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Genetic parameters for agronomic and nutritive traits of forage peanut in rainy and dry seasons. Parâmetros genéticos para características agronômicas e nutricionais do amendoim forrageiro nas estações chuvosa e seca.

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Abstract

Considering the productive seasonality, the objective of this work was to estimate genetic parameters for agronomic and nutritional traits of forage peanut for selection of more adapted and productive genotypes in the dry and rainy seasons. Sixty-seven genotypes were evaluated in three time-separated trials. Agronomic and nutritional data were analyzed by mixed model methodology (REML/BLUP), considering the seasons separately. There was genetic variability and environment influence for the traits in each season, except for the nutritional ones. There are favorable conditions for selection in the dry period, with high consistency among trials and high accuracy, for some agronomic traits. The selection for flowering is benefited in the rainy season.

Keywords: *Arachis pintoi* and *A. repens*. Seasonality. Heritability. Repeatability. Periods of the year.

Resumo

Considerando a sazonalidade produtiva, o objetivo deste trabalho foi estimar parâmetros genéticos de características agronômicas e nutricionais do amendoim forrageiro para seleção de genótipos mais adaptados e produtivos nas estações seca e chuvosa. Foram avaliados 67 genótipos em três ensaios temporalmente separados. Os dados agronômicos e nutricionais foram analisados pela metodologia de modelos mistos (REML/BLUP), considerando as estações separadamente. Houve variabilidade genética e influência do ambiente para as características em cada estação, exceto para as nutricionais. Há condições favoráveis para seleção de caracteres agronômicos na seca, com alta consistência entre os ensaios e alta precisão, para cobertura do solo e produção de matéria seca. A seleção para florescimento é beneficiada nas chuvas.

Palavras-chave: *Arachis pintoi* e *A. repens*. Sazonalidade. Herdabilidade. Repetibilidade. Períodos do ano.

Introduction

Brazil has the largest commercial cattle herd in the world and 90% of the animals are raised exclusively on pasture, with an expressive potential for expansion through intensified production (ARANTES et al., 2018; SANTOS et al., 2018). The low input production system, widely used, shows high performance variation. In areas with native pastures, the activity has low support capacity, whereas in areas with cultivated forage species there is greater support capacity and productivity, according to the technological levels employed. However, inefficient pasture management results in a drop in support capacity after a few years of pasture formation, and the area becomes of low productivity (BARBOSA et al., 2015).

Associated with inadequate management, climatic seasonality is one of the factors that affect support capacity, resulting in production seasonality and negatively affecting animal weight gain by reducing forage yield and quality (AMORIM et al., 2019; SOUZA SOBRINHO et al., 2011). The improved pasture allows mitigating the effects of forage production seasonality, especially through the consortium with forage legumes (PEREIRA et al., 2015).

In this context, the use of pastures intercropped with legumes, such as forage peanut, can contribute to the smaller production breadth between rainy and dry seasons, supplying nitrogen to the associated grass and reducing input costs (FIORELI et al., 2018; OLIVO et al., 2019; PEREIRA et al., 2015). Forage peanut has high nutritional stability and have shown good dry matter production potential, even in water restriction periods (FERNANDES et al., 2017; FIORELI et al., 2018; SIMEÃO et al., 2017), which could contribute to the minor losses of forage supply and animal production in the drier seasons (PEREIRA et al., 2015).

So, the analysis of forage peanut genotypes considering the reflexes of environmental influence in specific seasons is relevant for the species breeding program, since it provides subsidies for selection of genotypes with greater adaptability and productive stability throughout the year, since this influence acts on the species seasonal behavior (CARVALHO et al., 2009; MENEZES et al., 2012).

The objective of this study was to estimate the genetic parameters for agronomic and nutritive value traits of forage peanut in tropical conditions in order to improve the selection of more adapted and productive genotypes in the dry and rainy seasons.

Material and methods

Sixty-six forage peanut genotypes from the Active Germplasm Bank located at Embrapa Acre in Rio Branco, AC, Brazil, were evaluated in three different trials, beginning in December 2005 and ending in April 2013.

Each trial was conducted at the same site but was time-separated, and the evaluations consisted of measuring the agronomic traits of the aerial biomass. The local climate is hot and humid equatorial type, characterized by high temperatures, with average temperatures of maximum 31 °C and minimum 21 °C; relative humidity about 80%; and high rainfall, about 1,900 mm per year (ACRE, 2010). The rainy season extends from October to April, and the water deficit occurs from June to September.

The experimental area fertilization was performed based on pasture fertilization and liming, according to soil analysis for each trial. The Trial I was installed in Dystrophic Ultisol and the Trial II and III were installed in Dystrophic Oxisol (EMBRAPA, 2018).

Harvests were made after the establishment period, which for Trial I was 10 months after planting and for Trials II and III was 4 months. The nutritive (bromatological) analyses were performed with 70 days mean of regrowth in dry and rainy seasons.

The three trials were vegetatively implanted, with two stolons per pit and 0.5 m between pits and between rows. To standardize, each stolon was about 25 cm long with five internodes, which three were covered with soil. In Trial II, cv. BRS Mandobi was also implanted by seed with 0.5 m between pits and rows with two seeds per pit. All the trials had as control the cultivars BRS Mandobi and Belmonte vegetatively propagated and were conducted in a randomized complete block design, with four replications for Trial I and III and five replications for Trial II. The trials had 1 m^2 plot of usable area.

With respect to the implantation and harvests made along the seasons, Trial I was installed in December 2005, with an uniformization cut in October 2006. Twenty-one genotypes were evaluated in eight evaluations, one in the dry season and seven in the rainy season, from December 2006 to November 2008. Biomass cuts were performed in all evaluations except in the dry season because of low leaves production (Table 1).

In Trial II, 18 genotypes were evaluated in eight cuts from July 2009 to April 2011, in which six harvests were performed in the rainy season and two in the dry season. The Trial III was installed in December 2010 with an uniformization cut in April 2011. Thirty-three genotypes were evaluated in 12 evaluations with 11 harvests, from May 2011 to July 2013. Eight evaluations with harvests were made in the rainy season and four evaluations with three harvests were made in the dry season.

Harvests were made after the establishment period, which for Trial I was 10 months after planting and for Trials II and III were 4 months. The nutritive value analyses were performed with 70 days mean of regrowth in dry and rainy seasons. The evaluations consisted of the measurement of agronomic characters and nutritive value evaluation of the aerial biomass harvested. The occurrence of pests and diseases, plant vigor, flowering and ground cover (GC) were obtained visually by grading scale, according to increasing intensity observed for each trait, adapted from Menezes et al. (2012).

Total (TDMY) and leaf (LDMY) dry matter yield, with leaf blade separation, was quantified after each evaluation (with aerial biomass harvested at 2 cm above ground) by forced-air drying at 55 °C for 72 hours and estimated in kg ha^{-1}. The nutritive value characters, evaluated after weighing and total dry matter sampling, were neutral detergent fiber (NDF) and acid detergent fiber (ADF), according to Georing and Van Soest (1970), and crude protein content (CP), by the modified Kjeldahl method (SILVA; QUEIROZ, 2001), in kg ha^{-1} of dry matter.

Data were analyzed separately according to season (rainy and dry) for each trial by the Restricted Maximum Likelihood (REML) method (PATTERSON; THOMPSON, 1971) to estimate the variance components and by the Best Linear Unbiased Prediction (BLUP) (HENDERSON, 1975) to predict genotypic values. The models used were based on those proposed by Resende (2002) for the analysis of unrelated perennial plants and one observation per plot.

For each characteristic within each trial and according to season (when there was more than one evaluation, Table 1), the repeatability model was used: $\mathbf{y} = \mathbf{Xu} + \mathbf{Zg} + \mathbf{Wp} + \mathbf{Tm} + \mathbf{e}$; where **y** is the data vector, **u** is the vector of the effect of evaluation-repetition combinations (considered fixed) plus the general mean, **g** is the vector of genotypic effects (considered random), **p** is the vector of permanent environment effect (plots, considered random), **m** is the vector of the genotype x evaluations interaction effects and **e** is the vector of errors or residuals (random). Capital letters represent the incidence matrices for these effects.

For cases with only one evaluation (Trial I nutritive value traits and agronomic traits in dry season) the following model was used: **y** = **Xr** + **Zg** + **e**; where **y** is the data vector, **r** is the vector of repetition effects (considered fixed) plus the general mean, **g** is the vector of genotypic effects (considered random), and **e** is the vector of errors or residuals (random). Capital letters represent the incidence matrices for these effects.

Table 1 - Date and evaluation intervals of forage peanut genotypes for agronomic and nutritive value traits at three trials performed over the time.

	Agronomic traits			Nutritive Value traits		
Trial	Date	Days[1]	Season	Data	Days	Season
I	12/06/06	58	Rainy	02/06/07	62	Rainy
	02/06/07	62	Rainy			
	03/29/07	51	Rainy			
	05/15/07	47	Rainy			
	12/17/07	216	Rainy			
	04/15/08	120	Rainy			
	07/10/08[2]	86	Dry			
	11/26/08	225	Rainy			
II	07/27/09	108	Dry	07/27/09	108	Dry
	11/10/09	106	Rainy	01/22/10	73	Rainy
	01/22/10	73	Rainy	04/12/10	80	Rainy
	04/12/10	80	Rainy			
	07/19/10	98	Dry			
	11/22/10	126	Rainy			
	01/21/11	60	Rainy			
	04/25/11	94	Rainy			
III	05/20/11	46	Rainy			
	07/01/11[2]	42	Dry			
	08/26/11	98	Dry			
	10/28/11	63	Rainy	05/20/11	46	Rainy
	01/16/12	80	Rainy	03/02/12	46	Rainy
	03/02/12	46	Rainy	05/04/12	63	Rainy
	05/04/12	63	Rainy	07/30/12	88	Dry
	07/30/12	88	Dry	01/10/13	73	Rainy
	10/29/12	89	Rainy	07/04/13	83	Dry
	01/10/13	73	Rainy			
	04/12/13	92	Rainy			
	07/04/13	83	Dry			

[1]Days of budding. [2]With no harvest of aerial biomass.

The estimated genetic parameters of traits for each season were: mean heritability of plot (h^2_m), individual heritability in the broad sense (h^2_g), coefficient of determination of genotype x evaluation interaction (c^2_m) and permanent plot (c^2_p), genotypic correlation (r_m), individual repeatability (r), ratio of the coefficients of genetic and residual variation (CV_g/CV_e), accuracy of selection (Ac) and Pearson's correlation (ρ).

Because of the effect of serial correlation, intrinsic to repeated measurement data, several residual structures for the repeatability model were tested and selected by the likelihood ratio test (LRT) and the Akaike (AIC) and Bayesian Information (BIC) criteria, observed for each matrix in the models where convergence can be found (LITTELL et al., 2000). The variance components matrix, unstructured matrix (first-order) and analytical factor matrix (first-order) were selected.

The variance components obtained by the REML method for each analysis were used to estimate the respective genetic parameters (heritabilities, repeatabilities, coefficients of determination, coefficients of variation, and correlations), according to Holland et al. (2003) and Resende (2002). The genotypic, permanent plot and genotype x evaluations interaction variabilities, according to each model, were tested by the deviance analysis, also based on the LRT test, according to Resende (2007). This test subtracts the functions -2LogeL, where L is the likelihood equation of the complete model and of the model without the tested effect, and compares this difference to the tabulated χ^2 value. If the value is significant, the tested effect has variability. The same procedure is applied for selecting the residual structure matrices.

The repeatabilities were classified according to the criterion proposed by Resende (2002), considering low repeatability (< 0.30), moderate ($0.30 \leq r \leq 0.60$) and high (> 0.60); as well as the repeatabilities as low (< 0.15), moderate ($0.15 \leq h^2 \leq 0.50$) and high (> 0.50). The correlation classifications follow criteria proposed by Resende (2015), considering low (< |0.33|), moderate ($|0.33| \leq \rho \leq |0.66|$) and high (> |0.66|) magnitudes of correlations.

All statistical procedure was performed in the program SAS®, by the command PROC MIXED for the mixed models and PROC CORR for correlations (SAS, 2010).

Results and discussion

In the rainy season there was genotypic variability for all agronomic traits in the three trials. Only ADF and NDF in Trail I, NDF in Trail II and CP in Trail III presented no variation (Table 2), confirming the significant agronomic variability observed for forage peanut genotypes (CARVALHO; QUESENBERRY, 2012; FERNANDES et al., 2017; MENEZES et al., 2012) and the selection feasibility for this season.

Individual heritability (h^2_g) ranged from low to moderate, according to the classification of Resende (2002). There was a consistent moderate heritability in flowering, with influence of harvests (c^2_m), especially in Trials II and III. The heritability of CP also increased in the Trial III, starting to demonstrate no significant interaction of genotypes and harvests, which shows uniform biomass production in the season because of water supply distribution, in addition to the photosynthetic rate, reflecting the elevated solar incidence from the tropical region (SANTOS et al., 2016). However, heritability in Trail III was lower, probably because of the occurrence of rhizoctoniosis, causing damage to aerial biomass during the experimentation initial time.

In the rainy season, the coefficient of determination of genotype x evaluation interaction effects (c^2_m) was not significant for the nutritive value traits of Trial II and III, except for CP of Trial III, confirming the low variability of these traits for the species (PEREIRA et al., 2015). Studies indicate variability for nutritive value traits, however of low magnitude (FERREIRA et al., 2012; MENEZES et al., 2012; SIMEÃO et al., 2017), in addition to the interaction with the environment in regions with more extended dry seasons (FERNANDES et al., 2017), which tends to confirm the influence of seasonal environmental effects.

The occurrence of pest in Trial I was not significant for c^2_m, confirming the observed under the same study conditions by Menezes et al. (2012), which can be attributed to the reduced natural incidence of pests and diseases in the region for this species.

The other traits presented significant c^2_m, which tends to cause difficulties in the breeding program, since even in more homogeneous environmental conditions (rainy season) there is an oscillation in the rank of best genotypes. Occurrence of disease in Trial I, pest, disease and GC in Trial II, GC and LDMY in Trial III presented c^2_m values above h^2_g, reinforcing the higher environment influence. It is interesting to note that for flowering, despite the high magnitudes of c^2_m in all trials, the h^2_g values were higher and with moderate magnitude, indicating greater stability because of the genetic potential maximization in this season.

In general, the coefficients of determination of the permanent plot (c^2_p) were higher for the agronomic traits related to aerial biomass production, such as GC, vigor, height, and TDMY and LDMY. This variation can be explained by the environmental conditions within the plot, such as soil stains or moisture punctual accumulation, which in the rainy season are more evident and tend to reflect directly on the dry matter production (RESENDE et al., 2008; SANTOS et al., 2016).

Table 2 - Individual heritabilities in broad sense (h^2_g), coefficient of determination of genotype x evaluation interaction (c^2_m) and permanent plot (c^2_p) effects, genotypic correlation through the evaluations (r_m), mean heritabilities of plot (h^2_m), accuracy of selection (Ac), genetic (CV_g) and residual (CV_e) coefficients of variation and individual repeatability (r) in the rainy season for the three trials of forage peanut.

Traits	h^2_g	c^2_m	c^2_p	r_m	h^2_m	Ac	CV_g	CV_e	r
				Trial I					
Pest	0.05±0.03**	0.03	0.01	0.59	0.56	0.75	2.45	10.67	0.05
Disease	0.07±0.03**	0.11**	0.01	0.40	0.62	0.79	4.87	16.31	0.07
Vigor	0.38±0.07**	0.13**	0.09**	0.75	0.75	0.93	13.99	14.21	0.48
Flower	0.36±0.07**	0.20**	0.01*	0.64	0.88	0.94	34.64	38.20	0.37
GC	0.44±0.08**	0.30**	0.09**	0.60	0.86	0.93	22.17	14.01	0.53
Height	0.34±0.07**	0.18**	0.21**	0.66	0.79	0.89	33.61	29.83	0.55
CP[1]	0.55±0.23*	-	-	-	0.83	0.91	9.27	8.42	-
ADF[1]	0.19±0.13	-	-	-	0.48	0.69	3.61	2.10	-
NDF[1]	0.17±0.13	-	-	-	0.45	0.67	3.57	7.90	-
TDMY	0.30±0.06**	0.24**	0.15**	0.55	0.78	0.88	32.35	33.29	0.44
LDMY	0.30±0.06**	0.13**	0.12**	0.70	0.83	0.91	31.96	38.82	0.42
				Trial II					
Pest	0.11±0.04**	0.30**	0.02	0.28	0.61	0.78	17.03	38.37	0.13
Disease	0.10±0.04**	0.25**	0.01	0.29	0.62	0.79	18.28	45.80	0.10
Vigor	0.26±0.06**	0.20**	0.05*	0.56	0.81	0.90	4.92	6.84	0.30
Flower	0.37±0.07**	0.31**	0.03**	0.55	0.85	0.92	47.83	42.43	0.40
GC	0.13±0.04**	0.25**	0.14**	0.34	0.60	0.77	3.77	7.34	0.27
Height	0.35±0.07**	0.17**	0.15**	0.67	0.83	0.91	20.57	20.20	0.50
CP	0.42±0.14**	0.02	0.01	0.96	0.86	0.93	4.98	5.64	0.44
ADF	0.21±0.10*	0.10	0.07	0.68	0.63	0.79	3.27	5.62	0.28
NDF	0.08±0.06	0.09	0.01	0.48	0.40	0.63	1.81	5.68	0.08
TDMY	0.42±0.08**	0.19**	0.15**	0.69	0.86	0.93	20.27	15.46	0.57
LDMY	0.45±0.08**	0.14**	0.13**	0.76	0.88	0.94	20.89	16.53	0.58
				Trial III					
Pest	0.12±0.03**	0.08**	0.02	0.60	0.76	0.87	12.49	31.39	0.14
Disease	0.13±0.03**	0.18**	0.08**	0.42	0.67	0.82	23.96	52.76	0.21
Vigor	0.24±0.04**	0.08**	0.05**	0.74	0.85	0.92	6.46	10.53	0.29
Flower	0.46±0.06**	0.31**	0.02**	0.60	0.90	0.95	72.65	50.15	0.48
GC	0.11±0.03**	0.16**	0.09**	0.41	0.64	0.80	2.67	6.39	0.20
Height	0.47±0.06**	0.17**	0.13**	0.73	0.88	0.94	26.06	18.30	0.60
CP	0.05±0.03	0.25**	0.01	0.17	0.26	0.51	1.64	6.21	0.05
ADF	0.07±0.04*	0.06	0.01	0.54	0.41	0.64	1.98	7.20	0.07
NDF	0.10±0.04**	0.04	0.01	0.73	0.54	0.74	1.82	5.28	0.11
TDMY	0.28±0.02**	0.17**	0.16**	0.62	0.79	0.89	18.18	21.65	0.44
LDMY	0.21±0.06**	0.24**	0.08*	0.47	0.61	0.78	14.95	22.08	0.29

[1]Only one evaluation. * and ** significant at 5 e 1% by deviance analysis based on LRT test, respectively. (-) Values not available for this analysis. Occurrences of Pest and Disease: visual scale of 0 to 10; Vigor: visual scale of 0 to 9; Flower: flowering in scale of 0 to 10; GC: % of ground cover; Height: plant height, cm; CP: crude protein content of aerial biomass, kg ha^{-1}; ADF and NDF: acid and neutral detergent fiber content, kg ha^{-1}; TDMY: total dry matter yield per harvest, kg ha^{-1}; LDMY: leaf dry matter yield per harvest, kg ha^{-1}.

Genotypic correlation through the evaluations (r_m), which associated with c^2_m allow predicting the behavior of genotypes in relation to environmental changes (ROSADO et al., 2012), indicate the coincidence among the best genotypes. In general, the agronomic traits associated with aerial biomass production had values above 50%, except for GC in Trial II and III, indicating that more than half of the genotypes maintained good performance for these traits in the rainy season.

The nutritive value traits, TDMY and LDMY also showed higher r_m values in Trial II. However, these same traits had lower values in Trait III, indicating a larger environmental effect in this trial, possibly because of the incidence of rhizoctonia, as previously noted.

GC also had a drop in r_m values in Trial II and III, suggesting again that during the rainy season the genotypes tend to increase the variation in performance for this trait. This information provides significant implications, since under optimal development conditions, the genetic potential of each genotype is maximized, revealing differences in production that can result in high seasonality in more restricted environmental conditions.

Only occurrence of disease from Trial I and pest, disease and GC from Trial II and disease, GC, CP and LDMY from Trait III had r_m values below 50%, reinforcing the trend observed of production stability over the evaluations.

Mean heritabilities of plot (h^2_m), ranging from moderate to high magnitude, however occurrence of pest, GC and height from Trait II and GC, TDMY, LDMY and nutritive value traits from Trial III revealed lower values. The use of this parameter in the selection tends to improve the selection efficiency by increasing the level of precision due to the weighting of the variances by the number of repetitions and proportional evaluations in each plot (RESENDE, 2002; ROSADO et al., 2012). In addition, the selection accuracy, directly related to h^2_m, was above 70% for most traits, a level considered adequate for this stage of breeding program (VIANA; RESENDE, 2014).

Genetic coefficients of variation (CV_g) in the rainy season were relatively higher for occurrence of pest and height in the three trials and flowering in Trial II and III. Residual coefficients of variation (CV_e) of traits had changes, but with an increase in the three trials only in the occurrence of disease, which did not change the accuracy above 70% for selection, with lower values only for the nutritive value traits (ADF and NDF of Trial I, NDF of Trial II and CP and ADF in Trait III). CV_g/CV_e ratio values above 1 indicate more easily selection, with prospects for more gains because of larger genetic influence in relation to the environment effects.

Individual repeatabilities, that indicate the maximum genetic potential reached at the site (RESENDE, 2002), ranged from low to moderate magnitude ($r < 0.3$). This suggests that for most traits the number of evaluations needed to accurately predict the real value of individuals tends to be higher, increasing the evaluation time as well.

The means observed in the rainy season (Table 3) were high for the traits related to forage production, TDMY and LDMY, vigor, GC and height, which was also observed for regions of larger water restriction (FERNANDES et al., 2017; SIMEÃO et al., 2017), characterizing the production seasonality effect (SOUZA SOBRINHO et al., 2011). There was also an increase in fibers, which may have occurred because of the larger production of total and leaves biomass, as a result of the increase in the metabolic process provided by favorable climatic conditions and consequent acceleration of the physiological age of the plant. This tends to increase the insoluble fiber content of aerial biomass (VAN SOEST, 1994), however, in this case, still maintaining adequate levels for animal feed (FERREIRA et al., 2012; PEREIRA et al., 2015).

The CP content, despite the minor variation, showed less variability among the analyses, indicating the forage quality was more constant between the seasons studied. Furthermore, the genotypic means of occurrence of pest and disease in the rainy season were lower in the three trials, except for occurrence of pest in Trial I, which was also observed by Menezes et al. (2012) under the same study conditions. This may be related to the less favorable environment for the development cycle of pests and disease vectors in perennial plants because of high moisture, in addition to the increase in plant vigor during this season, which can contribute to lesser damage severity in plant tissue.

Table 3 - Genotypic means for the Trials I, II and III of forage peanut genotypes in the rainy and dry seasons.

Trial	Ps	Ds	Vg	Fw	GC	Hg	CP	ADF	NDF	TDMY	LDMY
Rainy season											
I	2.82	3.02	6.58	2.75	82.15	7.09	206.25	337.03	427.43	2,341.98	1,363.21
II	1.96	1.47	7.30	2.27	96.22	6.23	218.19	348.32	617.90	2,604.13	1,475.18
III	2.25	1.82	7.53	1.48	97.17	6.06	241.33	325.13	577.20	1,922.99	1,026.17
Dry season											
II	2.50	3.83	6.22	0.36	84.57	3.31	200.39	312.49	537.33	1,614.39	991.75
III	2.56	2.77	7.04	0.54	87.86	3.75	216.70	257.58	451.85	1,121.43	409.18

Occurrences of Pest (Ps) and Disease (Ds): visual scale of 0 to 10; Vigor (Vg): visual scale of 0 to 9; Flower (Fw): flowering in scale of 0 to 10; GC: % of ground cover; Height: plant height, cm; CP: crude protein content of aerial biomass, kg ha^{-1}; ADF and NDF: acid and neutral detergent fiber content, kg ha^{-1}; TDMY: total dry matter yield per harvest, kg ha^{-1}; LDMY: leaf dry matter yield per harvest, kg ha^{-1}.

Genotypic variability for most traits in the dry season indicates the possibility of selection, even under restricted environmental conditions, in Trial II and III (Trial I had no aerial biomass harvest) (Table 4). The occurrence of pest and flowering in Trial II and disease in Trial III did not contain their parameters estimated because of the lack of data convergence, caused by the null variability for the values obtained in the evaluations. For the other traits, only occurrence of disease and NDF from Trial II and ADF from Trial III did not have genotypic variability in this season.

Individual heritabilities in broad sense (h^2_g) varied in relation to the rainy season, with an increase in h^2_g of GC, height and CP and a reduction in flowering in the two trials, as observed in the Cerrado biome by Carvalho et al. (2009) because of the more restricted environmental conditions.

Indeed, with the reduction in magnitude concerning the rainy season of most traits, especially in Trial II, the coefficients of determination of the interaction with the environment effects (c^2_m) were significant. This did not occur for the traits height from Trial II and the nutritive value traits from Trial III, indicating, again, more homogeneous environmental conditions among evaluations in this season.

However, the coefficients of determination of the permanent plot effects (c^2_p), related to punctual influences throughout the evaluations, were higher, mainly for GC and LDMY in the two trials. Interestingly, this season exerts critical environmental influence on GC. This tends to reflect the effects of water restriction on the growth of stolons after aerial biomass harvest under drought conditions and indicates more elevate selection difficulties for GC, vigor and flowering.

Genotypic correlation through the evaluations (r_m) (Table 4) was above 50% for all traits of Trial II, except for the occurrence of disease, with a tendency to increase in relation to the rainy season analysis, reinforcing the reduction of the interaction effect. This can also be observed for the nutritive traits of Trial III, with high r_m values. In this trial, there was a reduction in the correlation through the evaluations for the traits flowering, vigor and GC, with values below 50%. In these cases, c^2_m was more pronounced than in the analysis in the rainy season, which may also be a reflection of the cumulative effects of water restriction on genotypes until the end of the dry season.

Mean heritabilities of plot (h^2_m) presented moderate to high magnitudes, but relatively smaller than the rainy season analyses (Table 2), except for the nutritive value traits of Trial II and CP and NDF and LDMY from Trial III, because of minor environment variation.

Table 4 - Individual heritabilities in broad sense (h^2_g), coefficient of determination of genotype x evaluation interaction (c^2_m) and permanent plot (c^2_p) effects, genotypic correlation through the evaluations (r_m), mean heritabilities of plot (h^2_m), accuracy of selection (Ac), genetic (CV_g) and residual (CV_e) coefficients of variation and individual repeatability (r) in the dry season for the Trial II and III of forage peanut.

Traits	h^2_g	c^2_m	c^2_p	r_m	h^2_m	Ac	CV_g	CV_e	r
	Trial II								
Pest	-	-	-	-	-	-	-	-	-
Disease	0.17±0.09	0.22*	0.07	0.44	0.49	0.70	17.62	31.84	0.24
Vigor	0.36±0.13*	0.19**	0.05	0.65	0.71	0.84	10.46	11.03	0.41
Flower	-	-	-	-	-	-	-	-	-
GC	0.20±0.09*	0.20**	0.25**	0.50	0.52	0.72	9.85	13.16	0.44
Height	0.39±0.13**	0.04	0.20**	0.91	0.80	0.90	16.66	16.21	0.59
CP	0.54±0.22*	-	-	-	0.86	0.93	7.15	6.55	-
ADF	0.50±0.21*	-	-	-	0.83	0.91	5.20	5.23	-
NDF	0.17±0.12	-	-	-	0.51	0.72	2.45	5.35	-
TDMY	0.40±0.13*	0.13**	0.13**	0.76	0.76	0.87	26.12	23.94	0.53
LDMY	0.35±0.12*	0.12**	0.15**	0.74	0.73	0.85	26.27	27.69	0.50
	Trial III								
Pest	0.08±0.03**	0.08*	0.01	0.52	0.53	0.73	8.62	27.61	0.08
Disease	-	-	-	-	-	-	-	-	-
Vigor	0.08±0.03*	0.23**	0.04	0.25	0.42	0.65	3.65	10.62	0.12
Flower	0.13 ±0.04*	0.57**	0.01	0.19	0.45	0.67	50.66	74.65	0.15
GC	0.15±0.05**	0.22**	0.18**	0.40	0.53	0.73	5.61	9.92	0.32
Height	0.47±0.08**	0.13**	0.05**	0.78	0.78	0.94	16.21	13.89	0.52
CP	0.20±0.06*	0.01	0.01	0.99	0.75	0.87	2.90	5.82	0.20
ADF	0.06±0.03	0.01	0.07	0.95	0.38	0.62	2.14	8.32	0.13
NDF	0.10±0.04*	0.01	0.01	0.99	0.57	0.76	2.03	6.05	0.10
TDMY	0.29±0.06**	0.13**	0.08**	0.70	0.74	0.86	22.77	29.63	0.37
LDMY	0.30±0.08**	0.14**	0.17**	0.69	0.72	0.85	37.05	42.31	0.47

[1]Only one evaluation. * and ** significant at 5 e 1% by deviance analysis based on LRT test, respectively. (-) Values not available for this analysis. Occurrences of Pest and Disease: visual scale of 0 to 10; Vigor: visual scale of 0 to 9; Flower: flowering in scale of 0 to 10; GC: % of ground cover; Height: plant height, cm; CP: crude protein content of aerial biomass, kg ha^{-1}; ADF and NDF: acid and neutral detergent fiber content, kg ha^{-1}; TDMY: total dry matter yield per harvest, kg ha^{-1}; LDMY: leaf dry matter yield per harvest, kg ha^{-1}.

Most traits also presented a decrease in CV_g in the dry season in relation to the rainy season. However, CV_e also increased, indicating more elevate environmental influence, mainly on TDMY and LDMY, which tended to reduce the selection accuracy in this season, except for the nutritive value traits of Trial II. Only the traits vigor, flowering and ADF of Trial III presented Ac values inferior to 70%.

Individual repeatabilities (r) increased in relation to the rainy season in Trial II, except for TDMY and LDMY, still maintaining the low to moderate magnitude level ($0.30 \leq r \leq 0.60$), as a direct consequence of higher heritability and permanent plot effects. On the other side, they decreased in Trial III, except for GC, height, CP and ADF, which suggests that the seasonal environmental effects were more elevated in relation to the genotypic effects and possibly influenced by the incidence of rhizoctoniosis.

The genotypic means (Table 3) were lower in relation to the rainy season analysis, with an increase only in the occurrence of pest and disease in Trial II and III, corroborating the reports of more elevated occurrences in the dry season (MENEZES et al., 2012). Another consequence observed was the reduction in forage production means, marking the typical seasonality of forage species in the tropical regions (SOUZA SOBRINHO et al., 2011). Even for traits with more elevated r_m, the increase in means in the dry season was accentuated for TDMY, LDMY and height, but with low c^2_p

and moderate h^2_g, maintaining the accuracy levels adequate for this stage of the breeding program (above 70%).

The genotypic correlations among forage production traits (TDMY, LDMY, GC and vigor) in the rainy season (Table 5) were positive, highly significant and with a high magnitude (> 0.67). Dry matter yields showed potential for indirect selection by vigor in the Trial I, a non-destructive variable that could facilitate the choice of highly productive genotypes only with visual evaluation. However, this indication did not occur in the other trials, because of the relatively lower correlations observed (below 90%), points the need for further studies in this sense. In Trait III, probably because of the effects of rhizoctoniosis incidence, this correlation was even lower, which could be reinforced by the indirect correlation of dry matter yields with the occurrence of disease which, despite the moderate magnitude, was equally consistent in Trial II.

High correlations additionally allow for a reduction in the number of traits used in genetic divergence studies, decreasing information redundancy (RESENDE, 2002; MENEZES et al., 2012).

In the dry season, correlations among traits of forage production were maintained, reinforcing the possibility of selection, especially because of the vigor that, despite the moderate correlation with TDMY and LDMY, presented consistency in both trials. Height also presented an increased correlation with dry matter production in the dry season, which would facilitate the process of choosing genotypes without the need for harvesting of aerial biomass in the period of more elevated restriction in forage production. However, more studies are required to confirm this hypothesis. Other directly related traits were height and occurrence of disease in the three trials in the rainy season and in Trial III in the dry season, indicating that the canopy height can harbor vectors that harm biomass production regardless of the season of the year. This reinforces the need for more studies about the incidence of pests and diseases for the crop, such as the recent report by Santos (2016). The occurrence of pest still presented a significant moderate correlation with ADF in the rainy season of Trials II and III, probably related to the more elevate vegetative growth of plants in this period.

The nutritive value traits revealed variable correlations among trials, especially with the biomass production traits and flowering, generally of moderate magnitudes. More constant was the direct relationship between fiber contents, even in the dry season, which reinforces the nutritional stability of the species.

In general, the analysis carried out in each season proved to be important in specific cases, such as the study of the natural incidence of pests and diseases, which intensify in the dry season. The analysis by seasons is also relevant for breeding programs aimed at reducing the forage production seasonality since there was no loss of information quality for this set of variables in this season.

Flowering, highly influenced by environmental conditions, was favored in the rainy season, with improved parameters estimated in this period. It is also interesting to emphasize that, despite the low variation, the CP also showed elevated genotypic influence in the dry season, which can be explored in more advanced stages of the species' genetic breeding program.

It is also noted that the interaction with the environment was already observed in the joint analysis for most traits since this type of analysis contains all evaluations over the year (CARVALHO et al., 2009; FERNANDES et al., 2017; MENESES et al., 2012; RESENDE et al., 2008; SANTOS et al., 2016; SIMEÃO et al., 2017). This interaction equally occurred in the season analyses, which of a more specific nature, expected to reveal more homogeneous environmental conditions, with a tendency to reduce the magnitude of the genotype x evaluations interaction. However, the interaction with the environment still revealed a significant effect for several traits, highlighting the importance of analysis by seasons in specific cases.

Table 5 - Genotypic correlations between agronomic and nutritive value traits of forage peanut in the Trial I, II and III, in rainy (below diagonal) and dry (above diagonal) seasons.

Traits	Pest	Disease	Vigor	Flower	GC	Height	CP	ADF	NDF	TDMY	LDMY
						Trial I[1]					
Ps	-	-	-	-	-	-	-	-	-	-	-
Ds	-0.06	-	-	-	-	-	-	-	-	-	-
Vg	-0.05	-0.17	-	-	-	-	-	-	-	-	-
Fw	0.13	0.24	-0.31	-	-	-	-	-	-	-	-
GC	-0.12	0.03	0.91**	-0.24	-	-	-	-	-	-	-
Hg	0.57**	-0.19	0.54*	0.04	0.33	-	-	-	-	-	-
CP	-0.25	-0.26	0.48*	-0.24	0.44*	-0.03	-	-	-	-	-
ADF	0.36	0.05	-0.17	-0.09	-0.31	0.21	-0.25	-	-	-	-
NDF	0.27	-0.09	-0.10	-0.45*	-0.03	-0.03	-0.11	0.51*	-	-	-
TDMY	-0.07	-0.22	0.96**	-0.38	0.84**	0.51*	0.39	-0.13	-0.10	-	-
LDMY	-0.09	-0.27	0.96**	-0.40	0.83**	0.48*	0.47*	-0.17	-0.14	0.98**	-
						Trial II[2]					
	Pest	Disease	Vigor	Flower	GC	Height	CP	ADF	NDF	TDMY	LDMY
Ps	-	-	-	-	-	-	-	-	-	-	-
Ds	0.59**	-	-0.74**	-	-0.81**	0.00	-0.39	-0.08	-0.36	-0.51*	-0,57*
Vg	-0.80**	-0.89**	-	-	0.78**	0.52*	0.20	0.21	0.28	0.89**	0,79**
Fw	0.25	0.50*	-0.46	-	-	-	-	-	-	-	-
GC	-0.43	-0.80**	0.76**	-0.43	-	0.22	0.28	0.26	0.47	0.69**	0,70**
Hg	0.62**	-0.08	-0.12	-0.04	0.32	-	-0.14	0.44	0.20	0.57*	0,42
CP	0.00	-0.12	0.20	0.19	0.15	-0.03	-	0.39	0.42	-0.06	0,07
ADF	0.56*	0.26	-0.23	-0.09	-0.15	0.43	0.24	-	0.55*	0.07	0,05
NDF	-0.01	-0.38	0.39	-0.41	0.34	0.18	0.45	0.54*	-	0.08	0,17
TDMY	-0.30	-0.60**	0.65**	-0.46	0.82**	0.41	0.05	0.11	0.35	-	0,91**
LDMY	-0.26	-0.61**	0.67**	-0.53*	0.84**	0.43	0.16	0.16	0.50*	0.96**	-
						Trial III[3]					
Ps	-	-	-0.33	0.18	-0.16	0.41*	-0.28	0.09	-0.25	0.44**	0,42*
Ds	0.23	-	-	-	-	-	-	-	-	-	-
Vg	-0.63**	-0.78**	-	0.03	0.65**	0.22	0.36*	-0.06	0.02	0.47**	0,49**
Fw	0.17	0.11	-0.17	-	-0.09	0.25	0.16	-0.03	-0.50**	0.38*	0,30
GC	-0.14	-0.66**	0.45**	-0.33	-	-0.09	0.21	-0.02	0.13	0.31	0,29
Hg	0.49**	0.22	-0.36*	0.29	-0.32	-	0.01	-0.31	-0.46**	0.74**	0,74**
CP	-0.05	-0.14	0.24	-0.24	0.22	-0.31	-	0.13	0.20	0.14	0,15
ADF	0.34*	-0.09	-0.11	0.45**	-0.19	0.08	-0.21	-	0.50**	0.05	0,03
NDF	-0.14	-0.25	0.29	-0.22	0.07	-0.58**	0.41*	0.32	-	-0.37*	-0,30
TDMY	0.27	-0.38*	0.16	0.24	0.36*	0.59**	-0.20	0.12	-0.40*	-	0,98**
LDMY	0.07	-0.40*	0.30	0.12	0.40*	0.50*	-0.12	0.01	-0.30	0.92*	-

[1]Trial I: performed between the years of 2006 and 2008; [2]Trial II: performed between the years of 2009 and 2011; [3]Trial III: performed between the years of 2011 and 2013.

* and ** significant by Student t test at 5% e 1%, respectively. (-) Missing values or data. Ps: pest; Ds: disease; Vg: vigor; Flower (Fw): flowering; GC: % of ground cover; Hg: height; CP: crude protein content of aerial biomass; ADF and NDF: acid and neutral detergent fiber content; TDMY: total dry matter yield per harvest; LDMY: leaf dry matter yield per harvest.

In addition, even at a low magnitude, the permanent plot effect tended to be greater in the season analyses, highlighting the specific differences within the trials, especially for the traits vigor, GC and height. This reinforces the effects of environmental and genotypic influences on the complex interactions among genotypes throughout the year.

The climate regime in tropical regions directly affects the phenotypic expression through seasonality, reflecting on the production range (MENEZES et al., 2012; SOUZA SOBRINHO et al., 2011). The performance of genotypes, in turn, is conditioned by their characteristics of potential use and adaptation in each condition and location (FERNANDES et al., 2017; SIMEÃO et al., 2017), justifying more detailed analysis at each season to complement the joint analysis of data. Therein manner, it is significant to point out the presence of variability for aerial biomass production in the dry season, and this should be explored to increase productivity at this time of year through the breeding program.

Conclusion

There is genetic variability among the accessions of the Active Bank of Germplasm of forage peanut for agronomic traits evaluated in the rainy and dry seasons, enabling the selection of genotypes even in the water restriction period. There is a high correlation among agronomic traits, mainly for forage production, even in the dry season. Analyze of specific traits with high seasonality, such as flowering and occurrence of pests and diseases, are best explored with studies in each season.

Conflicts of interest

There were no conflicts of interest for the authors.

Authors' contribution

Daniela Popim Miqueloni – carrying out the work, data analysis, interpretation and writing; Giselle Mariano Lessa de Assis – original idea, orientation, correction and revision; Paulo Marcio Beber – reading and revision.

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