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Genetic divergence among African cowpea lines based on morphoagronomic traits

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ABSTRACT. The aim of this study was to estimate the genetic divergence between African cowpea lines from the Cowpea Germplasm Bank of Embrapa Meio-Norte, Brazil. The morphoagronomic diversity of 57 cowpea lines was assessed using multivariate analysis. The germplasm was evaluated in August 2009 using a randomized block design with three replications based on the following traits: number of pods per peduncle, pod length (PL), number of grains per pod (NGP), grain length (GRL), grain width, 100-grain weight (W100G), and yield. The heritability values of the traits PL, NGP, GRL, and W100G were all higher than 70%, indicating the possibility of genetic progress with selection. The crosses between the lines IT82D-889 and IT89KD-245, IT85F-1380 and IT89KD-245, and IT89KD-245 and IT98K-1092-1 could result in promising genetic combinations. The characteristics that contributed most to genetic divergence were W100G (49.7%), PL (16.7%), GRL (12.0%), and NGP (9.7%).

Key words: *Vigna unguiculata*; Multivariate analysis; Cowpea accessions; Germplasm bank

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] is grown in all tropical regions over a total of at least 12.5 million hectares, with an annual worldwide production of over 3 million tons in 2007. Nigeria, Niger, and Brazil are the largest cowpea producers worldwide, accounting for 84.1% of the cropped area and 70.9% of global production (FAO, 2009).

Cowpea is a staple protein source for the population of the Northeastern region of Brazil (Bertini et al., 2009). This rather versatile crop is sold on the market in the form of dry grains, green grains or pods, flour for fried balls called "acarajé", and as seeds (Rocha et al., 2006). However, it is mostly sold in the form of dried beans, and is prepared either as a one-pot dish or together with rice (Mohammed et al., 2010).

Breeders have developed elite cultivars and improved lines of this crop, mainly by selection for higher yield, resistance to pests, diseases, nematodes, and weeds, and for drought and salinity tolerance (Ehlers and Hall, 1997). In Brazil, Embrapa Meio-Norte is in charge of actively collecting cowpea germplasm. Currently, the cowpea research network covers the North, Northeast, and Midwest regions, from the State of Roraima to Mato Grosso do Sul and from Pernambuco to Rondônia (Freire Filho et al., 2009).

Studies on genetic divergence provide important information by the characterization of accessions, enabling the identification of duplicates, variety protection, and selection of parents (Gupta and Gopalakrishna, 2009). Most of the information available on cowpea accessions in gene banks is based on morphological characteristics (Nkongolo, 2003). Several studies on the characterization of cowpea have been conducted using morphological (Vural and Karasu, 2007; Hegde and Mishra, 2009) or molecular characteristics (Aremu et al., 2007; Simon et al., 2007), or both (Ghalmi et al., 2009). This study aimed to estimate the genetic divergence between African cowpea lines from the Cowpea Germplasm Bank of Embrapa Meio-Norte.

MATERIAL AND METHODS

Of the cowpea lines (*V. unguiculata*) from the Cowpea Germplasm Bank of Embrapa Meio-Norte, 57 were characterized for morphological and agronomic traits. Of these, 53 had been acquired by exchange with the International Institute of Tropical Agriculture (IITA), located in Nigeria, one line came from California (CB-27), one cultivar came from Peru (Vaina Blanca), one was an African line (TVx 5058 - 09C), and one line originated from the Cowpea breeding program of Embrapa Meio-Norte (Table 1).

The experiment was installed in August 2009 in an experimental area of Embrapa Meio-Norte, in Teresina, State of Piauí, in a randomized block design with 57 treatments and three replications. Each experimental plot consisted of one 4-m row, containing 16 plants spaced 0.25 x 1.00 m apart. The following traits were assessed: number of pods per peduncle (NPP), pod length (PL), number of grains per pod (NGP), grain length (GRL), grain width (GRWi), 100-grain weight (W100G), and yield (YD).

The genetic variability between lines was determined by analysis of variance (ANOVA). Averages were compared with the Scott-Knott test at 5% probability. Genetic and environmental parameters were estimated, such as broad-sense heritability (h^2_a), coefficients of genetic variation (CV_g), and coefficients of environmental variation (CV_e).

Genetic divergence was quantified with the unweighted pair-group method of arithmetic means (UPGMA) method, using the Mahalanobis' generalized distance (D^2) of as the similarity measure. Besides its use in the study of genetic diversity, D^2 allows for quantification of the relative contribution of individual characteristics to overall divergence by using the criterion proposed by Singh (1981). The GENES software v. 2007.0.0 (Cruz, 2006) and a statistical program for ANOVA, SISVAR version 4.0 (Ferreira, 2000), were used for the analyses.

Table 1. Cowpea lines of Embrapa Meio-Norte Genbank.

Line number	Line	Origin	Line number	Line	Origin
1	IT93K-452-1	IITA	30	IT98K-1092-2	IITA
2	IT96D-610	IITA	31	IT98K-1103-13	IITA
3	IT97K 568-18	IITA	32	IT98D-1399	IITA
4	IT97K-1042-3	IITA	33	IT99K-718-6	IITA
5	IT98K-205-8	IITA	34	IT00K-901-5-2	IITA
6	IT98K-491-4	IITA	35	IT00K-1207	IITA
7	IT98K-506-1	IITA	36	IT00K-1217	IITA
8	IT98K-589-2	IITA	37	IT00K-1263-2	IITA
9	IT98K-1111-1	IITA	38	IT03K-316-1	IITA
10	IT99K-316-2	IITA	39	IT84S-2135	IITA
11	IT99K-491-7	IITA	40	IT89KD-245	IITA
12	IT99K-494-6	IITA	41	IT87D-697-2	IITA
13	IT99K-529-2	IITA	42	IT85F -1380	IITA
14	IT99K-573-2-1	IITA	43	IT85F-2687	IITA
15	IT99K-1060	IITA	44	IT89KD-349	IITA
16	IT99K-1122	IITA	45	IT96D-618	IITA
17	IT00K-898-5	IITA	46	IT97K-568-14	IITA
18	IT00K-901-5-1	IITA	47	IT98K-1101-5	IITA
19	IT00K-1263-1	IITA	48	IT93K-93-10	IITA
20	IT93K-625	IITA	49	IT92KD-279-3	IITA
21	IT97K-499-35	IITA	50	IT87D-1627	IITA
22	IT97K-1069-6	IITA	51	IT87D-611-3	IITA
23	IT98K-128-3	IITA	52	IT91K-118-2	IITA
24	IT98K-128-4	IITA	53	IT82D-889	IITA
25	IT98K-131-2	IITA	54	CB-27	California
26	IT98K-205-9	IITA	55	Vaina Blanca	Peru
27	IT98K-205-15	IITA	56	TVx 5058 - 09C	African line
28	IT98K-503-1	IITA	57	Mnc 03 720C-11	CPAMN
29	IT98K-1092-1	IITA	-	-	-

IITA = Internacional Institute of Tropical Agriculture; CPAMN = Centro de Pesquisa Agropecuária Meio-Norte, Embrapa Meio-Norte, Teresina, PI, 2009.

RESULTS

The mean squares were obtained from ANOVA for the quantitative traits (Table 2). The coefficient of variation values ranged from 5.83% for W100G to 31.28% for YD.

Table 2. ANOVA of 7 quantitative traits assessed in cowpea lines, in an experiment in Teresina, PI, 2009.

Trait	Mean squares		Mean	CV (%)
	Lines	Error		
Pod length (PL, cm)	9.61**	1.45	16.36	7.35
Number of grains per pod (NGP)	6.62**	1.44	11.91	10.08
Grain length (GRL)	2.00**	0.32	8.36	6.78
Grain width (GRWi, mm)	0.90**	0.37	5.60	10.90
Number of pods per peduncle (NPP)	0.34*	0.21	2.02	22.72
100-grain weight (W100G)	25.67**	1.05	17.54	5.83
Yield (YD, g)	11930.53**	5425.90	235.51	31.28

**Significant at 1% probability by the F-test.

The trait means (Table 3) showed a variation of 1.3 for line IT98K-1101-5 and 3.0 for line IT99K-1060 for the NPP. The PL ranged from 11.80 to 20.92 cm for the lines IT98K-1092-1 and IT82D-889, respectively, reaching a mean of 16.36 cm between the lines.

Table 3. Mean values and results of the Scott-Knott test for the assessed traits in 57 cowpea lines of the active germplasm bank for common bean-cowpea of Embrapa Meio-Norte, Teresina, PI, 2009.

Line number	Lines	NPP	PL	NGP	GRL	GRWi	W100G	YD
1	IT93K-452-1	2.30[a]	15.20[b]	11.77[b]	8.33[b]	5.95[a]	18.70[c]	187.70[b]
2	IT96D-610	2.00[a]	14.73[c]	11.13[b]	7.87[b]	4.51[b]	16.07[d]	365.50[a]
3	IT97K 568-18	2.50[a]	15.30[b]	11.10[b]	7.41[c]	5.38[a]	16.17[d]	183.67[b]
4	IT97K-1042-3	2.20[a]	18.40[a]	12.23[a]	7.69[b]	5.52[b]	14.20[e]	194.47[b]
5	IT98K-205-8	2.50[a]	15.13[b]	12.73[a]	8.36[b]	5.59[a]	15.87[d]	251.60[a]
6	IT98K-491-4	1.70[a]	15.30[b]	10.23[b]	9.07[a]	5.88[a]	21.33[c]	248.93[a]
7	IT98K-506-1	1.70[a]	17.57[a]	12.87[a]	8.19[b]	5.77[a]	18.80[c]	266.47[a]
8	IT98K-589-2	1.80[a]	14.60[c]	10.63[b]	7.87[b]	5.81[a]	16.13[d]	175.40[b]
9	IT98K-1111-1	2.00[a]	15.00[b]	11.25[b]	7.21[c]	6.28[a]	18.55[c]	157.70[b]
10	IT99K-316-2	2.30[a]	15.63[b]	11.53[b]	8.90[a]	5.29[b]	16.30[d]	252.97[a]
11	IT99K-491-7	2.00[a]	14.43[c]	11.40[b]	8.02[b]	5.12[b]	13.27[e]	290.53[a]
12	IT99K-494-6	1.70[a]	13.43[c]	10.57[b]	7.58[b]	4.91[b]	14.30[e]	150.30[b]
13	IT99K-529-2	1.80[a]	18.63[a]	12.27[a]	9.70[a]	6.35[a]	24.87[a]	218.63[b]
14	IT99K-573-2-1	2.20[a]	18.03[a]	11.40[b]	8.77[a]	5.93[a]	20.70[b]	172.13[b]
15	IT99K-1060	3.00[a]	14.83[c]	11.83[a]	9.29[a]	5.44[b]	15.60[d]	181.27[b]
16	IT99K-1122	1.80[a]	13.47[c]	14.63[a]	6.75[c]	5.47[b]	14.00[e]	305.90[a]
17	IT00K-898-5	2.30[a]	14.15[c]	10.15[b]	9.12[a]	5.43[b]	17.65[d]	244.35[a]
18	IT00K-901-5-1	2.00[a]	16.97[a]	13.80[a]	8.60[a]	5.55[a]	18.33[c]	253.47[a]
19	IT00K-1263-1	1.70[a]	17.83[a]	10.90[b]	9.44[a]	6.24[a]	19.93[b]	350.13[a]
20	IT93K-625	2.00[a]	15.80[b]	12.93[a]	7.25[b]	4.56[b]	15.80[d]	270.20[a]
21	IT97K-499-35	1.80[a]	17.33[a]	13.63[a]	8.02[b]	5.42[b]	18.07[c]	225.80[b]
22	IT97K-1069-6	1.80[a]	17.40[a]	12.60[a]	8.05[b]	5.12[b]	18.17[c]	270.80[a]
23	IT98K-128-3	1.70[a]	17.67[a]	13.67[a]	8.81[a]	4.33[b]	16.83[d]	285.03[a]
24	IT98K-128-4	2.20[a]	17.80[a]	12.53[a]	7.86[b]	5.15[b]	13.93[e]	163.67[b]
25	IT98K-131-2	2.20[a]	17.27[a]	13.27[a]	8.64[a]	6.01[a]	16.73[d]	174.50[b]
26	IT98K-205-9	2.20[a]	16.07[b]	11.37[b]	8.74[a]	5.70[a]	18.43[c]	205.87[b]
27	IT98K-205-15	1.50[a]	16.33[b]	13.57[a]	7.93[b]	6.16[a]	15.37[d]	196.00[b]
28	IT98K-503-1	2.20[a]	13.33[c]	9.50[c]	9.21[a]	5.99[a]	20.13[b]	358.80[a]
29	IT98K-1092-1	2.30[a]	11.80[c]	13.70[a]	6.29[c]	5.69[a]	13.50[e]	157.13[b]
30	IT98K-1092-2	2.50[a]	15.07[b]	10.90[b]	8.06[b]	5.06[a]	16.53[d]	226.50[b]
31	IT98K-1103-13	1.80[a]	16.57[b]	13.93[a]	7.49[c]	5.49[b]	18.07[c]	231.87[b]
32	IT98D-1399	1.80[a]	16.15[b]	12.65[a]	9.14[a]	5.85[a]	19.35[c]	194.75[b]
33	IT99K-718-6	2.00[a]	17.13[a]	12.50[a]	8.70[a]	5.24[b]	18.43[c]	212.07[b]
34	IT00K-901-5-2	2.70[a]	16.63[b]	12.73[a]	8.95[a]	6.02[a]	18.20[c]	275.53[a]
35	IT00K-1207	1.80[a]	14.80[c]	12.70[a]	6.53[c]	6.21[a]	15.13[d]	201.13[b]
36	IT00K-1217	2.00[a]	15.13[b]	11.93[a]	8.49[a]	5.66[a]	15.07[d]	146.40[b]
37	IT00K-1263-2	1.70[a]	19.77[a]	11.33[b]	9.42[a]	6.18[a]	20.23[b]	305.10[a]
38	IT03K-316-1	2.50[a]	16.20[b]	13.30[a]	8.68[a]	6.02[a]	19.95[b]	121.35[b]
39	IT84S-2135	2.30[a]	17.85[a]	13.30[a]	9.01[a]	5.89[a]	18.40[c]	102.70[b]
40	IT89KD-245	1.80[a]	15.53[b]	10.63[b]	9.00[a]	6.89[a]	25.93[a]	315.37[a]
41	IT87D-697-2	1.50[a]	14.23[c]	11.70[b]	7.74[b]	6.47[a]	17.47[d]	388.07[a]
42	IT85F -1380	1.80[a]	18.70[a]	14.40[a]	7.21[c]	5.43[b]	12.43[e]	301.30[a]
43	IT85F-2687	2.00[a]	15.73[b]	11.00[b]	8.29[b]	5.23[b]	17.30[d]	212.97[b]
44	IT89KD-349	1.70[a]	16.30[b]	11.97[b]	9.38[a]	4.98[b]	18.13[c]	204.23[b]
45	IT96D-618	2.20[a]	16.10[b]	10.40[b]	9.35[a]	5.98[a]	19.73[b]	310.30[a]
46	IT97K-568-14	2.00[a]	18.03[a]	14.77[a]	8.17[b]	5.77[a]	18.27[c]	290.77[a]
47	IT98K-1101-5	1.30[a]	16.77[a]	7.63[c]	9.83[a]	5.89[a]	22.43[a]	227.07[b]
48	IT93K-93-10	1.50[a]	18.83[a]	12.60[a]	8.21[b]	5.96[a]	15.50[d]	358.40[a]
49	IT92KD-279-3	2.20[a]	16.20[b]	12.00[a]	7.29[c]	4.26[b]	13.43[e]	254.40[a]
50	IT87D-1627	2.20[a]	17.83[a]	12.47[a]	8.15[b]	5.00[b]	15.43[d]	253.03[a]
51	IT87D-611-3	2.20[a]	17.97[a]	11.70[b]	7.71[b]	6.03[a]	14.57[e]	203.57[b]
52	IT91K-118-2	2.00[a]	20.60[a]	11.97[a]	9.14[a]	6.22[a]	16.23[d]	207.17[b]
53	IT82D-889	1.80[a]	20.92[a]	12.87[a]	8.37[b]	4.51[b]	13.13[e]	189.43[b]
54	CB-27	2.00[a]	16.45[b]	10.37[b]	9.14[a]	5.70[a]	20.33[b]	263.50[b]
55	Vaina Blanca	2.00[a]	16.40[b]	9.00[c]	9.50[a]	5.90[a]	21.45[b]	210.15[b]
56	TVX 5058 - 09C	2.90[a]	15.40[b]	10.35[b]	7.79[b]	5.40[b]	16.92[d]	237.53[b]
57	MNC 03 720C - 11	2.00[a]	15.83[b]	8.43[c]	9.01[a]	5.80[a]	23.95[a]	220.70[b]
Mean		2.02	16.36	11.91	8.36	5.60	17.54	235.51

For abbreviations, see Table 2. Means followed by the same letter do not differ from each other at 5% probability.

The NGP ranged from 7.63 to 14.77 for the lines IT98K-1101-5 and IT97K-568-14, with an average of 11.91 grains per pod for all lines. GRL values varied from 6.29 to 9.83 mm for the lines IT98K-1101-5 and IT98K-1092-1, respectively. The mean GRWi of the lines was 5.60 mm. For lines with greater GRL and GRWi, a higher grain weight was observed, which increased the W100G value. W100G ranged from 12.43 to 25.93 g for the lines IT85F-1380 and IT89KD-245. The greatest grain length (9.83 mm) and one of the highest W100G values (22.43 g) were observed for line IT98K-1092-1.

The YD ranged from 102.70 g (line IT84S-2135) to 388.07 g (line IT87D-697-2). Other lines also produced YD over 300 g, i.e., IT85F-1380 (301.30 g), IT99K-1122 (305.90 g), IT96D-618 (310.30 g), IT89KD-245 (315.37 g), IT00K-1263-1 (350.13 g), IT93K-93-10 (358.40 g), IT98K-503-1 (358.80 g), IT96D-610 (365.50 g), and IT87D-697-2 (388.07 g).

Estimates of genetic parameters for traits (Table 4) showed that the CV_g was highest for the traits YD (19.77%) and W100G (16.33%). The relationship between CV_g and CV_e was high for most traits (>1.0), except for GRWi (0.69), NPP (0.45), and YD (0.63). The heritability estimates ranged between 37.38 and 95.92% for NPP and W100G, respectively.

Table 4. Estimates of the coefficient of variation genetic (CV_g), heritability (h^2_a) and the ratio between the genetic and environmental coefficient of variation (CV_g/CV_e) corresponding to the 7 quantitative traits, derived from the expectations of the mean squares of ANOVA (Teresina, PI, 2009).

Trait	CV_g (%)	CV_g/Cv_e	h^2_a (%)
PL	10.08	1.37	84.95
NGP	11.03	1.09	78.23
GRL	8.95	1.32	83.96
GRWi	7.48	0.69	58.58
NPP	10.14	0.45	37.38
W100G	16.33	2.80	95.92
YD	19.77	0.63	54.52

For abbreviations, see Table 2.

According to D^2 (Figure 1), the dissimilarity measures were highest between the line pairs IT82D-889 and IT89KD-245 (221.35), IT85F-1380 and IT89KD-245 (206.04), and IT89KD-245 and IT98K-1092-1 (200.51). The shortest dissimilarity distances were found between the lines IT98K-128-4 and IT97K-1042-3 (1.21), IT97K-1069-6 and IT98K-506-1 (1.39), IT97K-1069-6 and IT97K-499-35 (1.41), IT97K-499-35 and IT00K-901-5-1 (1.65), and IT97K-499-35 and IT98K-506-1 (1.91).

Based on the UPGMA analysis, the lines were distributed into four distinct groups, which consisted of few lines, with the exception of the fourth group that contained 71% of the genotypes studied (Table 5 and Figure 2).

The characteristics with highest contribution to divergence, according to the criteria proposed by Singh (1981), were W100G (49.7%), PL (16.7%), GRL (12.0%), and NGP (9.7%), which together accounted for 88.1% of the variability between the lines tested (Table 6).

DISCUSSION

Genetic variabilities for all traits were observed between cowpea lines (Table 2). The coefficient of variation, indicated good experimental precision in the analysis of all traits, even the yield-related traits, which are complex and relatively more susceptible to environmental variation (Allard, 1971).

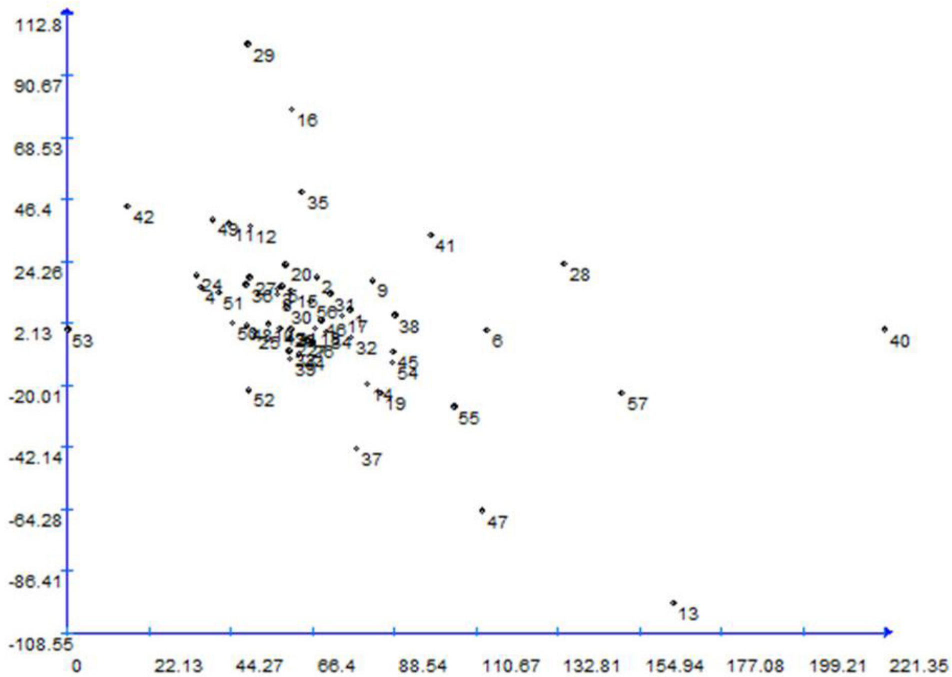

Figure 1. Estimates of Mahalanobis' generalized distances between 57 cowpea lines represented in a bidimensional dispersion graph. Teresina, PI, 2009. Lines with their identification number are listed in Table 1.

Table 5. Clustering of 57 cowpea lines by the hierarchical method UPGMA, based on Mahalanobis' generalized distance. Teresina, PI, 2009.

Groups	Lines
I	IT98K-503-1; IT99K-573-2-1; IT98K-491-4; CB – 27; IT96D-618; IT00K-1263-2; IT00K-1263-1; MNC03720C-11; Vaina Blanca; IT98K-1101-5; IT89KD-245; IT99K-529-2
II	IT98K-1092-1; IT99K-1122
III	IT82D-889; IT91K-118-2
IV	IT93K-452-1; IT96D-610; IT97K 568-18; IT97K-1042-3; IT98K-205-8; IT98K-506-1; IT98K-589-2; IT98K-1111-1; IT99K-316-2; IT99K-491-7; IT99K-494-6; IT99K-1060; IT00K-898-5; IT00K-901-5-1; IT93K-625; IT97K-499-35; IT97K-1069-6; IT98K-128-3; IT98K-128-4; IT98K-131-2; IT98K-205-9; IT98K-205-15; IT98K-1092-2; IT98K-1103-13; IT98D-1399; IT99K-718-6; IT00K-901-5-2; IT00K-1207; IT00K-1217; IT03K-316-1; IT84S-2135; IT87D-697-2; IT85F-1380; IT85F-2687; IT89KD-349; IT97K-568-14; IT93K-93-10; IT92KD-279-3; IT87D-1627; IT87D-611-3; TVX 5058-09C

External pod characteristics are important, especially in the case of consumption of unripe grain. According to Souza et al. (2006), cowpea pods are sold in bunches on the market, increasing the relevance of certain external characteristics, especially pod length and transverse diameter, which reflect the number and size of the green beans.

Mishili et al. (2009) surveyed consumer preferences regarding the characteristics and value of cowpea grain in the African markets of Nigeria, Ghana, and Mali and found that consumers preferred larger grains and were willing to pay higher prices for such grains. Similar results to those of the present study were previously reported for W100G of cowpea. Torres et

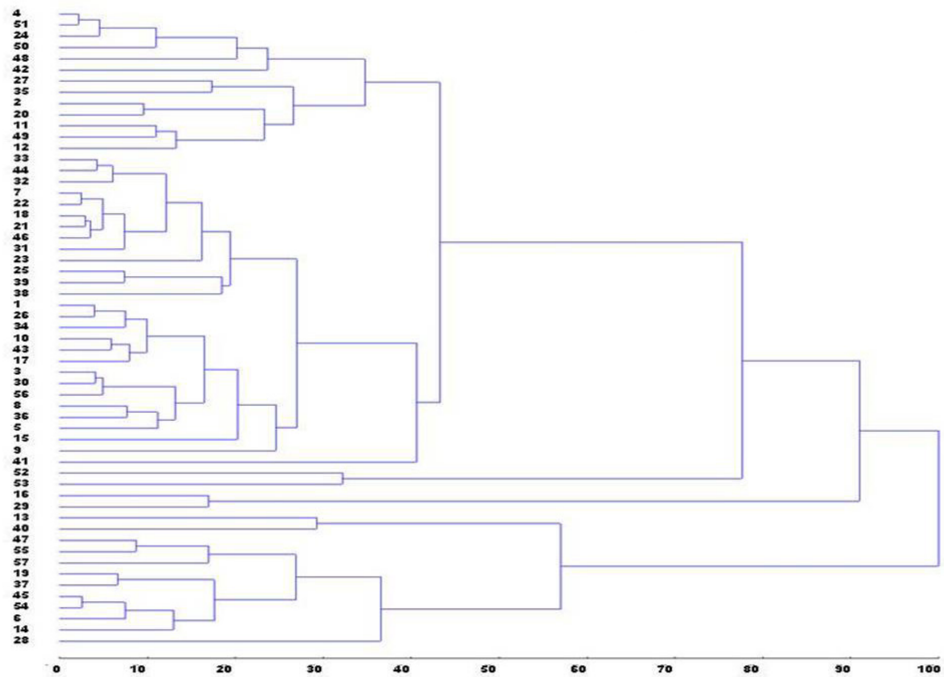

Figure 2. Representative dendrogram of genetic divergence among 57 cowpea lines obtained by the UPGMA method. Teresina, PI, 2009. Lines with their identification number are listed in Table 1.

Table 6. Relative contribution of the traits to divergence proposed by Singh (1981) (Teresina, PI, 2009).

Trait	S_j (%)
Pod length	16.69
Number of grains per pod	9.70
Grain length	11.98
Grain width	3.38
Number of pods per peduncle	3.44
Grain weight	49.68
Yield	5.09

al. (2008) evaluated 10 cowpea accessions in the soil-climatic conditions of Mossoró, RN, and reported that the average W100G ranged from 15.86 g (Pingo-de-ouro) to 23.47 g (Costela-de-vaca).

Bertini et al. (2009) evaluated 16 cowpea accessions of the germplasm bank of Universidade Federal do Ceará, and found a variation in grain yield, that is, 35.65-328.15 g. The YD was highest for accession CE-871, and the other accessions with high YD were CE-79 (312.29 g), CE-93 (292.73 g), and CE-873 (323.03 g). According to Lal et al. (2007), breeding programs involving the selection of parents based on genetic divergence in YD components can produce transgressive segregants with good YD potential.

The heritability for most traits was higher than 50%, suggesting the possibility of genetic progress by selection for these characteristics, including YD with a heritability of

54.52%. Lopes et al. (2001) evaluated 28 cowpea lines based on agronomic traits and found relatively high heritability values for the characteristics PL (75.66%) and W100G (81.74%), and intermediate values for YD (34.15%).

According to D^2, the line IT89KD-245 was the most divergent among all lines. According to Oliveira et al. (2007), crosses between the most divergent accessions can increase the variability, and possibly result in the establishment of superior plants. Furthermore, crosses between similar groups may not be well suited for obtaining superior genotypes in segregating generations (Bertini et al., 2009).

The recommendation of crosses between lines of different groups can help obtain favorable gene combinations, provided that the recommended lines have desirable agronomic traits for increasing the yield capacity. In this sense, crosses between the lines IT82D-889 and IT89KD-245, IT85F-1380 and IT89KD-245, and IT89KD-245 and IT98K-1092-1 appear to be promising.

Dias et al. (2009) assessed the genetic divergence between 28 cowpea lines from the germplasm bank of Universidade Federal do Ceará based on agronomic traits, and as well as in the present study, they observed that W100G was one of the most important traits contributing to genetic divergence. Oliveira et al. (2003) evaluated the influence of nine phenotypic traits on grain yield per plant based on genetic correlations, and identified that the average NPP followed by W100G were the most important traits in the selection for cowpea grain yield.

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