



## Repeatability and phenotypic stabilization of *Panicum maximum* accessions

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**ABSTRACT.** The experiment aimed at determining repeatability coefficients for four methods (analysis of variance, principal components-correlation and covariance matrices and structural analysis), number of harvests necessary to increase accuracy and phenotypic stability of yield characteristics of accessions of *Panicum maximum*. The experiment was conducted in a completely randomized design with 35 genotypes and three replications. Five cuts were made and material was weighed and dried to obtain total, stem, leaf and dead forage dry matter yields. The repeatability coefficients in the different methods, for the evaluated characteristics, ranged from 0.1867 and 0.6583. The estimates of repeatability coefficients obtained for the evaluated characteristics by analysis of variance were generally smaller than the ones obtained with the other methods. By the principal components (based on the covariance matrix), the estimates were usually larger than those for the other methods. Therefore, it is possible to recommend this method to estimate the coefficient of repeatability for traits evaluated in this study. Considering that levels of 80 or 90% of confidence in the evaluation of the relative superiority of the accessions for all the evaluated characteristics are satisfactory, five harvests are sufficient for the choice of the best accession.

**Keywords:** determination coefficients, forages, breeding.

## Repetibilidade e estabilização fenotípica em acessos de *Panicum maximum*

**RESUMO.** O experimento foi conduzido objetivando-se determinar os coeficientes de repetibilidade, por quatro métodos (Análise de Variância, de Componentes principais - matriz de correlação e covariância e a Análise estrutural), o número de cortes necessários para aumento de acurácia e a estabilização fenotípica de características de produção em acessos de *Panicum maximum*. O experimento foi conduzido em delineamento inteiramente casualizado com 35 genótipos e três repetições. Foram realizados cinco cortes e as amostras foram pesadas e secas para obtenção da produção de matéria seca total, de colmo, folhas e material morto. Os coeficientes de repetibilidade nos diferentes métodos, para todas as características, oscilaram entre 0,1867 e 0,6583. As estimativas da repetibilidade obtidas pelo método da análise de variância foram quase sempre menores que as obtidas pelos demais métodos. Pelo método dos componentes principais (baseado na matriz de covariância), as estimativas foram sempre maiores em relação aos demais métodos. Portanto, é possível recomendar esse método para estimativas do coeficiente de repetibilidade para as características avaliadas nesse estudo. Considerando satisfatórios os níveis de 80 ou 90% de confiabilidade para avaliação da superioridade relativa dos acessos para todas as características avaliadas, as cinco medições realizadas são suficientes para escolha do melhor acesso.

**Palavras-chave:** coeficiente de determinação, forrageiras, melhoramento.

### Introduction

For animal production to be economically viable and competitive productivity must be increased and pasture management should be seen as a primary source of increment in profits. However, no management is suitable without the correct choice of the forage. In this context, the producer of the Agreste ecosystem lacks variability of cultivars to

avoid monoculture and increase animal yield. Thus, studies addressing the specific choice of the forage to be used in this region could help producers, since, due to the uneven distribution of rainfall in the region, the options of forage plants for use in animal production systems is scarce. Therefore, there is a need for research on new cultivars that may be used in this region.

During the selection process of new cultivars to be implemented in a specific pastoral ecosystem, it is important to ensure the genetic superiority of the selected cultivar. The analysis of successive measurements of a particular agronomic trait is important in the selection of perennial forage plants, since it is expected that the initial superiority or inferiority of a cultivar, in relation to others, be maintained along the measurements. Thus, the measure of consistency of the position in relation to the classification of individuals during successive measurements of a particular character is called repeatability (Turner & Young, 1969). According to Cruz and Regazzi (1997) repeatability can be defined as the correlation between successive measurements obtained from a same individual, with assessments made over time or space.

In perennial species propagated by apomixes (clonal reproduction), as in the case of *Panicum maximum*, the estimate of the repeatability coefficient indicates the degree of influence of the permanent effects on the phenotypic variation observed and allows the prediction of the performance of individuals (Di Renzo et al., 2000). Furthermore, the repeatability expresses the maximum value that the broad-sense heritability can achieve, since it expresses the proportion of phenotypic variance that is attributable to genetic differences confounded with the permanent effects that act on the cultivar. In this context, the repeatability coefficient will address the heritability coefficient when the variance provided by the permanent effects of the environment is reduced. Therefore, repeatability is an essential tool to guide breeding studies (Cruz & Regazzi, 1997; Shimoya et al., 2002).

When a characteristic presents high repeatability, there is an indication that a small gain in accuracy will be achieved with an increase in the number of repeated measurements. On the other hand, when repeatability is low, a large number of measurements will be required in order to achieve a satisfactory value of determination.

Thus, the aim of this work was to determine the repeatability coefficients for four methods (analysis of variance, principal components-correlation and covariance matrices and structural analysis), the number of harvests needed to increase accuracy and phenotypic stability of yield characteristics in *P. maximum* accessions grown in the Agreste region of the Alagoas State.

## Material and methods

The experiment was conducted in the experimental area of the Federal University of Alagoas / *Campus* Arapiraca, from July 2010 to July 2011. The city of Arapiraca is located in the region of the sub-humid Agreste, where the climate is of the As' type according to Koppen climate classification, with a dry season in summer and rainy fall/winter. The soil of the experimental area, classified as oxisol (red-yellow latosol - (EMBRAPA, 2006) was collected and evaluated for chemical characteristics. Soil samples were collected in the layer 0-20 cm and sent to a specialized laboratory for analysis, which presented the following results: pH (H<sub>2</sub>O) = 5.4; Ca<sup>+2</sup> = 4.7 cmol<sub>c</sub> dm<sup>-3</sup>; Mg<sup>+2</sup> = 2.2 cmol<sub>c</sub> dm<sup>-3</sup>; Al<sup>+3</sup> = 0.0 cmol<sub>c</sub> dm<sup>-3</sup>; H + Al = 4 cmol<sub>c</sub> dm<sup>-3</sup>; SB = 7.23 cmol<sub>c</sub> dm<sup>-3</sup>; CTC = 11.23 cmol<sub>c</sub> dm<sup>-3</sup>; V (%) = 64.4; P = 68 cmol<sub>c</sub> dm<sup>-3</sup> e K<sup>+</sup> = 142 cmol<sub>c</sub> dm<sup>-3</sup>.

The experiment was conducted in a completely randomized design with 35 treatments, characterized by *P. maximum* genotypes PM04, PM10, PM11, PM13, PM14, PM15, PM17, PM18, PM19, PM20, PM21, PM22, PM23, PM25, PM30, PM32, PM33, PM34, PM35, PM36, PM37, PM38, PM39, PM40, PM41, PM43, PM44, PM45, PM46, PM47, PM271 (previously selected by Embrapa Beef Cattle) and cultivars Mombaça, Tazânia, Massai and Milênio, and three replications. The experiment was established in 4 m<sup>2</sup> plots (2 x 2 m), spaced 1 m between plots. The cultivars were sown at a spacing of 10 cm between rows and 5 cm between plants. According to the results of the soil analysis, 20 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> as superphosphate (applied in the row), 100 kg ha<sup>-1</sup> N (urea) and 80 kg ha<sup>-1</sup> K<sub>2</sub>O (KCl) were applied (topdressing) to the soil used in the experiment. Fertilization with nitrogen and potassium was performed after complete establishment of the plants. After the harvests, maintenance fertilization consisted of 50 kg ha<sup>-1</sup> N (urea) and 30 kg ha<sup>-1</sup> K<sub>2</sub>O (KCl).

During the experimental period, five harvests per plot were done, four in the rainy season (July 19, 2010, September 5, 2010, June 3, 2011 and July 7, 2011) and one in the dry season (March 28, 2011). The plants were cut at 20 cm from the soil.

Plant height in the plots was measured with a ruler before the cuts. Immediately after the harvest, the material was weighed to obtain the green matter yield (MV). Samples were separated into leaves, stem plus sheath and dead/senescent material, and taken to an air forced oven at 55°C until achieving constant weight, to estimate total dry matter yield (TDM), stem (SDM) and leaf (LDM) dry matter yields, dead forage dry matter yield (DDM) and leaf percentage (LP).

The repeatability coefficient ( $r$ ) was estimated by four statistical procedures in order to evaluate the consistency of the estimate, allowing more reliable conclusions about the characteristics surveyed. The estimators of the repeatability coefficients were obtained using: method of analysis of variance, principal components method (based on the covariance or correlation matrix) and structural analysis (based on the correlation matrix).

To estimate the repeatability coefficient by the method of analysis of variance (ANOVA), the statistical model with two factors of variation was used:

$$Y_{ij} = \mu + g_i + a_j + e_{ij}$$

in which  $\mu$  = overall mean;  $g_i$  = random effect of the  $i^{\text{th}}$  cultivar under the influence of the permanent environment;  $a_j$  = fixed effect of the temporary environment on the  $j^{\text{th}}$  measure;  $e_{ij}$  = effect of the temporary environment associated to the  $j^{\text{th}}$  measure on the  $i^{\text{th}}$  cultivar.

For this model, the coefficient of repeatability was determined as:

$$r = \frac{\text{cov}(Y_{ij}, Y_{ij'})}{\sqrt{V(Y_{ij}, Y_{ij'})}} = \frac{\hat{\sigma}_g^2}{\hat{\sigma}^2 + \hat{\sigma}_g^2}$$

where  $\hat{\sigma}_g^2$  is the covariance between repeated measurements in each cultivar.

By the method of principal component analysis, the repeatability coefficient based on the correlation matrix and the matrix of phenotypic variances and covariances was estimated. The method of the correlation matrix was proposed by Abeywardena (1972) and is based on the attainment of the matrix of correlations between repeated measurements and subsequent estimation of the eigenvalues and the normalized eigenvectors. Among the estimated eigenvectors those that have the elements with the same sign and close magnitudes are identified, since this is the one that best expresses the tendency of the cultivars to maintain their relative positions in the various periods. The coefficient was estimated by the equation:

$$r = \frac{\hat{\lambda}_1 - 1}{\eta - 1}$$

where  $\hat{\lambda}_1$  is the eigenvalue of the correlation matrix associated to the eigenvector which elements have the same sign and similar magnitude and  $\eta$  is the number of measurements;

By the method based on the phenotypic variance and covariance, the repeatability coefficient was obtained by the equation:

$$r = \hat{\rho} = \frac{\hat{\lambda}_1 - \hat{\sigma}_Y^2}{\hat{\sigma}_Y^2(\eta - 1)}$$

where  $\hat{\lambda}_1$  is the eigenvalue of the phenotypic variance and covariance matrices associated to the eigenvector whose elements have the same sign and similar magnitude,  $\hat{\sigma}_Y^2 = \hat{\sigma}_g^2 + \hat{\sigma}_e^2$  is the variance of the character  $Y$  and  $\eta$  is the number of measures.

The method of the structural analysis based only on the interclass correlation matrix and was estimated by the equation:

$$r = \frac{\hat{\alpha}' R \hat{\alpha} - 1}{\eta - 1}$$

where  $\hat{\alpha}' R \hat{\alpha} = \hat{\lambda}_1$  eigenvalue of the matrix of the intraclass correlations associated to the eigenvector which elements have the same sign and similar magnitude and  $\hat{\alpha}'$  is the eigenvector associated to  $\hat{\lambda}_1$  so that  $\hat{\alpha}' \hat{\alpha} = 1$  and  $\eta$  is the number of measures.

For each characteristic, the minimum number of measurements necessary to achieve efficiency in the selection process ( $\eta_0$ ), based on the pre-determined determination coefficients (80, 85, 90, 95 and 99%) was estimated by:

$$\eta_0 = \frac{R^2(1-r)}{(1-R^2)r}$$

where  $R^2$  = determination coefficients and  $r$  = coefficient of repeatability.

The stability of phenotypic traits was evaluated using the methods of principal components obtained from the intraclass correlation matrix for the successive measurements, considering 2, 3, subsequently, until all  $n$  evaluations were performed. Therefore,  $n-1$  analyses were done on two consecutive measures;  $n-2$  analyses were done on three consecutive evaluations until reaching five measurements (Martuscello et al., 2007).

All analyzes were performed using the GENES software in the Biometrics section (Computational Genetics and Statistics Applicative).

## Results and discussion

The coefficient of repeatability ( $r$ ) observed for the *P. maximum* accessions ranged from 0.1867 to 0.6583 (Table 1). The highest values were recorded for plant

height (principal components method: correlation) and the lowest values for dry matter of dead/senescent forage (method of analysis of variance).

Generally, low repeatability was observed for the characteristic dry matter of dead/senescent forage, irrespective of the method used for estimating the coefficient. This may be explained by the fact that this characteristic presents high variation throughout the year, as reported in other studies (Cano et al., 2004; Martuscello et al., 2006). Furthermore, the low coefficient of repeatability may have occurred due to the higher accumulation of forage dead matter in the dry season, with consequent uneven distribution of that morphological component on the other harvests. Considering the accumulation of dead/senescent forage dry matter an undesirable trait in forage breeding and the low coefficient of repeatability observed for this trait in this study, the prerogative of choosing accessions that accumulate less dead forage dry matter may not be supported by the results obtained here.

The repeatability coefficients for plant height and total, leaf and stem dry matter yields, regardless of the method, may be considered medium to high (Table 1). These characteristics are important in breeding forage plants. Plant height is a characteristic that correlates with biomass yield and could be essential in indicating particular forage to the production system proposed, since shorter plants can be used in production systems with goats and sheep, while those that are taller may be indicated for cattle production. Lédó et al. (2008) observed repeatability coefficients between 0.603 and 0.748 for height of plots established with accessions of *P. maximum* assessed by different estimation methodologies in 15 harvests.

The repeatability coefficient of stem dry matter yield ranged from 0.4458 (method of analysis of variance) to 0.6087 (principal components: covariance; Table 1). Stem accumulation is critical in the choice of the forage since higher values of stem dry matter yield necessarily indicates lower quality forage, considering that, at the level of rumen, stems have lower digestibility than leaves. Forage species that tend to elongate and accumulate

stems throughout the seasons should be considered inadequate in relation to the others, being those with higher yields and repeatability of leaf dry matter yields more indicated. The highest values of repeatability for stem dry matter yield indicate that accessions with higher accumulation of stems tend to exhibit this trait repeatedly, which prevents their choice in relation to the others. Thus, selection based on leaf dry matter yield tends to make the breeding process more efficient, especially in the final stage, where the evaluation of animal weight gain is the main indicator of the potential use of the plant.

Stem accumulation is a characteristic that directly influences the production of total dry matter yield, since all morphological components (leaf blade and stem) are considered. This is because stem elongation favors the exposure of leaf eaves to light, promoting higher accumulation of the total forage. It is observed in Table 1 that the coefficient of repeatability for total dry matter yield ranged from 0.4530 (method of analysis of variance) to 0.5238 (principal component method: covariance), with a coefficient of determination above 80%.

For leaf dry matter yield, the repeatability coefficients ranged from 0.4719 (method of analysis of variance) to 0.5150 (principal component method: covariance) and for percentage of leaves they ranged from 0.3119 (method of structural analysis) to 0.5772 (principal components method: covariance; Table 1). For these characteristics, the values of repeatability indicate reliability in identifying the best accessions, considering the five evaluations used. However, medium magnitude of the repeatability coefficient values of these characteristics may be explained by the variation in climatic conditions over repeated measurements. In this sense, to improve the confidence in the selection of this character, two strategies may be suggested: increasing directly the number of measurements and the use of measurements taken in the rainy and dry seasons as two distinct variables. This approach has been used by some breeders on forage breeding in Brazil (Botrel et al., 2000; Ferreira et al., 1999; Martuscello et al., 2009).

**Table 1.** Estimates of repeatability coefficient and coefficient of determination (in parentheses) of the characteristics plant height (HT), leaf dry matter yield (LDM), stem dry matter yield (SDM), dead/senescent forage dry matter yield (DDM), total dry matter yield (TDM) and percentage of leaves (LP) evaluated by four methods.

	HT	LDM	SDM	DDM	TDM	LP
ANOVA <sup>1</sup>	0.4443(79.99)	0.4719(81.71)	0.4458(80.09)	0.1867(53.44)	0.4530(80.55)	0.3623(73.96)
PCARV	0.5750(87.12)	0.5150(84.15)	0.6087(88.61)	0.4409(79.77)	0.5238(84.61)	0.5752(87.13)
PCCOR <sup>2</sup>	0.6583(90.60)	0.4804(82.22)	0.4771(82.02)	0.2693(64.82)	0.4694(81.56)	0.4230(78.57)
SACOR <sup>4</sup>	0.6417(89.95)	0.4760(81.95)	0.4659(81.35)	0.2557(63.21)	0.4620(81.11)	0.3119(69.38)

<sup>1</sup>analysis of variance; <sup>2</sup>principal components analysis based on the residual variance and covariance matrices; <sup>3</sup>principal components analysis based on the correlation matrix; <sup>4</sup>structural analysis based on the correlation matrix.

Regardless of the method used to estimate the coefficient of repeatability, the coefficients of determination of the evaluated characteristics ranged from 53.44 to 90.60% and may be classified as medium to high (Table 1). Since the coefficient of determination expresses the accuracy in predicting the actual value of the individual, the reliability in the selection of the best accessions of *P. maximum*, based, for example, on the phenotypic value of LDM, will be 84.15% (principal components method: covariance). Thus, five harvests were sufficient to achieve high reliability in predicting the performance of the different accessions.

It was found that the estimates of the repeatability coefficient obtained for the traits evaluated through the analysis of variance, were usually lower than the estimates obtained by the other methods (Table 1). It was also noticed that by the principal components method (based on the covariance matrix) these estimates were usually higher than those obtained for the other methods. Still, for all the evaluated traits, the estimates obtained for the four methods used demonstrated accuracy in the measures done and consistency in the superiority of the individuals. Martuscello et al. (2007) reported the advantages of the principal components method (based on the covariance matrix) to assess repeatability of agronomic characters in *P. maximum*. In addition, Cargnelutti Filho et al. (2004) evaluated *P. maximum* cultivars with and without sunshine restriction, and reported higher repeatability coefficients of yield characteristics when using the principal components method (based on the covariance matrix). According to Martuscello et al. (2007), differences among the estimates of the coefficients of repeatability from the methods used indicate the need for using the various methods available to obtain a precise interval within which, most likely, the actual value for the parameter may be found. Moreover, the identification of the most appropriate methods to evaluate forage traits may also be used as a strategy to improve the estimate of the parameter.

Table 2 shows the simulation of the number of measurements required to obtain different coefficients of determination of the characteristics evaluated in *P. maximum* accessions using the four methods. Note that as the accuracy increases when compared to the prediction of the real value of the evaluations with the methods used the number of measurements for all the characteristics increases considerably.

Data (Table 2) suggests that the attempt to increase accuracy beyond 95% would require a great increase in the number of measurements, which in

turn would add little in terms of precision, thus not justifying its use. With the selection of *P. maximum* hybrids, Resende et al. (2004) obtained an estimate of 80% accuracy for leaf dry matter yield, with four years of harvests, but with low increase in selection efficiency after three years of evaluation (15 harvests). For *Brachiaria brizantha*, Basso et al. (2009) obtained 80% accuracy for this variable with six to 14 harvests, depending on the genotypes evaluated in different locations. Martuscello et al. (2007) in a study with half-sib hybrids of *P. maximum*, reported that the number of harvests needed to characterize dry matter yield with 80% probability of its actual value was a maximum of four (for the method of analysis of variance), and only one and two, for the method of principal components (based on the covariance matrix).

**Table 2.** Number of measurements of agronomic traits in hybrids of *Panicum maximum* in four methods of estimating the coefficient of repeatability.

R <sup>2</sup>	ANOVA <sup>1</sup>	PCCOV <sup>2</sup>	PCCOR <sup>3</sup>	SACOR <sup>4</sup>
Plant height				
0.85	7.1	4.2	2.9	3.2
0.90	11.3	6.7	4.7	5.0
0.95	23.8	14.0	9.9	10.6
0.99	123.8	73.2	51.4	55.3
Leaf dry matter yield				
0.85	6.3	5.3	6.1	6.2
0.90	10.1	8.5	9.7	9.9
0.95	21.3	17.9	20.6	20.9
0.99	110.8	93.2	107.1	109.0
Stem dry matter yield				
0.85	7.0	3.6	6.2	6.5
0.90	11.2	5.8	9.9	10.3
0.95	23.6	12.2	20.8	21.8
0.99	123.1	63.6	108.5	113.5
Dead/senescent forage dry matter yield				
0.85	24.7	7.2	15.4	16.5
0.90	39.2	11.4	24.4	26.2
0.95	82.8	24.1	51.6	55.3
0.99	431.3	125.5	268.6	288.2
Total dry matter yield				
0.85	6.8	5.2	8.7	9.1
0.90	16.4	8.3	13.8	14.4
0.95	34.7	17.5	29.1	30.4
0.99	180.6	90.9	151.6	158.2
Leaf percentage				
0.85	10.0	4.2	7.7	12.5
0.90	15.8	6.6	12.3	19.9
0.95	33.4	14.0	25.9	41.9
0.99	174.3	73.1	135.0	218.4

<sup>1</sup>analysis of variance; <sup>2</sup>principal components analysis based on the residual variance and covariance matrices; <sup>3</sup>principal components analysis based on the correlation matrix; <sup>4</sup>structural analysis based on the correlation matrix.

For total and stem dry matter yields, the coefficient of determination was greater than 80% (Table 1), which indicates the need of only five harvests for selecting the best plants based on these traits. For plant height, five harvests provided 90% efficiency in plant selection (methods of principal

components - structural analysis and correlations). On the other hand, for dead/senescent forage dry matter yield, the five measurements done were not sufficient to achieve 85% efficiency in the selection of the accessions. Accordingly, to achieve such a determination, between 7 and 25 harvests are necessary.

Table 3 presents the results of the phenotypic stability of the characteristics in the five harvests evaluated. Leaf dry matter yield and plant height presented the greatest coefficients of repeatability when harvests one and two were correlated (Table 3). For stem dry matter yield and leaf percentage, the highest repeatability coefficients were observed when harvests four and five were correlated, and, for total dry matter yield, when harvests three and four were correlated. For dead/senescent forage dry matter yield, a low repeatability coefficient was observed independently of the harvest correlations, which indicates non-stabilization of the genotypes for this trait.

**Table 3.** Stability of phenotypic traits in accessions of *Panicum maximum*.

Evaluations	N	Leaf dry matter yield		Plant height	
		r	R <sup>2</sup>	r	R <sup>2</sup>
1-2	2	0.6405	78.08	0.8957	94.50
2-3	2	0.5807	73.47	0.4094	58.10
3-4	2	0.3409	50.84	0.5148	67.97
4-5	2	0.6015	75.12	0.7247	84.04
1-3	3	0.5661	79.65	0.6027	81.99
2-4	3	0.4465	70.76	0.5764	80.32
3-5	3	0.3979	66.47	0.5381	77.75
1-4	4	0.5099	80.62	0.6613	88.65
2-5	4	0.4359	75.56	0.5865	85.02
1-5	5	0.4804	82.22	0.6583	90.60
		Stem dry matter yield		Total dry matter yield	
1-2	2	0.4662	63.59	0.3935	56.47
2-3	2	0.2175	35.72	0.5735	72.89
3-4	2	0.5317	69.43	0.6008	75.06
4-5	2	0.6920	81.80	0.5582	71.64
1-3	3	0.3038	56.70	0.4316	69.49
2-4	3	0.4452	70.65	0.5652	79.59
3-5	3	0.5684	79.80	0.5611	79.32
1-4	4	0.4418	76.00	0.4771	78.49
2-5	4	0.5035	80.22	0.5401	82.45
1-5	5	0.4771	82.02	0.4694	81.56
		Leaf percentage		Dead/senescent forage dry matter yield	
1-2	2	0.5672	72.38	0.2497	39.97
2-3	2	0.0930	17.02	0.6071	75.55
3-4	2	0.0581	10.98	0.0447	8.55
4-5	2	0.7433	85.28	0.4482	61.90
1-3	3	0.2848	54.43	0.4297	69.33
2-4	3	0.2383	48.42	0.3138	57.84
3-5	3	0.3961	66.31	0.2753	53.26
1-4	4	0.3845	71.42	0.2881	61.81
2-5	4	0.3778	70.84	0.2524	57.45
1-5	5	0.4230	78.57	0.2693	64.82

r = coefficient of repeatability.

Independent of the characteristic evaluated and the harvest combination, the correlation of harvest three with the others, tended to decrease the coefficient of repeatability of the characteristics

(Table 3), which may be explained by the season of harvest. The third harvest was performed at the end of the dry season, and it is known that there are changes in the ratio of morphological components of the plant along the seasons. The use of stabilized genotypes when obtaining repeatability estimates is of extreme importance.

There is, in some cases, the possibility of a trait to be governed by different gene sets, and genes are more or less active depending on the state of development of the individuals. In some cases, the inclusion of evaluations in an early stage where there is no expression of the full genetic potential of the plant, or later evaluations, where the forage already presents a certain degree of senescence, the repeatability may be underestimated. Thus, if the measured genotype is not stabilized, the variation within individuals will contain a substantial proportion of the variance of the genotype versus temporary environment interactions, and an increase in the number of measurements in order to reduce the variation within individuals may not be advantageous, since the additional variance may be sufficient to neutralize the reduction of the component.

## Conclusion

For a reliable selection (80% probability) based on total, leaf and stem dry matter yields and plant height of *P. maximum* accessions in the region of the Agreste of Alagoas State, at least five harvests are necessary. Using the principal components (based on the covariance matrix), the estimates were usually larger than those of the other methods. Therefore, it is possible to recommend this method to estimate the coefficient of repeatability for traits evaluated in this study. The inclusion of dry season harvest decreases the estimate of the repeatability coefficient.

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## References

- Abeywardena, V. (1972). An application of principal component analysis in genetics. *Journal of Genetics*, 61(1), 27-51.
- Basso, K. C., Resende, R. M. S., Valle, C. B., Gonçalves, M. C. & Lempp, B. (2009). Avaliação de acessos de *Brachiaria brizantha* Stapf e estimativas de parâmetros genéticos para caracteres agrônômicos. *Acta Scientiarum. Agronomy*, 31(1), 17-22.

- Botrel, M. A., Ferreira, R. P., Cruz, C. D., Pereira, A. V., Viana, M. C. M., Rocha, R. & Miranda, M. (2000). Estimativas de coeficientes de repetibilidade para produção de matéria seca em cultivares de alfafa, sob diferentes ambientes. *Revista Ceres*, 47(274), 651-663.
- Cano, C. C. P., Cecato, U., Canto, M., Rodrigues, A. B., Jobim, C. C., Rodrigues, A. M., Galbeiro, S. & Nascimento, W. (2004). Produção de forragem do capim-tanzânia (*Panicum maximum* Jacq. cv. Tanzânia-1) pastejado em diferentes alturas. *Revista Brasileira de Zootecnia*, 33(6), 1949-1958.
- Cargnelutti Filho, A., Souza Castilhos, Z. M. & Savian, L. S. J. F. (2004). Análise de repetibilidade de caracteres forrageiros de genótipos de *Panicum maximum*, avaliados com e sem restrição solar. *Ciência Rural*, 34(3), 1-8.
- Cruz, C. D. & Regazzi, A. J. (1997). *Modelos biométricos aplicados ao melhoramento genético* (Vol. 2): Ed. UFV.
- Di Renzo, M. A., Ibanez, M. A., Bonamico, N. C. & Poverene, M. M. (2000). Estimation of repeatability and phenotypic correlations in *Eragrostis curvula*. *The Journal of Agricultural Science*, 134(2), 207-212.
- EMBRAPA. (2006). *Sistema brasileiro de classificação de solos* (Vol. 412).
- Ferreira, R. P., Botrel, M. A., Pereira, A. V. & Cruz, C. D. (1999). Avaliação de cultivares de alfafa e estimativas de repetibilidade de caracteres forrageiros. *Pesquisa Agropecuária Brasileira*, 34(6), 995-1002.
- Lédo, F. J. d. S., Pereira, A. V., Souza Sobrinho, F. d., Auad, A. M., Jank, L. & Oliveira, J. S. (2008). Estimativas de repetibilidade para caracteres forrageiros em *Panicum maximum*. *Ciência Agrotecnologia*, 32(4), 1299-1303.
- Martuscello, J. A., Fonseca, D. M. d., Nascimento Júnior, D., Santos, P. M., Cunha, D. & Moreira, L. d. M. (2006). Características morfológicas e estruturais de capim-massai submetido a adubação nitrogenada e desfolhação. *Revista Brasileira de Zootecnia*, 35(3), 665-671.
- Martuscello, J. A., Jank, L., Fonseca, D. M. d., Cruz, C. D. & Cunha, D. d. N. F. V. (2007). Agronomic characters repeatability in *Panicum maximum* Jacq. *Revista Brasileira de Zootecnia*, 36(6), 1975-1981.
- Martuscello, J. A., Jank, L., Fonseca, D. M. d., Cruz, C. D. & Cunha, D. d. N. F. V. (2009). Among and within family selection and combined half-sib family selection in *Panicum maximum* Jacq. *Revista Brasileira de Zootecnia*, 38(10), 1870-1877.
- Resende, R. M. S., Jank, L., Valle, C. B. d. & Bonato, A. L. V. (2004). Biometrical analysis and selection of tetraploid progenies of *Panicum maximum* using mixed model methods. *Pesquisa Agropecuária Brasileira*, 39(4), 335-341.
- Shimoya, A., Pereira, A. V., Ferreira, R. d. P., Cruz, C. D. & Carneiro, P. C. S. (2002). Repetibilidade de características forrageiras do capim-elefante. *Scientia Agricola*, 59(2), 227-234.
- Turner, H. N. & Young, S. S. (1969). *Quantitative genetics in sheep breeding* (Vol. 1). London: Macmillan & Co. Ltd.

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