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Evaluation of yield performance in cowpea genotypes (*Vigna unguiculata* (L.) Walp.)

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Abstract

Nineteen cowpea genotypes from the Germplasm Bank of the Genetic Improvement Program of the Agronomic Institute of Pernambuco, Brazil (IPA) were evaluated in three locations in Northeast of Brazil, featuring edaphoclimatic characteristics of Tropical Savanna (Cerrado) and Caatinga (Semiarid) biomes. The aim of this study was to evaluate genotypes with production potential for these regions. An experimental design of randomised blocks was used, with 19 treatments (genotypes) and four replications. Six characteristics relating to yield components were studied. There was no significant difference in yield between the genotypes under evaluation for the region of Pesqueira, PE or Lajedo, PE, both in Caatinga biome. However, the studied genotypes displayed variations in yield for Balsas, MA, Cerrado region, demonstrating that this growth environment was suitable for the expression of production potential in the genotypes. The differences presented by genotypes for the characteristics under study favour their recommendation, and demonstrate the possibility of their selection for genetic improvement of the species. The average yield of 840.8 kg ha^{-1} indicates good adaptation by the genotypes for cultivation in tropical savanna region.

Keywords: *Vigna unguiculata* (L.) Walp., adaptability, stability, agronomic evaluation.

Introduction

In Brazil, the bean that is most widely cultivated and consumed belongs to the species *Phaseolus vulgaris* (L.) (the common bean) and it is precisely this species that suffers the greatest effects from inflation. Other bean varieties, such as the black bean and black-eye bean, are not affected to such a degree by increases in price, since their realities regarding domestic production are different; the former may be easily imported, and the latter maintains good yield within the domestic context.

Diversified production is therefore a fundamental point in avoiding such socioeconomic problems. Production alternatives, such as the string bean or cowpea (*Vigna unguiculata* (L.) Walp.) favour the diversification of products and prices in the market, although they face some resistance, as they are considered exotic by Agricultural Policy Journal of the Secretariat for Agricultural Policy at the Ministry of Agriculture, Livestock and Supply in Brazil (2016). These varieties are short-cycle legumes with worldwide distribution, and are mainly found in tropical regions of the globe due to the characteristics of soil and climate in these regions being similar to their probable centre of origin in Africa (Mousinho et al., 2008).

In Brazil, cultivation of the cowpea occurs in the North and Northeast Regions, and comprises one of the main socioeconomic alternatives, both in the supply of food and the generation of employment and income; no longer a mere subsistence crop, it has assumed a certain technological standard through the use of fertilisers and agricultural correctives, and through mechanisation, technifying the harvesting process, considered the main bottleneck in the production system (Freire Filho et al., 2005; Pereira et al., 2016; Souza et al., 2016).

Cowpea has expanded into the cerrado of the Central-West Region, where it displays high production potential, mainly due to the adoption of improved cultivars. An example is the state of Mato Grosso do Sul, where the crop has aroused the interest of producers as an alternative for diversification and as a low risk option, considering the frequent periods of climatic instability that have compromised crops which are less tolerant to periods of dry, hot weather (Freire Filho et al., 2005).

The selection of improved varieties of cowpea adapted to different ecosystems and mechanised management, more erect and with a short cycle, was studied by the breeding team of Brazilian Agricultural Research Corporation (Embrapa), launching the BRS Guariba and BRS Nova Era cultivars in 2004 and 2007 respectively, and the BRS Tumucumaque and BRS Itaim cultivars in 2009 (Andrade, 2010). In this sense, the study of adaptability and stability in genotypes is fundamental for identifying those genotypes that maintain a stable level of yield irrespective of variations in the environment, and those that respond well to environmental improvement. Genotypes with the highest predictability are those most suitable for small producers, who do not use, or make little use of, modern inputs (Nunes et al., 2014a).

In each environment, phenotypic manifestation is the result of the action of the genotype under the influence of the environment. However, when considering a series of environments, in addition to the genetic and environmental effects, an additional effect can be detected from their interaction (Des Marais, 2013; Nunes et al., 2014b). Evaluation of the genotype x environment interaction can be very important, because where it exists, there is the possibility of the best genotype in one environment not being the best in another (Malosetti et al., 2014). The aim of this study therefore, was to evaluate the productive performance of cowpea genotypes in different environments.

Results and Discussion

ANOVA assessments

A summary of the joint analysis of variance for the 19 cowpea genotypes from the Germplasm Bank of the Genetic Improvement Program of Agronomic Institute of Pernambuco and Brazilian Agricultural Research Corporation is presented in Table 1. There was a significant effect at 1% probability for the sources of variation genotype (G) and location (L). However, no significant effect was seen for the interaction (L x G), except on the characteristic yield. At least two genotypes differed for this variable, thereby rejecting the null hypothesis, denoting differences between these genotypes and the locations, and showing that the productive performance of the genotypes was not constant in the environments under study.

Production Components

An analysis of the results for pod weight, pod length, number of grains per pod, shell weight and hundred-grain weight showed statistical differences between the genotypes studied (Table 2). Genotype 3 (G3) had a longer pod length (20.2 cm). Pod length in all the other genotypes under evaluation was less than the commercial standard of 20 cm proposed by Silva and Oliveira (1993), as large pods are preferable for manual harvesting. However, in mechanised and semi-mechanised harvesting systems, large pods and many grains are of no interest, since smaller pods with a smaller number of grains are lighter, allowing better support and reducing losses due to bending and breaking of the peduncle. In addition, because they are smaller and lighter, the pods do not touch the ground, avoiding losses through rotting (Silva and Neves, 2011).

It was also found that G3 had the best results for pod weight, shell weight and hundred-grain weight (HGW), with average values of 39.6 g, 9.6 g and 22.4 g respectively. For the latter, similar results were found by Mingotte et al. (2013) when they evaluated 17 bean genotypes in a Eutrophic Red Latosol in the region of Jaboticabal in the State of São Paulo and observed a mean value for hundred-grain weight of 24.4 g. These values are higher than those found by Teixeira et al. (2010) in cowpea cultivars in the Cerrado region (Catalão, in the state of Goiás), where 17 g were obtained for the cultivar BRS Marataoã and 19 g for the cultivar BRS Guariba. Silva and Neves (2011) found an HGW for the cultivars BRS Marataoã (15 g) and BRS Paraguaçu (16.7 g) similar to that considered as standard, and lower than the weight obtained in this study. However, these values are like those found by Pereira et al. (2016), but lower than those seen by Souza et al. (2016), who for the cultivar Setentão obtained a mean value for hundred-grain weight of 26.7g.

No correlation was seen between HGW and NGP (data not shown). For the number of grains per pod, genotype 1 had the best results (15.6 grains per pod), being 70.5% higher than the values found by Mingotte et al. (2013). No significant positive correlation was found between NGP and PL (data not shown).

Cowpea yield

Table 3 shows grain yield (kg ha^{-1}) in the 19 cowpea genotypes for the three environments under evaluation. The individual analyses are of great importance, as it is possible to evaluate the magnitude of the genetic variability and see the discrepancies between the residual variances obtained in each environment (Cruz and Regazzi, 1994).

There was no significant difference seen in yield between the evaluated genotypes for the regions of Pesqueira, PE and Lajedo, PE. However, the genotypes studied presented highly significant variations in yield ($p \leq 1$) in the region of Balsas, MA, demonstrating that this growth environment was sufficient for expressing the production potential of the genotypes with adaptability to favourable environment.

It is important to note that the mean value for yield for the 19 genotypes in Balsas, MA, (840.8 kg ha^{-1}) was 6.1% and 30.6% higher than in Pesqueira, PE, (788.5 kg ha^{-1}) and Lajedo, PE, (582.5 kg ha^{-1}) respectively. Genotype 14 was 63.3% more productive than the average for the worst performing genotypes (G6 and G10). The mean yield (1,210.9 kg ha^{-1}) for the best genotype in this study was 62.8% higher than the national average of 400 to 500 kg ha^{-1} (Freire Filho et al., 2005; Alves et al., 2009), also higher than the 1,016 kg ha^{-1} found by Santos et al. (2009); however lower than obtained by Mingotte et al. (2013), which was 2,945 kg ha^{-1}. The value was also lower than approximately 1.3 t ha^{-1} reported by Teixeira et al. (2010) and Pereira et al. (2016).

The good yield for the cowpea genotypes in Balsas, MA, is probably due to the soil and climate conditions in the region. According to Melo and Cardoso (2000), soils with a pH of around 5.5, a level of aluminium saturation below 20%, and medium to high levels of fertility are considered suitable for cultivation of the cowpea. The results of the soil analysis for the areas where the experimental units were set up showed moderate acidity in the region of Balsas, MA, to the detriment of the other regions. This condition, which is associated with the fertiliser applied at planting, possibly contributed to the greater yield displayed by the genotypes.

Materials and Methods

Environments of study

The experiment was carried out in the crop year of 2014, at three locations in Brazil: at Maranata Farm, in the town of Balsas, MA, latitude 08º01'42" S and longitude 45º11'07" W, Red Latosol and Tropical Savanna Biome; at Nossa Senhora do Rosário Farm, in the town of Pesqueira, PE, latitude 8º34'17" S and longitude 37º1'20" W, Fluvic Neosol and Caatinga (semiarid) biome; and at Grossos Farm, in the town of Lajedo, PE, latitude 08°44'41.5" S and longitude 36°17'31.9" W, Regosol Caatinga (semiarid) biome.

Plant materials

A total of 19 genetic materials were evaluated among strains and cultivars from the Germplasm Bank of the Genetic Improvement Program of Agronomic Institute of Pernambuco

Table 1. Summary of analysis of variance for the characteristics PW (pod weight), PL (pod length), NGP (number of grains per pod), SW (shell weight), HGW (hundred-grain weight) and Y (yield) in 19 cowpea genotypes.

SV	DF	PW	PL	NGP	SW	HGW	Y
Genotype (G)	18	66.72**	14.75**	9.81**	8.63**	14.98**	160498.43**
Location (L)	2	494.49*	173.79**	244.24**	64.92**	257.48**	1417638.61^{ns}
LxG	36	10.18^{ns}	2.21^{ns}	1.11^{ns}	0.93^{ns}	2.52^{ns}	90920.55**
Block (Location)	9	102.44**	8.33**	23.39**	1.66*	26.10**	452220.20**
Balsas, MA	18	31.32*	10.77**	5.0747**	6.284**	11.688**	180087.00**
Pesqueira, PE	18	38.234^{ns}	5.583^{ns}	4.146*	2.970**	5.616**	75453.00*
Lajedo, PE	18	17.544**	2.827^{ns}	2.821^{ns}	1.250*	2.738^{ns}	86800.00*
Mean residual	162	14.76	2.42	1.89	0.75	2.18	45152.50
CV	-	11.38	8.58	9.81	11.49	7.40	28.82

Table 2. PW (pod weight), PL (pod length), NGP (number of grains per pod), SW (shell weight) and HGW (hundred-grain weight) in 19 cowpea genotypes.

Genotype	PW	PL	NGP	SW	HGW
G1	35.5 abc	19.5 ab	15.6 a	9.4 ab	19.5 bcd
G2	35.3 abc	18.8 abc	13.9 abcde	8.1 bcd	20.2 abc
G3	39.6 a	20.2 a	13.2 cdef	9.6 a	22.4 a
G4	38.2 ab	16.7 cd	14.3 abcde	7.5 cd	20.9 abc
G5	35.2 abcd	18.9 abc	13.9 bcde	8.3 abc	19.5 bcd
G6	33.7 bcd	16.3 d	12.8 def	6.8 cd	20.1 abc
G7	33.4 bcd	18.1 abcd	13.9 bcde	7.1 cd	19.8 bc
G8	32.7cd	17.4 bcd	14.1 abcde	6.65 d	19.0 bcd
G9	32.2cd	17.6 bcd	13.2 cdef	7.1 cd	20.1 abc
G10	33.8 bcd	17.7 bcd	14.4 abcde	7.0 cd	21.3 ab
G11	32.6cd	16.3 d	12.8 ef	6.6 d	20.3 abc
G12	35.0 abcd	18.8 abc	14.7 abc	7.9 bcd	18.7 cd
G13	33.1 cd	17.0 cd	14.7 abc	6.8 cd	20.2 abc
G14	32.5 cd	18.8 abc	14.4 abcd	7.4 cd	19.6 bcd
G15	31.2 cd	18.9 abc	14.2 abcde	7.5 cd	19.0 bcd
G16	33.6 bcd	19.5 ab	14.3 abcde	7.9 cd	19.3 bcd
G17	30.2 d	17.9 abcd	14.9 ab	7.2 cd	17.2 d
G18	30.9 cd	17.9 abcd	11.8 f	6.9 cd	21.1 ab
G19	31.7 cd	17.5 bcd	14.8 ab	7.2 cd	20.1 abc

and Brazilian Agricultural Research Corporation (Table 4)

Experimental design and conduction

Soil collection for analysis was carried out at a depth of 20 cm (Table 5). The soil was prepared mechanically, which consisted of ploughing and levelling. Planting was done manually in holes with a depth of 5.0 cm, placing four seeds per hole. Thinning was at fifteen days after planting, leaving one plant per hole in order to obtain the desired populations.
Fertilisation was manual, distributing the equivalent of 300 kg ha^{-1} of 06:24:12 commercial formulation in the furrows, by mixing the fertiliser with the soil at the bottom of the grooves. At the time, the fertiliser was heaped, to avoid loss due to the weather. Sowing was in accordance with the recommendations for agricultural zoning for climate-risk of the Ministry of Agriculture, Livestock and Supply for each town, and carried out in Balsas. MA on 18 March, Pesqueira, PE on 7 May, and Lajedo, PE on 05 July 2014. An experimental design of randomised blocks was used, with 19 treatments (genotypes) and four replications. The experimental lots were composed of four rows of plants, 5.0 m in length, at a spacing of 0.50 m between rows and 0.20 m between plants; the two central rows were considered as the working area to obtain data for analysis, with five plants being labelled for data collection. Cropping treatments were carried out using manual weeding and narrow leaf herbicides to control weeds. Pests and diseases were controlled

Table 3. Yield (kg ha^{-1}) in 19 cowpea genotypes, Balsas, MA; Pesqueira, PE; and Lajedo, PE.

Genotype	Balsas, MA	Pesqueira, PE	Lajedo, PE
G1	656.8 BCD	794.5 A	829.5 A
G2	722.9 ABCD	928.4 A	748.5 A
G3	861.6 ABCD	1039.5 A	807.6 A
G4	862.9 ABCD	846.5 A	566.4 A
G5	953.8 ABCD	869.8 A	415.2 A
G6	436.9 D	613.7 A	541.6 A
G7	907.9 ABCD	774.3 A	529.4 A
G8	787.0 ABCD	929.8 A	447.7 A
G9	981.7 ABC	690.7 A	479.9 A
G10	451.4 D	572.6 A	486.4 A
G11	580.2 CD	628.4 A	471.7 A
G12	1176.1 AB	940.7 A	766.4 A
G13	808.8 ABCD	614.4 A	509.7 A
G14	1210.9 A	811.6 A	412.0 A
G15	1037.6 ABC	680.7 A	451.9 A
G16	1037.1 ABC	650.0 A	534.1 A
G17	808.7 ABCD	907.6 A	518.8 A
G18	774.4 ABCD	912.1 A	813.2 A
G19	917.7 ABCD	775.7 A	735.9 A

Table 4. Description of the 19 genetic materials evaluated.

Code	Genotype	Origin
G1	IPA1.13	IPA and EMBRAPA
G2	IPA 1.50	IPA and EMBRAPA
G3	BRS XIQUEXE	IPA and EMBRAPA
G4	IPA 10.37	IPA and EMBRAPA
G5	IPA 11.3	IPA and EMBRAPA
G6	IPA 16.9	IPA and EMBRAPA
G7	IPA 17.16	IPA and EMBRAPA
G8	IPA 17.40	IPA and EMBRAPA
G9	IPA 3.25	IPA and EMBRAPA
G10	IPA 17.4	IPA and EMBRAPA
G11	IPA 17.11	IPA and EMBRAPA
G12	IPA 17.33	IPA and EMBRAPA
G13	IPA 17.34	IPA and EMBRAPA
G14	IPA 18.8	IPA and EMBRAPA
G15	IPA 18.21	IPA and EMBRAPA
G16	IPA 18.50	IPA and EMBRAPA
G17	IPA 206	IPA and EMBRAPA
G18	BRS TUMUCUMAQUE	IPA and EMBRAPA
G19	BRS PAJEÚ	IPA and EMBRAPA

IPA - Agronomic Institute of Pernambuco, Brazil; EMBRAPA - Brazilian Agricultural Research.

Table 5. Result of the soil chemical analysis carried out at the experimental areas.

Location	pH ($CaCl_2$)	OM g Kg^{-1}	P mg dm^3	K	Ca	Mg	Al	H+Al	BS	CEC pH 7,0	V %
				------------cmolc/dm^3------------							
Balsas	4.9	34.4	16.0	0.20	4.0	1.23	0.0	4.47	5.43	9.9	54.8
Pesqueira	6.2	34.4	100	0.25	28	1.23	0.0	3.31	29.48	32.79	89.90
Lajedo	6.2	16.7	47	0.30	3.75	0.75	0.0	4.26	4.80	9.06	52.98

chemically, using insecticides and fungicides recommended and registered for the crop.

Traits measured

When 90% of the pods were at physiological maturity and ready for harvest, and the grains displayed 13% to 15% humidity, the following characteristics were evaluated: pod weight, pod length, number of grains per pod, shell weight, mean hundred-grain weight and grain yield ha^{-1}.

Statistical analysis for stability and adaptability (GxE interaction)

All the characteristics were submitted to correlation analysis to observe the effects of the different locations on the genotypes. The F-test was applied to verify the statistical significance of the mean squares of the treatments relative to the characteristics. The differences between cultivars and strains were verified by Tukey's test at 5% probability.

Conclusion

The differences presented by the genotypes for the characteristics under study support recommendation of the genotypes, and demonstrate the possibility of selecting characteristics for the genetic improvement of the species. The average yield of 840.8 kg ha^{-1} shows the genotypes to be well adapted for cultivation in Balsas, MA.

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