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Adaptability and stability parameters for immature seeds and pods and mature dried seeds in cowpea genotypes in Brazil northeast

Deisy Aiane Lima de Aquino[1], Carlos Antonio Fernandes Santos[2]* and Danillo Olegário Matos da Silva[3]

[1]Federal Rural University of Pernambuco, Av. Manuel de Medeiros, s / n, Dois Irmãos, Recife, Brazil.
[2]Brazilian Agricultural Research Corporation (Embrapa Semiarid), Rodovia BR-428, km 152, s/n. Petrolina, Pernambuco, Brazil.
[3]State University of Feira de Santana, Avenida Transnordestina, s/n, Novo Horizonte, Feira de Santana, Bahia, Brazil.

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The aim of this study was to estimate adaptability and stability parameters in genotypes of cowpea for the yield of immature seeds and pods and mature dried seeds, in order to enable the recommendation of cultivars for the region of São Francisco Submedium valley. We evaluated 30 cowpea genotypes, being fourteen lines of Embrapa Semiarid, six commercial cultivars and 10 landraces in the municipalities of Juazeiro-BA and Petrolina-PE. The experiments were conducted in the second semester, during the years 2013, 2014 and 2015. For adaptability and stability analysis, the methodologies of Eberhart and Russell, Lin and Binns were used, in addition to the multiplicative method, based on principal components analysis (AMMI). A significant difference was observed for the mean squares of treatments in all environments, as well as the pooled ANOVA (P<0.01) for the effects of genotypes (G), environments (E) and G*E interaction. The lines P290, P303, P508 and PC950409D02E showed yield of immature seeds exceeding 2140 kg ha^{-1}, broad stability and good predictability in the series of evaluated environments, and has great potential to be recommended as new cultivars for the region of São Francisco Submedium Valley.

Key words: Vigna unguiculata, G*E interaction, semiarid, additive effects and multiplicative interaction (AMMI).

INTRODUCTION

Cowpea yield (*Vigna unguiculata* (L.) Walp.) in Brazil is concentrated in the Northeast and North, and it has been expanding in the cerrado of the north and center-west regions, where it has been cultivated using large areas and high technology, reaching new markets (Freire Filho et al., 2011). Cowpea is distinguished for its

*Corresponding author. E-mail: aktugume@cns.mak.ac.ug.

socioeconomic importance, being one of the main components of diet in these two regions, especially to the rural populations, generating jobs and income (Freire Filho et al., 2005). Due to its genetic variability, large capacity for adaptation, high yield potential and excellent nutritional value, cowpea is considered a species of great value (Santos et al., 2013).

Despite being traditionally cultivated and marketed as mature dried seeds, the marketing of immature seeds of cowpea gains prominence in some regions of the Northeast, because it presents some advantages in relation to the dried seeds, as the less time to cook (Andrade et al., 2010). The immature seeds correspond to the pods around the maturity, with seeds with approximately 50 to 60% moisture (Freire Filho et al., 2005). Rocha et al. (2006) reported yield of 826 to 2.975 kg ha^{-1} for yield of immature pods and 519 to 2.818 kg ha^{-1} for yield of immature seeds in the evaluation of 14 accessions under irrigated conditions.

Although considered a crop with broad adaptation to the most diverse environments, Leite et al. (2009) point out that the cowpea still has low yield of dried seeds, around 300 kg ha^{-1}, in the Northeast region. According to Silva et al. (2010) the climatic adversities, the use of low agricultural technology and the planting of not improved seeds are the main causes of low yield in this semiarid region. The conditions of cultivation practiced in areas that produce cowpea causes unsimilar performance of genotypes in different environments where they are cultivated (Carvalho et al., 2013).

Among the main objectives of the genetic improvement of cowpea in Brazil, Rocha et al. (2013) emphasize the increased yield and high adaptability and stability for different cultivation environments. According to Santos (2008) the cowpea breeding program to the region of São Francisco Valley considers the development of cultivar, both for the rainfed area as well for irrigated area, once the recommendation for cultivars developed in other regions is not the best option from the agronomic standpoint. This behavior is due to G*E interaction and this is a factor that hinders the selection of genotypes better adapted (Cruz et al., 2012).

Several studies have identified genotypes with broad adaptability and good stability for yield of dried seeds (Nunes et al., 2014; Silva et al., 2016). The most used methods for assessing the adaptability and stability have been the model used by Eberhart and Russell (1966), Lin and Binns (1988) and the model of additive effects and multiplicative interaction (AMMI). However, studies with this purpose involving the cultivation of cowpea genotypes for the yield of immature seeds are unusual (Rocha et al., 2012). Until then, farmers of the region carried out the yield of seeds independently, without any study that indicate what the best cultivar for this activity.

The purpose of this study was to estimate adaptability and stability parameters in cowpea genotypes cowpea for immature seeds and pods yields and mature dried seeds in order to enable the recommendation of cultivars for the São Francisco Submedium Valley.

MATERIALS AND METHODS

Plant material

Thirty cowpea genotypes were evaluated, among then, 14 lines of Embrapa Semiarid, six commercial cultivars and 10 landraces from the municipalities of Juazeiro-BA and Petrolina-PE (Table 1). The experiments were conducted in the second semester, during 2013, 2014 and 2015, in experimental fields of Bebedouro, Petrolina-PE, and Mandacaru, Juazeiro-BA, totaling six environments. The adopted experimental design was a randomized block with three replications in a plot with a total area of 6 m^2, with two rows. The spacing used was 1.0 m × 0.1 m, corresponding to the density of 100,000 plants ha^{-1}. Fertilizations were not used, and the irrigation was done through micro sprinkling. The area was weeded and the pest controlled by using insecticide.

Variable and statistical analysis

Immature seed yield (kg ha^{-1}), mature dried seed yield (kg ha^{-1}) and immature pod yield (kg ha^{-1}) were analyzed taking individuals and pooled environments data. Immature seed and pod harvesting were done two times per week in one row, until 70 days after seed sowing. Mature dried seeds harvesting were done in the opposite row in complete mature pods.

For analysis of adaptability and stability the methodologies of Eberhart and Russell (1966) and Lin and Binns (1988) were used by means of the computational program Genes (Cruz, 2006), and the multiplicative method based on main components (AMMI) using SAS software (1989), as described by Duarte and Vencovsky (1999).

The method Eberhart and Russell (1966) is based on linear regression analysis, providing an estimate of the stability as well as to the adaptability, that is, both the regression coefficients of phenotypic values of each genotype in relation to environmental index, and the deviations of the regression provide estimates of adaptability and stability parameters, respectively (Cruz et al., 2006). The genotypes with index $\beta i = 1$ have broad adaptability, being that deviations from the regression equal to zero ($\sigma^2_{di}=0$) indicate good stability. In the method of Lin and Binns (1988), based on non-parametric analysis, Pi defines the stability of a genotype, being defined as the mean square of the distance between the mean of a genotype and the maximum mean response for all locations, so that genotypes with lower values correspond to those with a better performance.

The methodology AMMI, combines in a single model, components additives for the main effects of genotypes (gi) and environment (aj) and multiplicative components for main effects of interaction G x E (ga)ij (Duarte and Vencovsky, 1999). This

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*Corresponding author. E-mail: carlos-fernandes.santos@embrapa.br.

Table 1. List of cowpea genotypes evaluated for adaptability and stability parameters for immature seeds and pods and mature dried seeds.

Treatments	Genotypes	Origin
1	BRS Acauã	EmbrapaSemiárido
2	BRS Guariba	EmbrapaSemiárido
3	BRS Marataoã	EmbrapaSemiárido
4	BRS Patativa	EmbrapaSemiárido
5	BRS Pujante	EmbrapaSemiárido
6	BRS Rouxinol	EmbrapaSemiárido
7	Lineage PC951015D01E	EmbrapaSemiárido
8	Lineage PC950409D02E	EmbrapaSemiárido
9	Lineage PC951016D01E	EmbrapaSemiárido
10	Lineage CPCR3F6L15	EmbrapaSemiárido
11	Lineage CPCR3F6L17	EmbrapaSemiárido
12	Lineage C1J	EmbrapaSemiárido
13	Lineage C2M	EmbrapaSemiárido
14	Lineage C2S	EmbrapaSemiárido
15	Lineage C3F	EmbrapaSemiárido
16	Lineage C3Q	EmbrapaSemiárido
17	Lineage C3S	EmbrapaSemiárido
18	Lineage P290	EmbrapaSemiárido
19	Lineage P303	EmbrapaSemiárido
20	Lineage P508	EmbrapaSemiárido
21	PJJ21	Nilo Coelho N8-Petrolina, PE
22	PJM22	Nilo Coelho - Petrolina, PE
23	PL23	Mandacaru-Juazeiro, BA
24	PAG24	Maniçoba-Juazeiro, BA
25	PC25	Nilo Coelho N9-Petrolina, PE
26	PD26	Maniçoba-Juazeiro, BA
27	PJ27	Maniçoba-Juazeiro, BA
28	PJJ28	Nilo Coelho N8-Petrolina, PE
29	PJN29	Nilo Coelho - Petrolina, PE
30	PLP30	Mandacaru-Juazeiro,BA

This analysishelps to identify high yield genotypes and broadly adapted, as the location of agronomic zoning, with the purpose of recommendation and selection of test sites (Gauch and Zobel, 1996).

RESULTS

Evaluation of environments for yield of immature seeds and pods and mature dried seeds in lines of cowpea

Significant difference was observed for the mean squares of treatments in all environments for all three variables analyzed. The average yields of immature seeds ranged from 766 to 2.705 kg ha^{-1}, highlighting the environments MAND13 and BEB13, for having presented the highest averages (Table 2). The yield of immature pods ranged from 1.150 to 4.866 kg ha^{-1}, highlighting the environments MAND13 and BEB13 (Table 2). The average yield of dried seeds ranged from 625 to 1,716 kg ha^{-1}, and the environments MAND13 and BEB13 were more productive (Table 2). The relations between the smaller and larger residues mean squares were below or near to seven for all variables, which, according to Cruz and Regazzi (1997) are necessary conditions for the experiments pooled analysis, indicating homogeneity of variances.

In the pooled variance analysis we observed statistically significant differences by F test ($p<0.01$) for environments (E), genotypes (G) and G*E interaction to the three variables (Table 3). This indicates that genotype and environment showed variability, and that the genotypes showed different behavior for yield of immature seeds and pods and dried seeds in different environments evaluated. The significance of G*E interaction justifies the need to conduct a study to identify

Table 2. Treatment mean square (QMT), mean square of the residue (QMR), means and variation coefficient (CV) for yield of immature seeds and pods and mature dried seeds in 30 cowpea genotypes evaluated in six environments.

Environments	Immature seed				Immature pod				Mature dried seed			
	QMT	QMR	Average	CV	QMT	QMR	Average	CV	QMT	QMR	Average	CV
BEB13	656873.5**	218879.2	2203.9	21.22	2787283.3**	727179.9	3912.35	21.79	681285.7*	340725.7	1716.2	34.01
BEB14	1025124.2*	526881.6	1846.7	39.30	6222743.7**	1819366	3505.1	38.48	131880.8*	61898.8	698.20	35.63
BEB15	655582.1**	96334.3	1081.8	28.69	1547479.0*	751098.2	2202.5	39.34	282801.9**	83557.2	806.1	35.86
MAND13	4351374.**	569927.8	2705.1	27.91	13097469.2**	1770712	4866.4	27.34	-	-	-	-
MAND14	561450.1**	106699.4	1743.7	18.73	3054582.7**	817605.4	3772.6	23.97	184097.9**	50210.0	1129.56	19.83
MAND15	235758.3**	61452.8	766.4	32.34	263005.9^{NS}	244941.7	1150.6	43.01	202945.8**	38864.7	625.6	31.51

Table 3. Pooled variance analysis for immature seed and pods (kg/ha^{-1}) and mature dried seed (kg/ha^{-1}) in 30 cowpea genotypes evaluated in six environments.

Variation source	Mean square					
	DF	Immature seeds	DF	Immature Pods	DF	Dried seed
Genotype (G)	29	2682995.0**	29	9828703**	29	421011.6**
Environment (E)	5	41728529.3**	5	294687733**	4	12019400.8**
G x E	145	875044.6**	145	3075365**	116	273778.2**
Residue	305	314418.6	343	1017424.0	208	117719.7
CPI1	33	0.77**	33	2.13**	32	0.26**
CPI1%		54.69		46.16		55.47
CV(%)		31.95		34.66		34.88

**,*, ns significant at 1%, 5% or non-significant by F test, respectively.

the genotypes of greater adaptability and stability.

Adaptability and stability parameters for yield of immature seeds and pods and mature dried seeds in cowpea genotypes

The average yield of immature seeds for the genotypes, in six environments, ranged from 932 kg ha^{-1}, in the cultivar BRS Marataoã, 2.532 kg ha^{-1}, in the line P-508, with an overall average of 1.706 kg ha^{-1} (Table 4). Only six genotypes showed yield above 2000 kg ha^{-1} (BRS Guariba, P290, P303, PC951015D01E, PC950409D02E and CPCR3F6L17). Those genotypes also showed the highest values for yield of immature pods, which ranged from 3.515 to 4.294 kg ha^{-1}, and yield of dried seeds above the overall average (1.002 kg ha^{-1}).

Among the cultivars, BRS Guariba, BRS Acauã and BRS Pujante were the most productive for all three variables (Table 4). As for the genotypes of the producers, only three showed yield above the overall average for yield of immature seeds and pods, and for yield of dried seeds, two presented averages higher than the general average. That was explained by the fact that the farmers perform the dried cowpea cultivation without selection for the yield of immature seeds.

In the analysis of adaptability and stability, the method Eberhart and Russell highlighted the genotypes BRS Guariba, P-290 and PC950409D02E with high yield, broad adaptability and good stability. The analysis with the Lin and Binns method emphasized the genotype P-508 (1) with high immature seed yield and good stability

Table 4. Stability and adaptability for immature seeds and pods and mature dried seeds yields in 30 lines of cowpea, evaluated in six environments, using the method of Eberhart and Russell (1966) and Lin and Binns (1988).

Genotypes	Immature seeds				Immature pods				Mature dried seeds			
	Eberhart and Russell			Lin and Binns	Eberhart and Russell			Lin and Binns	Eberhart and Russell			Lin and Binns
	βo	βi	σ_{dii}	Pi	βo	βi	σ_{dii}	Pi	βo	βi	σ_{dii}	Pi
BRS Acauã	1986	1.29^{NS}	177726.6*	635590^{9}	3388	1.24^{NS}	366482.4^{NS}	3720816^{10}	1209	1.66**	106569.0*	142904^{3}
BRS Guariba	2029	1.20^{NS}	373336.8**	595452^{7}	3516	1.09^{NS}	787292.2*	3364203^{9}	1082	0.66^{NS}	-5238.8^{NS}	298069^{13}
BRS Marataoã	932	0.50*	328831.5**	2807197^{30}	2748	1.11^{NS}	539015.7*	5846900^{20}	770	0.64^{NS}	223516.8**	723521^{29}
BRS Patativa	1616	0.88^{NS}	-8995.6^{NS}	1173306^{16}	2641	0.71^{NS}	698906.9*	7352452^{23}	1228	1.31^{NS}	-19620.1^{NS}	166151^{4}
BRS Pujante	1776	0.99^{NS}	271589.6**	891303^{10}	3343	1.00^{NS}	690921.1*	4464629^{15}	1045	1.26^{NS}	107474.3*	284312^{12}
BRS Rouxinol	1248	0.57*	126292.1^{NS}	2027764^{25}	2376	0.70^{NS}	610139.3*	7538238^{25}	1117	0.76^{NS}	126995.1**	350370^{14}
L. PC951015D01E	2165	1.64**	298108.5**	432024^{5}	4128	1.56**	33436.4^{NS}	2120414^{4}	1145	1.73**	22831.0^{NS}	199726^{7}
L. PC950409D02E	2177	1.34^{NS}	-17675.7^{NS}	421522^{4}	4019	1.40*	-2368.9^{NS}	2539971^{6}	1051	-0.07**	3410.9^{NS}	524299^{23}
L. PC951016D01E	1340	1.08^{NS}	197336.2*	1728546^{22}	2565	1.01^{NS}	1012301.5**	7444748^{24}	686	1.02^{NS}	-17821.2^{NS}	597324^{28}
L. CPCR3F6L15	2400	1.75**	696760.3**	337378^{2}	4386	1.89**	1098029.6**	1946225^{2}	1261	1.44*	217750.9**	135474^{2}
L. CPCR3F6L17	2149	1.81**	446183.8**	611276^{8}	3850	1.41*	1517760.2**	3828157^{12}	1140	1.50*	119371.6**	200775^{8}
L. C1J	1749	1.24^{NS}	118038.9^{NS}	900659^{11}	4167	1.67**	1373829.2**	2580664^{7}	751	0.72^{NS}	1801.0^{NS}	550515^{26}
L. C2M	1716	1.25^{NS}	273688.3**	1147839^{15}	4544	0.97^{NS}	2786782.8**	2312880^{5}	871	0.75^{NS}	79504.5*	519785^{21}
L. C2S	1761	0.98^{NS}	301122.0**	1173646^{17}	3101	0.29**	-76491.9^{NS}	5361070^{18}	901	1.41^{NS}	4531.1^{NS}	368037^{16}
L. C3F	1214	0.89^{NS}	64616.5^{NS}	1765082^{23}	2909	1.15^{NS}	-141603.9^{NS}	5393301^{19}	895	0.57^{NS}	122759.8**	555746^{27}
L. C3Q	1478	1.15^{NS}	-92103.1^{NS}	1323130^{19}	2990	1.04^{NS}	-164273.6^{NS}	5075775^{17}	1012	1.76**	16228.4^{NS}	267994^{11}
L. C3S	1587	1.01^{NS}	-66533.2^{NS}	1181694^{18}	3725	1.02^{NS}	569419.4*	3766503^{11}	903	1.01^{NS}	140699.0**	515621^{20}
L. P290	2141	0.93^{NS}	-23310.1^{NS}	499448^{6}	4294	1.18^{NS}	-6469.1^{NS}	2085384^{3}	1148	1.29^{NS}	16138.5^{NS}	180601^{5}
L. P303	2282	1.71**	112577.4^{NS}	371543^{3}	3976	1.68**	61682.6^{NS}	2618724^{8}	1089	0.87^{NS}	-26523.5^{NS}	262500^{10}
L. P508	2532	1.56**	281022.4**	166379^{1}	4716	1.37^{NS}	2039686.5**	1283228^{1}	1351	1.22^{NS}	6845.3^{NS}	103249^{1}
PJJ21	1291	0.22**	50193.9^{NS}	2060685^{26}	2588	0.20**	693802.9*	7873413^{26}	957	1.03^{NS}	-36439.6^{NS}	358504^{15}
PJM22	1981	1.22^{NS}	201690.0*	904855^{12}	3593	1.11^{NS}	366140.8^{NS}	3961597^{13}	1263	2.44**	-14613.4^{NS}	186871^{6}
PL23	1301	0.52*	12120.0^{NS}	1922153^{24}	2163	0.52*	-30147.4^{NS}	8807759^{28}	949	0.63^{NS}	32185.9^{NS}	466630^{18}
PAG24	1543	0.62^{NS}	168704.8*	1593046^{21}	2677	0.76^{NS}	350431.3^{NS}	6604367^{22}	979	0.34**	77842.1*	525751^{24}
PC25	1123	0.41**	-16916.9^{NS}	2221915^{28}	1942	0.42**	-179017.1^{NS}	9652145^{29}	777	0.76^{NS}	7454.3^{NS}	521307^{22}
PD26	1089	0.49*	53334.1^{NS}	2322003^{29}	1783	0.35**	-166658.9^{NS}	10395120^{30}	950	1.12^{NS}	62392.7^{NS}	422759^{17}
PJ27	1698	0.21**	-31265.4^{NS}	1324245^{20}	3115	0.59*	-202460.1^{NS}	5040849^{16}	976	-0.04**	73531.3*	547289^{25}
PJJ28	1918	0.94	213617.1*	990547^{13}	3452	1.06^{NS}	262504.6^{NS}	4154864^{14}	881	0.39**	43082.6^{NS}	502961^{19}
PJN29	1741	1.04	7834.9^{NS}	1040486^{14}	2895	0.88^{NS}	88347.0**	5962821^{21}	1137	1.27^{NS}	8105.8^{NS}	201810^{9}
PLP30 ereira	1234	0.51*	245556.9*	2167848^{27}	2412	0.59*	1063932.7	8222718^{27}	557	0.56*	49760.1^{NS}	867983^{30}
Geral	1707				3267				1003			

**,*, ^{ns} significant at 1%, 5% or non-significant, respectively, by F test F.(^{1}-^{30}) numbering according to lower and higher P value.

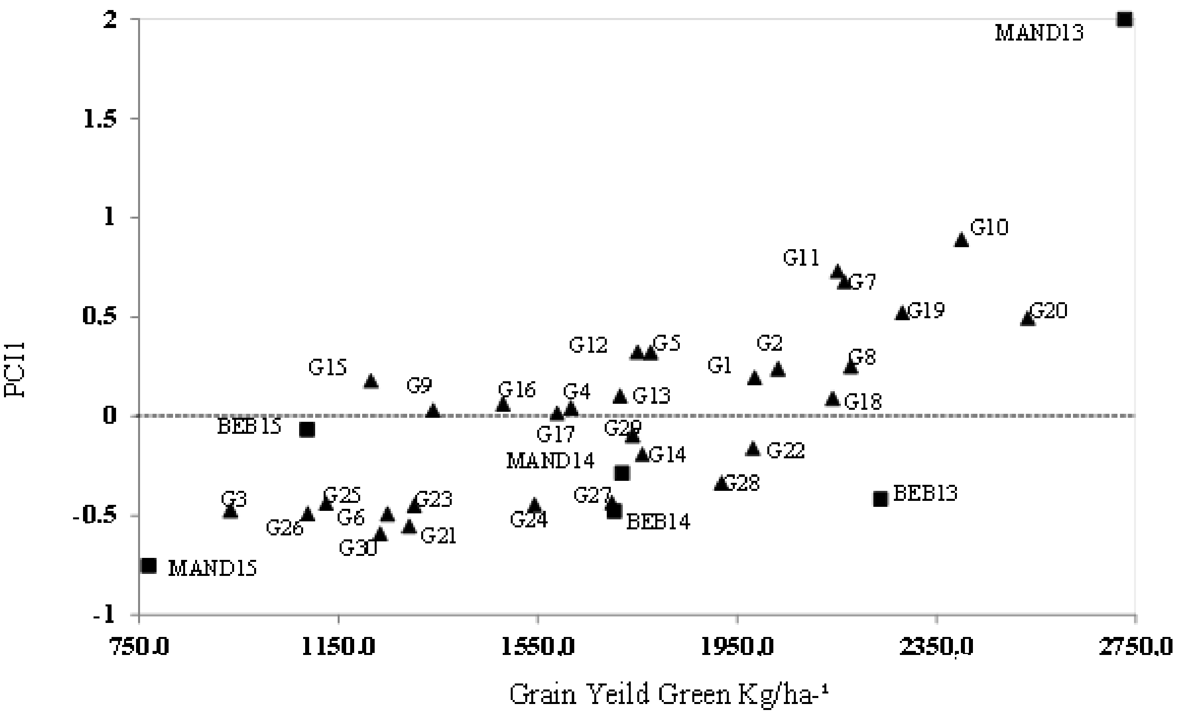

Figure 1. Biplot AMMI for immature seed yield of 30 cowpea genotypes (▲) (*Vigna unguiculata*) evaluated in six environments (■).G1=BRS Acauã; G2=BRS Guariba; G3=BRS Marataoã; G4=BRS Patativa; G5=BRS Pujante; G6=BRS Rouxinol; G7=Lin.PC951015D01E; G8=Lin.PC950409D02E; G9= Lin.PC951016D01E; G10= Lin. PCCR3F6L15; G11= Lin.CPCR3F6L17; G12= Lin.C1J; G13= Lin.C2M; G14= LinC2S; G15= Lin.C3F; G16= Lin.C3Q; G17= Lin.C3S; G18= Lin.P290; G19= Lin.P303; G20= Lin.P-508; G21= PJJ21; G22=PJM22; G23=PJL23; G24=PAG24; G25=PC25; G26=PD26; G27=PJ27; G28=PJJ28; G29=PJN29; G30=PLP30.

(Table 4). For immature pods, only the genotypes PC951015D01E, PC950409D02E, CPCR3F6L15, PJM22 and the BRS Acauã have been highlighted by Eberhart and Russell method, with good yield, broad adaptability and stability. As for Lin and Binns method, the genotypes P-508 (1) and CPCR3F6L15 (2) showed the lowest values of Pi for immature pods, being considered the most stable (Table 4).

For yield of dried seeds, using the Eberhart and Russell method, the genotypes BRS Rouxinol, BRS Guariba, BRS Pujante and BRS Patativa, PC951015D01E, C1J, C2M, C3F, PL23 and PC25 showed broad adaptability and stability. While by the analyses of Linn and Binns, the genotypes BRS Acauã, Patativa, P508 and CPCR3F6L15 were the most stable (Table 4).Using the multivariate method AMMI, the interaction G*E was performed in five main components of interaction (CPI) for yield of immature seeds and pods and four main components of interaction (CPI) for yield of dried seeds. Only the first axis (CPI1) had its significant residue ($p<0.01$), using the model AMMI1 for all the variables evaluated (Table 2).

The first principal component of the interaction explained 54.7% for yield of immature seeds, 46.2% for yield of immature pods and 55.5% for yield of dried seeds (Table 2). These values correspond to the pattern adjacent to the G*E interaction and agronomic importance. The values that represent the noise, that is, random variation resulting from the influence of factors micro environment and without agronomic importance were 55.5, 54.7 and 46.2 for yield of immature seeds and pods and dried seeds, respectively.

Considering the analyses of AMMI, the genotypes CPCR3F6L15, PC951015D01E and PC950409D02E showed high yield of immature seeds and good stability (Figure 1). For yield of immature pods the genotypes P-290, P-508 showed high yield and good stability (Figure 2). As for yield of dried seeds, the genotypes stood out by the AMMI method were BRS Patativa and P-508 (Figure 3). The environments MAND2013 and BEB2013 were the most productive, presenting, the last one, the greater stability for yield of immature seeds and pods (Figures 1 to 3).

DISCUSSION

Cowpea is grown in Brazil, by family farming, predominantly in the Northeastern region, presenting low technological level, without irrigation and unimproved

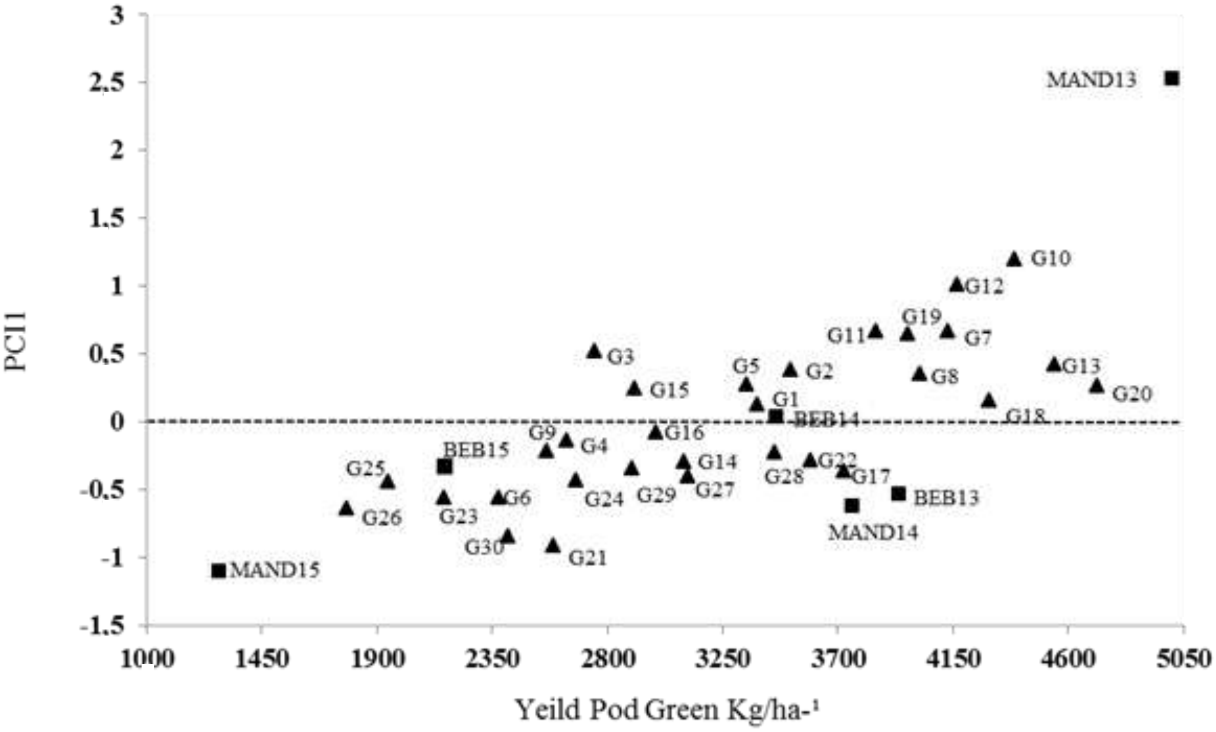

Figure 2. Biplot AMMI for immature pod yield of 30 cowpea genotypes(▲) (*Vigna unguiculata*) evaluated in six environments (■).G1=BRS Acauã; G2=BRS Guariba; G3=BRS Marataoã; G4=BRS Patativa; G5=BRS Pujante; G6=BRS Rouxinol; G7=Lin.PC951015D01E; G8=Lin.PC950409D02E; G9= Lin.PC951016D01E; G10= Lin. PCCR3F6L15; G11= Lin. CPCR3F6L17; G12= Lin.C1J; G13= Lin.C2M; G14= LinC2S; G15= Lin.C3F; G16= Lin.C3Q; G17= Lin.C3S; G18= Lin.P209; G19= Lin.P-303; G20= Lin.P-508; G21= PJJ21; G22=PJM22; G23=PJL23; G24=PAG24; G25=PC25; G26=PD26; G27=PJ27; G28=PJJ28; G29=PJN29; G30=PLP30.

crops, what results low yield. Ratings of lines of cowpea genotypes at different locations, either for yield of dried grain or immature seeds, are of great importance because they can allow the selection of genotypes with good performance in different environments and different technological levels.

The yield of cowpea type immature seeds presents great potential for expansion of consumption, since it is broadly used in cooking from the northeast and the cultivation has been carried out independently by the farmers, without studies that indicate what the best cultivar for this activity. The selection of cultivars with high yield of immature seeds is a great contribution to the populations of semiarid regions.

Several methodologies have been developed to interpret the G*E interaction and identify genotypes which have predicted behavior in various evaluated environments. The methods of linear regression (Eberhart and Russell, 1966) and non-parametric (Lin and Binns, 1988) have been the most broadly used, and according to Silva and Duarte (2006) they presented a low correlation between them, indicating that one method does not replace the other, and they must be applied together (Pereira et al., 2009), as performed in this study.

Silva et al. (2016) evaluated the adaptability and stability for the protein content and grain yield in 44 lines of cowpea genotypes, in seven environments, and observed that the methods of Eberhart and Russell and Lin and Binns showed similar results regarding the selection of superior materials. Using parametric methods and non-parametric tests in 20 cowpea genotypes, Nunes et al. (2014) found that some methodology should not be used simultaneously, and that others must be complementary. Freire Filho et al. (2005) used the AMMI, evaluating the grain yield of 15 lines of cowpea genotypes in 13 environments and observed that the Evx91-2E and Evx63-4E can be cultivated in all environments studied.

The application of these methods is essential for the recommendation of new cultivars. In the state of Piauí, Rocha et al. (2008) evaluated the grain yield of 20 lines of cowpea, and by means of the methodology of Eberhart and Russell (1966) indicated that the cultivars Canapuzinho, Canapu-BA and BRS Xiquexique with broad adaptability and stability. Using this same methodology, Santos et al. (2008) evaluated 64 lines of cowpea genotypes, in a variety of environments in the São Francisco Valley, and the lineage PC 95-05-12-2-2 was released as cultivar BRS Pujante and recommended for cultivation in the semiarid region of Pernambuco and

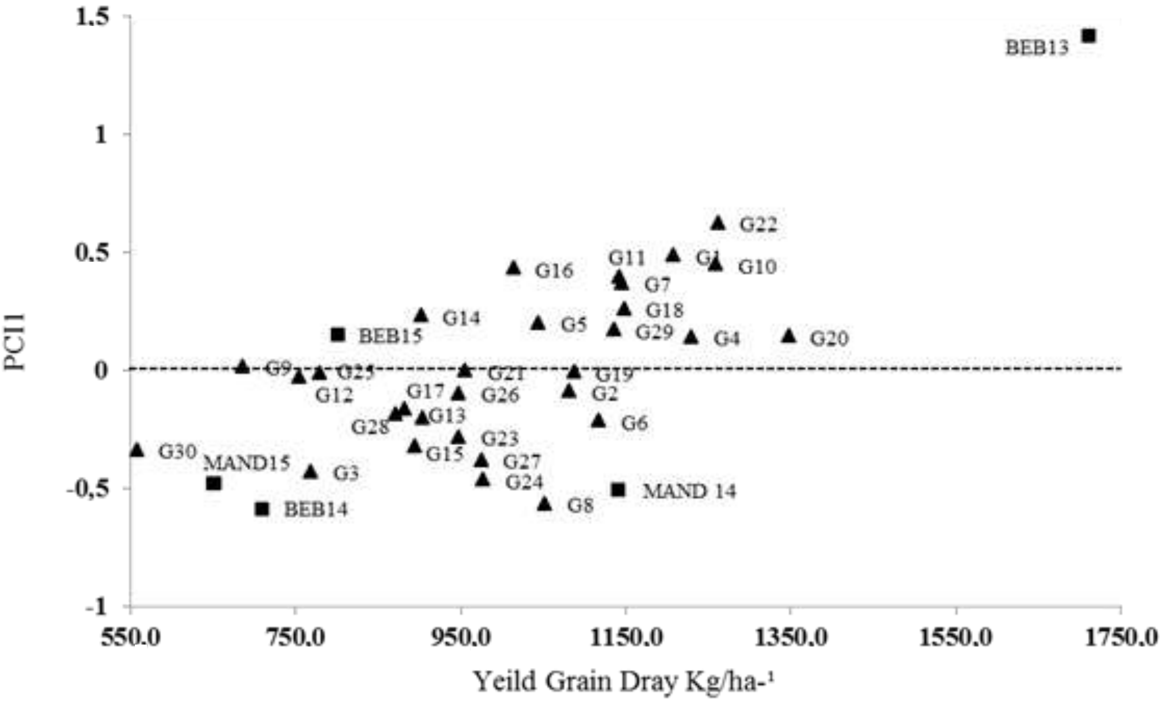

Figura 3. Biplot AMMI for mature dried seed yield of 30 cowpea genotypes (▲) (*Vigna unguiculata*) evaluated in six environments(■).G1=BRS Acauã; G2=BRS Guariba; G3=BRS Marataoã; G4=BRS Patativa; G5=BRS Pujante; G6=BRS Rouxinol; G7=Lin.PC951015D01E; G8=Lin.PC950409D02E; G9= Lin.PC951016D01E; G10= Lin. PCCR3F6L15; G11= Lin. CPCR3F6L17; G12= Lin.C1J; G13= Lin.C2M; G14= LinC2S; G15= Lin.C3F; G16= Lin.C3Q; G17= Lin.C3S; G18= Lin.P209; G19= Lin.P-303; G20= Lin.P-508; G21= PJJ21; G22=PJM22; G23=PJL23; G24=PAG24; G25=PC25; G26=PD26; G27=PJ27; G28=PJJ28; G29=PJN29; G30=PLP30.

Bahia.

Studies have been conducted with the objective of evaluating cowpea genotypes for cowpea market, especially for traits associated with the yield (Andrade et al., 2010; Oliveira et al., 2003). Ramos et al. (2014) evaluated cowpea genotypes under different irrigation levels and yield of immature seeds was 2.937 kg ha^{-1} (BRS Guariba) and 2.493 kg ha^{-1} (BRS Paraguaçu). However, there are no recommended varieties for immature seeds market, considering adaptability and stability parameters.

The genotypes P290, P303, P508 and PC950409D02E showed immature seeds yield higher than the averages of the experiments. They also showed higher yield in comparison with the evaluated cultivars, stability and good predictability in the evaluated environments, both for the methodology of Eberhart and Russell and Lin and Binns (Table 4), as well as by the multiplicative method, based on main components (Figure 1), having great potential to be recommended as new cultivars for the region of São Francisco Valley.

Conclusion

The lines P290, P303, P508 and PC950409D02E showed yield of immature seeds exceeding 2140 kg ha^{-1}, broad stability and good predictability in the series of evaluated environments, and has great potential to be recommended as new cultivars for the region of São Francisco Valley.

Conflicts of Interests

The authors have not declared any conflict of interests.

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