	8.30a	8.50a	8.90a	8.57A	4.20b	3.30c	3.20c	3.57C	12.30c	12.70c	12.10d	12.37C
Lupia Jizani	6.50d	6.80c	6.50c	6.60C	3.90c	3.80b	4.30a	4.00B	13.50b	13.50b	13.60b	13.53B
Lupia Baladi	6.50d	6.80c	6.50c	6.60C	3.90c	3.80b	4.30a	4.00B	13.50b	13.50b	13.60b	13.53B
Kafr El Sheikh	8.20a	8.50a	8.60a	8.43A	3.40cd	3.80b	3.20c	3.47C	12.40c	12.20d	12.50c	12.37C
YG 30119	7.10c	6.90c	6.50c	6.83C	4.50a	4.60a	4.10a	4.40A	15.10a	14.90a	14.70a	14.90A
LSD (P 0.05)	0.41	0.35	0.32	0.44	0.29	0.28	0.22	0.31	0.26	0.28	0.29	0.31
	Aspartic acid (g 100 g^{-1})				Histidine (g 100 g^{-1})				Cysteine (g 100 g^{-1})			
Yemeni	8.20c	8.90c	8.50b	8.53C	3.40b	3.10bc	3.40ab	3.30AB	0.40bc	0.50bc	0.50bc	0.47B
Daijiarh Baladi	7.50d	7.30d	7.80c	7.53D	2.70c	2.80bc	2.30d	2.60C	0.50b	0.50bc	0.60ab	0.53AB
Daijiarh Hassawi	9.30b	9.50ab	9.70a	9.50B	3.90a	3.40b	3.50a	3.70A	0.80a	0.70a	0.70a	0.73A
Lupia Jizani	10.20a	9.90a	9.80a	9.97A	4.10a	3.90a	3.70a	3.90A	0.50a	0.70a	0.60ab	0.60AB
Lupia Baladi	10.20a	9.90a	9.80a	9.97A	4.10a	3.90a	3.70a	3.90A	0.50b	0.70a	0.60ab	0.63A
Kafr El Sheikh	9.90a	9.90a	9.70a	9.83A	2.40c	2.50bcd	2.70c	2.53C	0.70a	0.60ab	0.60ab	0.63A
YG 30119	10.20a	10.30a	9.90a	10.13A	3.20b	3.50b	3.70a	3.47AB	0.70a	0.80a	0.80a	0.77A
LSD (P 0.05)	0.51	0.57	0.53	0.48	0.39	0.31	0.29	0.41	0.15	0.11	0.12	0.15
Genotypes	Methionine (g 100 g^{-1})				Lysine (g 100 g^{-1})				Arginine (g 100 g^{-1})			
Yemeni	1.30b	1.00c	1.20b	1.17B	5.40c	5.70b	5.90c	5.67D	7.30c	7.50d	7.20b	7.33C
Daijiarh Baladi	1.50a	1.40a	1.50a	1.47A	7.10a	6.90a	7.50a	7.17A	6.50d	6.30f	6.20c	6.33E
Daijiarh Hassawi	0.90d	0.80d	0.70c	0.80C	6.30b	6.50a	6.10c	6.30C	7.80b	7.90c	7.40b	7.70B
Lupia Jizani	1.10c	1.30a	1.20b	1.20B	7.20a	6.80a	7.50a	7.17A	8.40a	8.90a	8.30a	8.53A
Lupia Baladi	1.10c	1.30a	1.20b	1.20B	7.20a	6.80a	7.50a	7.17A	8.40a	8.90a	8.30a	8.53A
Kafr El Sheikh	1.30b	1.20ab	1.10b	1.20B	4.60d	4.90c	4.10d	4.53E	8.30a	8.60b	8.20a	8.37A
YG 30119	0.90d	0.80d	0.80c	0.83C	6.30b	6.80a	6.90b	6.67B	6.50d	6.70e	7.20b	6.80D
LSD (P 0.05)	0.11	0.12	0.18	0.19	0.21.	0.41	0.36	0.34	0.35	0.29	0.31	0.35

Means sharing the same case letter, for a parameter, do not differ significantly at $P \leq 0.05$

traits varied due to genotypic differences, locations (environments) and genotype by environment interactions. The extent of such variations is vital to design breeding strategies and improve the selection methods. This kind of multi-locational trails helps the crop improvement programs to evaluate the relative performance of diverse group of genotypes and recommend genotypes for each region/location.

Growth habit and pattern are very important characteristics of cowpea, which dictates the choice for its utility. For instance, erect genotypes have their pod raceme positions above the canopy, which facilitates the visibility of pods for harvesting, whereas the prostrate types have more canopies, and pod raceme positions are within the canopy and could be used as cover crop or as livestock forage. With high intercrop adaptability, erect types may fetch better returns (Ravelombola *et al.,* 2017). However, in the situations of mixed crop-livestock farming systems, the prostrate types may be a better choice as these produce more leaves for use as livestock forage (Ravelombola *et al.,* 2017). However, the erect type for pod attachment to the peduncle is a desired character especially for the plants with prostrate growth to facilitate the pod harvesting at maturity. In this study, the determinate genotypes, Lupia Jizani, Lupia Baladi and Kafr El Sheikh were short statured than the indeterminate cowpea genotypes. IPGRI (1982) described five grain shapes, namely, rhomboid, kidney, globose, crowder, and ovoid. However, in this study, we noted only three shapes *viz.* rhomboid, kidney and ovoid. Interestingly, the determinate genotypes had large kidney shaped grains.

The grain yield and other related traits showed high diversity among the genotypes irrespective of environmental and their interaction effects. The magnitude of genotypic variance was the major contributor, which was greater than the environmental variance interactions of G × E (Manggoel *et al.,* 2012; El-Shaieny *et al.,* 2015). Cowpea plants flowered earlier by 5 days in the central part of Saudi Arabia than in the Eastern region, and the earliest flowering genotypes were Lupia Jizani and Lupia Baladi at the three locations with mean days of 37, 39 and 39, respectively, whereas Yemeni was a late flowering genotype and flowered after 42 days. Overall, better growth and yield of cowpea genotypes was recorded in the western part of Saudi Arabia.

In this study, the determinate genotypes produced more number of branches than the indeterminate genotypes (data not given) resulting in more pods and grains per plant. Moreover, grain size of the determinate genotypes was large than the indeterminate genotypes. These all attributes contributed for better yield of determinate genotypes. In this regard, genotype Kafr El Sheikh yielded more in the centre whereas Lupia Jizani yielded better both in the eastern and western parts of Saudi Arabia. The indeterminate genotypes continue their vegetative growth even after the flower appearance whereas in determinate genotypes, upon shift of terminal meristems to terminal flower, the vegetative growth ceases (Bradley *et al.,* 1997). Therefore, the assimilates are distributed to both vegetative and reproductive organs depriving the developing grains from the major share (Reinhardt and Kuhlemeier, 2002), which may result in yield reduction as was observed in this study. However, some of the previous researchers reported higher grain yield from the indeterminate genotypes than the determinate genotypes (Kamara *et al.,* 2011). Probably those studies were conducted in dry environments which favored indeterminate genotypes while during this study sufficient water and nutrients were made available resulting in excessive vegetative growth of indeterminate genotypes.

Highly significant differences for grain composition suggested that genotypes Daijiarh Hassawiand Lupia Baladihad the highest protein (32.2 and 31.2% respectively) and fat (each 3.1%) contents with less carbohydrate percentage (59.0 and 60.5% respectively),whereas genotype Lupia Jizani showed the highest carbohydrate contents (69.4%).The grain mineral contents as Ca, K, Mg, Fe, Cu and Zn were high in all cowpea genotypes, which are enough for the human requirement to prevent malnutrition as recommended by Recommended Dietary Allowance (NRC/NAS 1989). Unlike other minerals, K, followed by Mg and Na, were high in cowpea grains. Highest K, Mg and Ca contents were recorded in genotype Daijiarh Baladi. Furthermore, in the present study, low grain phytate concentration (anti nutrient compound) and high Zn and Fe in the cowpea seeds indicate high bioavailable Fe and Zn (Rehman *et al.,* 2018a, b). Genotypes with high Zn and Fe also have high protein concentration showing that these traits can be improved simultaneously, and these genotypes can be used in future breeding programs.

The grains of cowpea were also enriched with antioxidants including phenolics, flavonoids and DPPH radical scavenging activity. Therefore, the increased consumption of cowpea grains can lessen some types of cancer and cardiovascular diseases. The genotype Daijiarh Baladi had the highest phenolics, flavonoids, and DPPH radical scavenging activity, in addition to the lower values of tannin and phytic acid. Lowest trypsin inhibitor units were measured in Yemeni. Higher accumulation of flavonoids and phenolics shows the ability of cowpea genotypes to withstand biotic and environmental stresses as phenol derivatives act as precursor of flavonoids, anthocyanin and lignans (Alam *et al.,* 2016), while flavonoids help plants against UV radiations, disease resistance, pigmentation, nitrogen fixation and growth regulation (Kumar and Pandey, 2013). The total phenolics are an important component of antioxidant activity (Siddhuraju and Becker, 2007; Martin *et al.,* 2013; Mtolo *et al.,* 2017).

Grains of cowpea also contained high amount of amino acids as leucine (genotypes Yemeni, Lupia Jizani, Lupia Baladi and YG 30119) and lysine (genotypes Daijiarh Baladi, Lupia Jizani, and Lupia Baladi) and low amount of methionine and tryptophan. The major non-essential amino acids found were glutamic acid and aspartic acid.

Conclusion

The phenotypic expression of yield and other quantitative traits varied due to genotypic differences, locations and genotype by environment interactions. In terms of grain yield, the determinate genotypes Kafr El-Sheikh and Lupia Jizani yielded better. Genotype Kafr El Sheikh yielded more in the centre whereas Lupia Jizani yielded better both in the eastern and western parts of Saudi Arabia. Overall, cowpea produced better yield in western region. The genotype Lupia Baladi with high Zn, Fe and antioxidants also have high protein and essential amino acids showing that these traits can be improved simultaneously, and this genotype can be used in future breeding programs.

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