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Repeatability and number of measurements for productive variables in vegetable crops experiments

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ABSTRACT

One of the ways to optimize the evaluation of the experiment and obtain high precision of the results is with the use of an adequate number of measurements for each variable observed in the experiment. In this sense, the objective of this study was to estimate the repeatability coefficient and the number of measurements necessary for the analysis of characters of production of zucchini, cucumber, pout pepper and pea. In the experiments carried out with zucchini and cucumber the variables number of fruits, fruit mass, fruit length, largest fruit diameter and smallest fruit diameter were evaluated. For pea the number, length and mass of pods, number and mass of grains per pod and for pout pepper number and mass of fruits, largest fruit diameter and length were evaluated. The repeatability coefficient (r) was estimated by the principal component method using the correlation matrix and the covariance matrix. The number of measurements for each variable was also determined based on the coefficients of determination of 0.80, 0.85, 0.90, 0.95 and 1.00. The estimated repeatability coefficient obtained the highest estimates using the covariance matrix, ranging from 0.67 to 0.84 for zucchini, from 0.66 to 0.97 for cucumber, from 0.47 to 0.70 for pea and from 0.57 to 0.71 for pout pepper. To evaluate the fruit mass in zucchini, cucumber, pea and pout pepper, are exactly, respectively, 7, 4, 8 and 8 measurements for a coefficient of determination of 95%.

Keywords: *Capsicum chinense*, *Cucumis sativus*, *Cucurbita pepo*, *Pisum sativum*, variability, experimental precision.

RESUMO

Repetibilidade e número de mensurações para caracteres produtivos em experimentos com olerícolas

Uma das formas de otimizar a avaliação do experimento e obter elevada precisão dos resultados é com o uso de quantidade adequada de mensurações para cada variável observada no experimento. Neste sentido, o objetivo deste estudo foi estimar coeficiente de repetibilidade e o número de mensurações necessárias para análise de caracteres de produção de abobrinha, pepino, pimenta biquinho e ervilha. Os experimentos foram realizados no Departamento de Fitotecnia da Universidade Federal de Santa Maria. Para abobrinha e pepino avaliaram-se as variáveis número, massa e comprimento de frutos, maior e menor diâmetro dos frutos. Para ervilha avaliou-se o número, massa e comprimento de vagens, número e massa de grãos, e para pimenta biquinho avaliou-se número, massa, maior diâmetro e o comprimento dos frutos. O coeficiente de repetibilidade (r) foi estimado pelo método dos componentes principais usando a matriz de correlação e a matriz de covariâncias. Determinou-se ainda, o número de mensurações para cada variável com base nos coeficientes de determinação de 0.80, 0.85, 0.90, 0.95 e 1.00. O coeficiente de repetibilidade estimado obteve as maiores estimativas com o uso da matriz de covariâncias, variando de 0,67 a 0,84 para abobrinha, de 0,66 a 0,97 para pepino, de 0,47 a 0,70 para ervilha e de 0,57 a 0,71 para pimenta biquinho. Para avaliar a massa de frutos em abobrinha, pepino, ervilha e pimenta biquinho, são necessárias, respectivamente 7, 4, 8 e 8 mensurações para um coeficiente de determinação de 95%.

Palavras-chave: *Cucurbita pepo*, *Cucumis sativus*, *Capsicum chinese*, *Pisum sativum*, variabilidade, precisão experimental.

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Vegetables in general have multiple benefits that help human health in preventing diseases (Canella *et al.*, 2018), in addition to contributing to the generation of employment and income around the world. Given the vast economic and social importance conferred by vegetable industries, the need for research in the most diverse areas is essential, aiming at increasing productivity and product quality.

Generally, when conducting experiments, it seeks to measure as many variables as possible to try to identify and elucidate the influence and response of plants about the evaluated treatments. This condition requires therefore high demand for labor, laboratory materials, and time, and result in a high number of measurements. This could be minimized by using a smaller number of measurements during the evaluation of variables, ensuring the same reliability and accuracy of the data and the results (Diel *et al.*, 2020a).

One way to optimize the evaluation of the experiment and reducing experimental variability to obtain high accuracy of the results is through the use of adequate measurements for each variable observed in the experiment. In this sense, the repeatability coefficient is a statistical method used in genetic improvement to measure the expression of a specific treatment over time (Cruz *et al.*, 2012). The repeatability coefficient of each variable makes it possible to estimate the number of measurements of this variable. Thus, there are the possibility of not wasting time, labor, and financial resources necessary to better discriminate the effects of different treatments under evaluation (Della Bruna *et al.*, 2012; Diel *et al.*, 2020a).

The repeatability coefficient (r) can be estimated by several methodologies, including structural analysis, determined based on the theoretical eigenvalue of the correlation matrix, principal components obtained from correlation or covariance matrices, and the method based on the analysis of variance (Cruz *et al.*, 2012), and these present differences in the results. Diel *et al.* (2020a), studying the repeatability for strawberry variables, indicated that the r-values were better estimated by the principal component analysis method, being the most efficient one that uses the covariance matrix.

Some studies have estimated the plot size and the number of replications for the cultures of *Cucumis sativus* (Lúcio *et al.*, 2020), *Cucurbita pepo* (Santos *et al.*, 2014), and *Pisum sativum spp. arvense* (Cargnelutti Filho *et al.*, 2015). However, it is important to estimate the repeatability coefficient and the number of measurements required for high experimental precision in these cultures, a fact that has not yet been studied. Given the above, the present work aims to estimate the repeatability coefficient and the number of measurements necessary to collect observations of production variables in experiments with zucchini (*Cucurbita pepo*), cucumber (*Cucumis sativus*), pout pepper (*Capsicum chinense*) and pea (*Pisum sativum*).

MATERIAL AND METHODS

Site description

The experiments were conducted in the experimental area of the Crop Science Department at Federal University of Santa Maria (29°42’23”S; 53°43’15”W, 95 m altitude). The climate of this region is the Cfa type, according to the Köppen’s classification (Alvares *et al.*, 2013). The soil in the experimental area is classified as Typic Hapludalf (Streck *et al.*, 2008).

The soil preparation of the experimental area, in all experiments, was carried out with the rotary hoe and the basic fertilization for each of the crops according to soil analysis (CQFS, 2016). The other cultural managements were carried out according to recommendations for each studied species and by good agricultural practices.

Experimental design of zucchini

The experiments were conducted in the years 2018 and 2019. Sowing was held on September 26, 2018 for the spring-summer season (S/S) and February 2, 2019 for the summer-autumn season (S/A), in 128 cell trays containing Carolina® substrate. The seedling transplantation was carried out in beds on October 24, 2018 for S/S and March 10, 2019 for S/A (28 and 19 days after sowing, respectively), with 0.70 m spacing between plants.

A randomized block design with eight replications and plots composed of seven plants was used, which were composed of three treatments, being evaluated the genotypes: Caserta, PX13067051, and Tronco.

The plants were individually tutored and irrigation was performed by drip according to crop necessity. The harvests were carried out in all plants of the plot, 25 days after the transplant, being repeated every three days. The fruit size for the harvest was standardized at 15 cm in average. The evaluated variables were the number of fruits per plant (NF), fruit mass (FM, g), fruit length (FL, cm), the largest fruit diameter (LFD, cm) and the smallest fruit diameter (SDF, cm), measured in all fruits harvested in the experiment.

Experimental design of pout pepper

The experiment was conducted in 2019/2020. Sowing was carried out on August 28, 2019 and transplanted in beds on November 8, 2019, with spacing between plants of 0.7 m and 1 m between beds.

A randomized blocks design with eight replications was used, which were composed of five treatments, being evaluated the genotypes: Airetama, BRS Moema, Iracema, Guadalajara, and Bico. Each experimental unit was composed of six plants.

Irrigation was carried out by drip according to the needs of the crop. The harvests were started on January 13, 2020, 66 days after the transplant in all plants in the plot, being repeated every four days. The evaluated variables were number of fruits per plant (NF), fruit mass (FM, g), fruit diameter (FD, cm), and fruit length (FL, cm). For the variables, FD and FL, five fruits from each plant were sampled and later represented by the average due to the high number of fruits produced per plant.

Experimental design of pea

The uniformity test was conducted in the field in 2016, without the use of irrigation. The used cultivar was Ervilha Grão 40; it was implemented on March 5, 2016 in four beds with two rows of cultivation and 0.45 m spacing between plants and 0.80 m between rows. Each row was composed of 30 pits, containing four plants per pit and each one was considered a basic unit (BU).

The pods were harvested in all BUs when they had a light green color. After collected, they were packed in identified plastic bags and sent to the laboratory for counting and weighing on a digital scale. Five BUs of each row were randomly obtained to measure the number of pods per plant (NP, un.), the mass of pods (MP, g), pod length (PL, cm), the number of grains per pod (NGP, un.) and mass of grains per pod (MGP, g). For the variables MGP, MP, and PL, 5 plants were sampled randomly from each row for measurements, and then the mean values were calculated.

Experimental design of cucumber

The experiment was conducted in 2019 in a randomized block design with six replications and four plants per plot. The treatments consisted of three cultivars: Atlântico, Caipira, and Fuyu. Sowing was carried out in trays on January 4, 2019 using the substrate Carolina®. The seedlings were transplanted into beds on January 28, 2019 spaced 0.80 m between plants and between beds.

The plants were tutored individually, the beds were covered with mulching plastic-type and irrigation was performed by drip hoses. The evaluated variables were the number of fruits per plant (NF), fruit mass (FM, g), fruit length (FL, cm), the largest fruit diameter (LFD, cm) and the smallest fruit diameter (SFD, cm), measured in all fruits harvested in the experiment.

Estimation of repeatability coefficients

The repeatability coefficient (r) was estimated using two methodologies. The first method was that of principal components analysis using the correlation matrix (PCAcor), which consists of obtaining a correlation matrix between the genotypes in each measurement pair, determining the eigenvalues and normalized eigenvectors.

$$r = \frac{\lambda_k}{\sum_j \lambda_j} (j = 1, 2, ..., \eta)$$

where η is the number of periods evaluated and λ_k is the eigenvalue associated with the eigenvector, whose elements have the same sign and similar magnitudes (Cruz *et al.*, 2012). The second method used was the principal component analysis using the covariance matrix (PCAcov), which is an alternative technique that can be applied in the phenotypic covariance matrix, as follows:

$$\Gamma = \sigma_y^2 \begin{bmatrix} 1 & \rho & \dots & \rho \\ \rho & 1 & \dots & \rho \\ \rho & \dots & \dots & \dots \\ \rho & \rho & \dots & 1 \end{bmatrix}$$

where

$$V(y_{ij}) = V(y_{ij'}) = \sigma^2 + \sigma^2_g = \sigma^2_y$$

and

$$Cov(y_{ij}, y_{ij'}) = (\sigma_g^2 + \sigma^2)\rho = \rho\sigma_y^2.$$

The first eigenvalue is given by

$$\lambda_1 = \sigma_y^2 [1 + (\eta - 1)\rho]$$

thus, the coefficient repeatability is given by

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

being $\hat{\lambda}_y$ the eigenvalue $\hat{\Gamma}$ associated with the eigenvector whose elements have the same sign and similar magnitudes.

Number of measurements

For all estimates, the determination coefficient (R^2) and the minimum number of measurements (η_m) necessary to predict the real genotypic value associated with preset R^2 magnitudes were estimated.

The determination coefficient was estimated based on the averages of the measurements and in the estimation of the repeatability coefficient (r), according to the following expression

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

The minimum number of measurements was estimated by the expression

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

based on the preset determination coefficients of 0.80, 0.85, 0.90, 0.95, and 1.0.

All analyzes were performed using the Genes and R statistical software, using the ggplot2 package (R Development Core Team, 2019).

RESULTS AND DISCUSSION

The coefficients of determination (R^2) estimates were above 0.90, independent of the adopted estimation repeatability coefficient, except for pea in the method of adopting correlation matrix (PCAcor). This condition shows the high capacity of the methods to predict the treatment characteristic except for pea, where for the variables number of pods, mass of pods, and number of grains per plant, they presented low values of R^2 (0.4924, 0.5251 and 0.6356 respectively), estimated by the PCAcor method. However, using the PCAcov estimation method, high values of the coefficient of determination and repeatability are observed (Table 1).

The repeatability coefficient increased in all variables when the estimation method used was PCAcov. When using this way, the coefficient of determination also increased for all variables and species evaluated, indicating its greater precision about PCAcor (Table 1).

The lower the repeatability coefficient (r), the greater the number of measurements needed to be made to achieve the required level of precision, that is, more measurements must be done for a given genotype to express its full potential. With this increase in the number of measurements, there will be greater demands on time, labor, and financial resources to experiment. In this idea, one should choose the estimation method that presents the highest "r" and, consequently, the lowest number of measurements. Thus, the number of measurements to evaluate the production variables of the studied species were lower for the PCAcov than for the PCAcor method (Table 1), and you should choose to use one of them.

For pea, the lowest repeatability coefficient was found for the variable number of pods (NP), estimated by the PCAcor method (r = 0.24). This result increases the number of measurements so that the results of the experiment are more accurate.

The repeatability coefficient is widely used in the area of genetic improvement to predict results and select higher genotypes (Cruz *et al.*, 2012). In this sense, several studies have already been carried out, such as Dutra Filho *et al.* (2020) who used repeatability analysis methods for the selection of *Saccharum officinarum* genotypes, with greater longevity in the stalks. Azevedo *et al.* (2020) estimated the repeatability coefficients for the number of chestnut fruits and determined the appropriate number of measurements necessary for an efficient selection of promising chestnut trees (*Bertholletia excelsa*). Diel *et al.* (2020a) estimated the repeatability coefficient and the number of measurements required for

Table 1. Repeatability coefficients (r) and coefficient of determination (R^2) estimated by the principal component analysis methods based on the correlation matrix (PCAcor) and the covariance matrix (PCAcov) for production variables of different vegetable crop species. Santa Maria, UFSM, 2021.

Variables	PCAcor		PCAcov	
	r	R²	*r*	R²
Zucchini S/S[1]				
Number of fruits	0.62	0.96	0.68	0.97
Fruit mass	0.61	0.96	0.77	0.98
Fruit length	0.71	0.98	0.84	0.99
Largest fruit diameter	0.61	0.96	0.67	0.97
Smallest fruit diameter	0.61	0.96	0.67	0.97
Zucchini S/A[1]				
Number of fruits	0.74	0.99	0.76	0.99
Fruit mass	0.67	0.98	0.73	0.98
Fruit length	0.72	0.98	0.84	0.99
Largest fruit diameter	0.68	0.98	0.82	0.99
Smallest fruit diameter	0.68	0.98	0.79	0.99
Cucumber				
Number of fruits	0.65	0.95	0.66	0.95
Fruit mass	0.69	0.96	0.82	0.98
Fruit length	0.84	0.98	0.97	0.99
Largest fruit diameter	0.63	0.95	0.76	0.97
Smallest fruit diameter	0.63	0.95	0.79	0.98
Pea				
Number of pods	0.24	0.49	0.54	0.78
Mass of pods	0.27	0.53	0.70	0.88
Pod length	0.67	0.91	0.68	0.92
Number of grains	0.26	0.64	0.47	0.82
Mass of grains per pod	0.52	0.84	0.62	0.89
Pout pepper				
Number of fruits	0.52	0.94	0.72	0.98
Fruit mass	0.48	0.93	0.71	0.97
Fruit diameter	0.59	0.96	0.68	0.97
Fruit length	0.56	0.95	0.57	0.95

[1] S/S: Spring/Summer growing season; S/A: Summer/Autumn growing season.

character evaluation in the culture of *Fragaria x ananassa*, when grown on substrates. However, there are still few studies in the literature that provide this information on the number of measurements needed to evaluate variables in experiments with vegetable crops from multiple harvests with adequate experimental precision and accuracy.

Resende (2002) proposes the following classification for the repeatability coefficient: high repeatability ($r \geq 0.60$), medium repeatability ($0.30 < r < 0.60$), and low repeatability ($r \leq 0.30$). In the present work, the results of the repeatability coefficient can be considered high, except for the experiment with pea by the PCAcor method, which should be considered average.

The number of measurements required for evaluation (η_m) of agricultural experiments with the species analyzed in this study, based on the coefficient of determination (R^2) shows differences between the PCAcor and PCAcov methods. For the PCAcov method, the η_m needed to evaluate the experiments were lower about PCAcor in all situations (Table 1). The greater the precision of the results sought by the researcher, the greater the number of measurements required. When seeking to obtain 100% accuracy of the results of the experiment, the number of measurements required is high and practically impossible to carry out in practice, due to the time, the human and financial resources they demand, which might make the execution of the experiment unfeasible.

For the S/S season in the experiment with zucchini the η_m required for the evaluation of FL, LFD, SDF, FM, and NF variables are, respectively, approximately 4, 9, 9, 6, and 9 measurements by the PCAcov method. By the PCAcor method, approximately 8, 12, 12, 12, and 12 measurements are required, respectively, both estimated from R^2 of 0.95 (Figure 1).

For the S/A season in the experiment with zucchini the η_m required to obtain 95% confidence level was 4, 4, 5, 7, and 6 measurements for the evaluation of the FL, LFD, SFD, FM, and NF variables by the PCAcov method, while for PCAcor method the number of measurements required was 7, 9, 9, 9 and 7, respectively (Figure 2).

For cucumber, with a 95% confidence level, the η_m necessity to evaluate the variables FL, LFD, SFD, FM, and NF was 1, 6, 5, 4 and 10 measurements respectively by the PCAcov and 4, 11 method, 11, 8 and 10 measurements, respectively, for the same variables, using the PCAcor method (Figure 3).

In the culture of pea, due to the low values of the repeatability coefficient, the values η_m were higher when compared with the other evaluated species. We observed that by the PCAcov method, the number of measurements necessary to assess PL, MGP, MP, NGP, and NP, with 95% confidence, is 8, 12, 8, 21, and 15 respectively. As for the PCAcor method, the η_m increases it even more for the same variables, as 9, 17, 51, 54, and 58 measurements are required, respectively, with 95% confidence, making the experiment unfeasible if the researcher chooses the 100% confidence level (Figure 4).

For pout pepper, using the PCAcov method, the ηm evaluation of FL, FD, FM, and NF variables is 14, 9, 8, and 7, respectively. However, considering the estimated by PCAcor there increases considerably, mainly for the variables FD, FM, and NF, being necessary 15, 13, 20, and 17 measurements for these variables FL, FD, FM, and NF respectively (Figure 5).

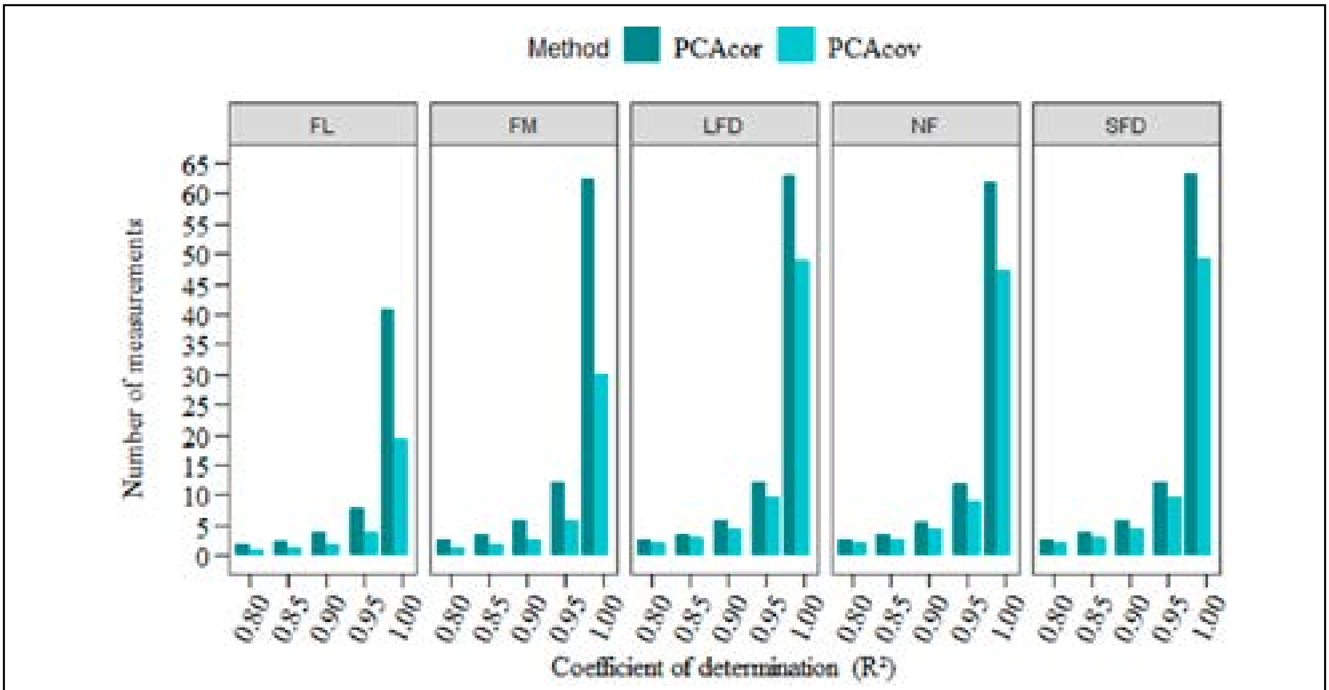

Figure 1. Number of measurements required for different coefficients of determination (R^2) estimated by the methods of principal component analysis based on the correlation matrix (PCAcor) and the covariance matrix (PCAcov) for the variables fruit length (FL, cm), largest fruit diameter (LDF, cm), smallest fruit diameter (SDF, cm), fruit mass (FM, g/plant) and the number of fruits (NF, un.) in zucchini in spring-summer season. Santa Maria, UFSM, 2021.

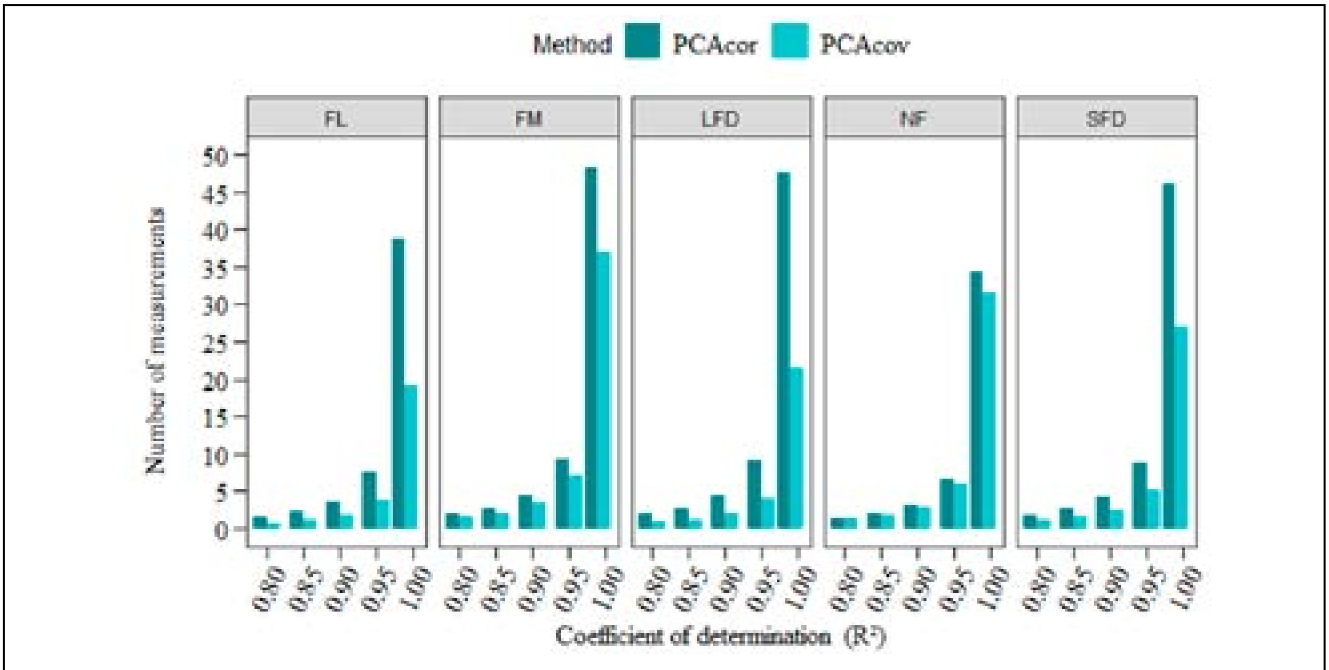

Figure 2. Number of measurements required for different coefficients of determination (R^2) estimated by methods of principal component analysis based on the correlation matrix (PCAcor) and the covariance matrix (PCAcov) for the variables fruit length (FL, cm), largest fruit diameter (LFD, cm), smallest fruit diameter (SFD, cm), fruit mass (FM, g/plant) and the number of fruits (NF) in zucchini in summer-autumn season. Santa Maria, UFSM, 2021.

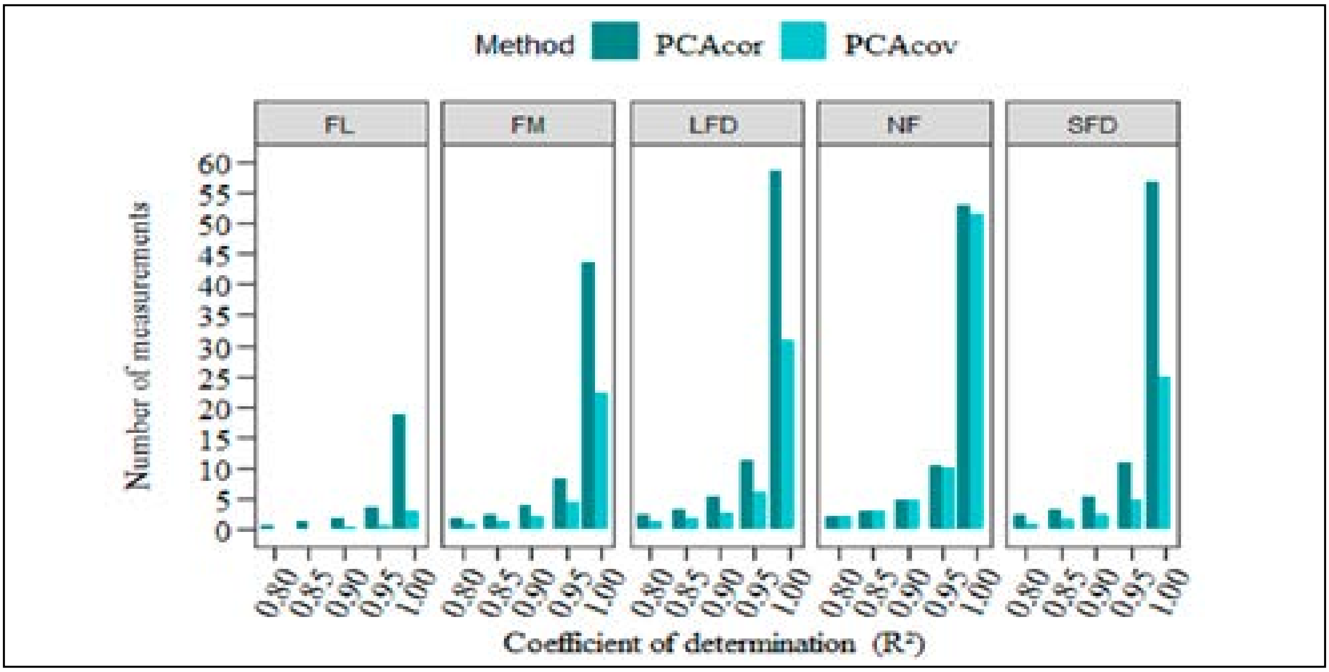

Figure 3. Number of measurements required for different coefficients of determination (R^2) estimated by the methods of principal component analysis based on the correlation matrix (PCAcor) and the covariance matrix (PCAcov) for the variables fruit length (FL, cm), largest fruit diameter (LFD, cm), smallest fruit diameter (SFD, cm), fruit mass (FM, g/plant) and the number of fruits (NF) in cucumber. Santa Maria, UFSM, 2021.

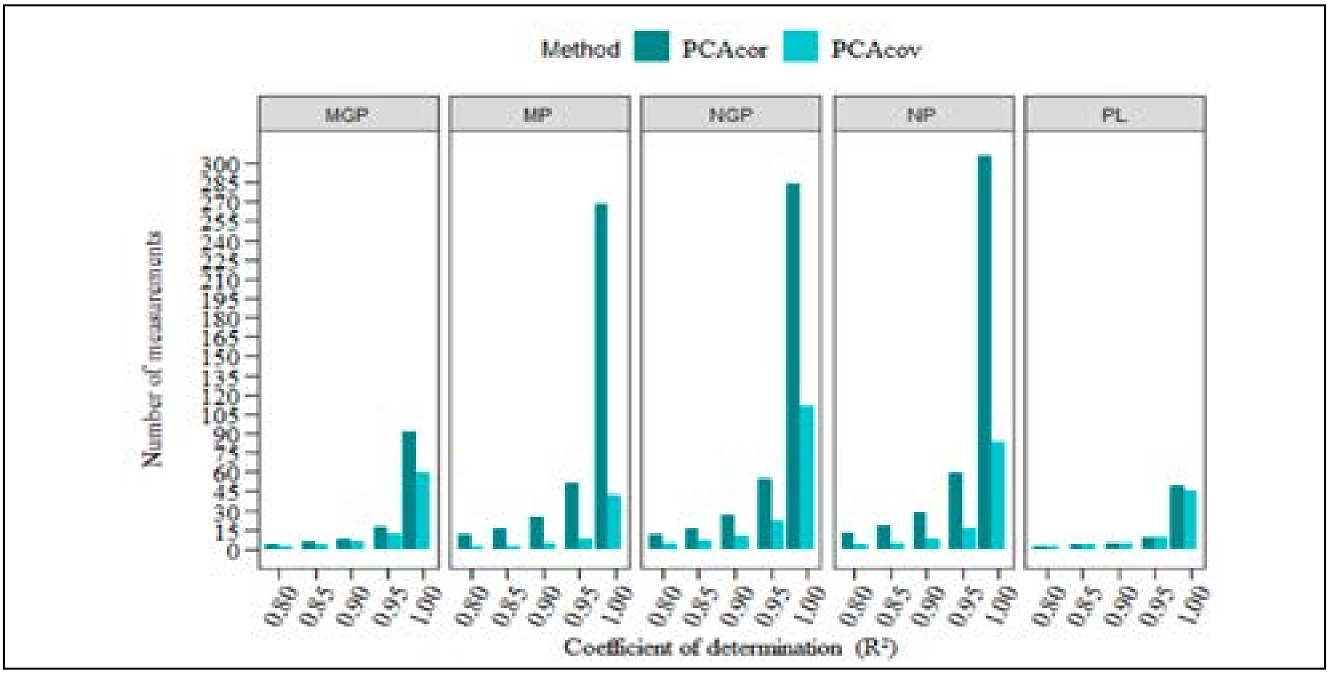

Figure 4. Number of measurements required for different coefficients of determination (R^2) estimated by the methods of principal component analysis based on the correlation matrix (PCAcor) and the covariance matrix (PCAcov) for the variables pod length (PL, cm), mass of grains per pod (MGP, g), mass of pods (MP, g), number of grains per pod (NGP) and number of pods (NP) in pea. Santa Maria, UFSM, 2021.

According to Cruz *et al.* (2014), the higher the repeatability coefficient, the smaller the number of measurements needed to predict the real value of individuals. On the other hand, when the repeatability coefficient is low, it indicates that a large number of measurements is needed to predict the real effect of treatments (Della Bruna *et al.*, 2012).

According to Manfio *et al.* (2011), the use of the principal component method allows isolating the effect of the alternation, which is not possible in the analysis of variance, where this component is included in the experimental error. Cruz *et al.* (2014) mention that, when the estimated

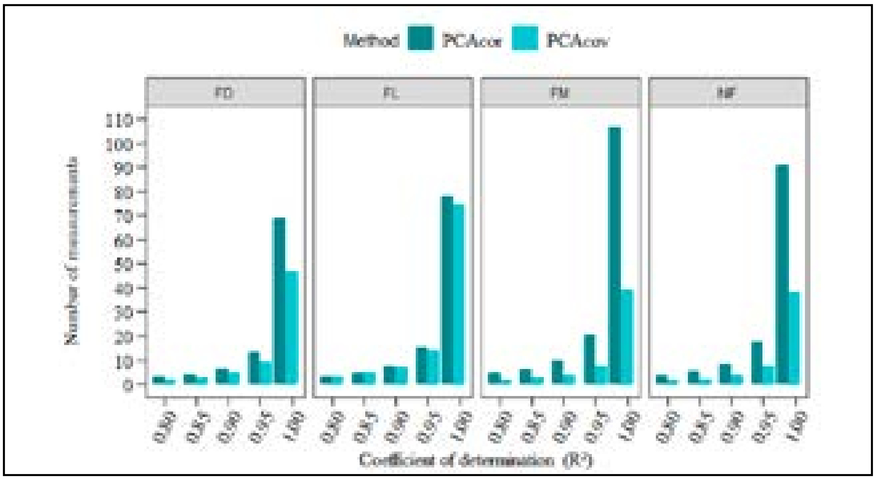

Figure 5. Number of measurements required for different coefficients of determination (R^2) estimated by the methods of principal component analysis based on the correlation matrix (PCAcor) and the covariance matrix (PCAcov) for the variables fruit length (FL, cm), fruit diameter (FD, cm), fruit mass (FM, g/plant) and the number of fruits (NF) in pout pepper. Santa Maria, UFSM, 2021.

repeatability coefficient values are low, the difference between the results obtained by the different methods increases, as occurred with pea in this study.

The more uniform the experiments and the less variability there is in the cultivation site, the smaller the number of measurements required. Thus, the occurrence of a high number of measurements and a low coefficient of repeatability for pea, may be directly related to experimental variability. This high variability can be generated by the occurrence of insect pest attack, disease occurrence, competition with weeds, heterogeneity of soil fertility, uneven irrigation, plant damage in the experiment by intensive management, or even the presence of null values in the database, common in multiple harvest crops (Carpes *et al.*, 2010; Lúcio & Benz, 2017; Krysczun *et al.*, 2018; Lúcio *et al.*, 2020). In the present work, the experiment with pea, the presence of the fungus *Fusarium oxysporum* f. sp. *pisi* was detected through laboratory analysis, and the high humidity of the experimental area in a good part of the crop cycle, which according to Muniz *et al.* (2018) is a favorable environment for the development of diseases which influences directly the yield and quality of pea grains. These factors caused high variability in the experiment.

The use and indication of the number of measurements for variables in different cultures are important from the point of view of rationing resources, mainly labor in evaluations of agricultural experiments. Diel *et al.* (2020a) emphasized that, if the objective of the study is to differentiate cultivars, a smaller number of measurements can be performed. The same does not happen if the total fruit production in the cycle is to be determined, being important that the researcher previously determines his objectives before the beginning of the evaluations of the variables.

The number of measurements made by each researcher is distinct in different agricultural species. Pagoto *et al.* (2020), evaluating the efficiency of different forms of pollination for zucchini with or without fertilization with boron, when harvesting the fruits selected the commercial quality ones, and measured the diameter, length, and average mass of the fruits. According to the present study, these measures could have been carried out only four times for the diameter of the fruit, and nine times for the length and mass of the fruit, reducing the time, labor, and financial resources used in the evaluations.

For the culture of pout pepper, Diel *et al.* (2020b) evaluated the production of two cultivars in different growing seasons. The authors carried out 16 harvests for the first growing season, 12 harvests for the second growing season, and only six harvests for the third growing season, as this showed the death of plants due to frost. As the author's objective was to indicate which cultivar is most productive and which is the time of best production, the measurements of the first and second seasons would already be more than necessary proposed by the present study (eight measurements for FM by the PCAcov method). In compensation, for the third season evaluated by the authors, the measures taken would not be enough for the treatments to show their full potential since only six harvests were carried out.

For the culture of pea, Zárate *et al.* (2012) carried out experiments with different treatments between plant spacing and ground cover with poultry litter, which consisted of evaluating the fresh and dry mass of pods, grains, number of pods, length, width and thickness of the pods. Based on the results of the present study, so that researchers could find significant differences between their treatments with precision and reliability of the results, they should perform 8, 12, 8, and 15 measurements, respectively, to assess PL, MGP, MP, and NP.

Sediyama *et al.* (2014) studied the types of pruning in cucumber, from the Aodai, Japonês, and Caipira groups, which underwent 12 harvests to detect differences in productivity between hybrids and choose the most productive in the different treatments. However, according to the present study, the researchers could have performed only eight harvests for FM to obtain differences between their treatments, thus reducing 33% of the number of evaluations performed.

These are some examples of experiments where the number of measurements is not previously considered before the beginning of the evaluations of the variables, further evidencing the importance of research to estimate the number of adequate measurements for each species and observed variables.

For vegetable crops with multiple

harvests or when more than one measurement of a given character is needed in the same individual, these questions must be taken into account, allowing the researcher to promote studies with the greatest precision and in some cases, reduce the time, labor and waste of financial resources to carry out the evaluations of the variables in the experiment.

The repeatability coefficient estimated by the PCAcov method obtained the highest estimates for experiments with zucchini, cucumber, pout pepper and pea.

For the experiment with zucchini, in the S/S season, 4, 9, 9, 6, and 9 measurements are required and 4, 4, 5, 7, and 6 measurements in the S/A season to evaluate the variables FL, LFD, SFD, FM, and NF, respectively. For experiments with cucumber, the η_m necessity to evaluate the variables FL, LFD, SFD, FM, and NF is 1, 6, 5, 4, and 10 measurements, respectively.

For pea, 8, 12, 8, 21, and 15 measurements are needed to evaluate the PL, MGP, MP, NGP, and NP, respectively, and in experiments with pout pepper, the η_m necessity to evaluate the variables FL, FD, FM, and NF is 14, 9, 8 and 7, respectively.

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REFERENCES

ALVARES, CA; STAPE, JL; SENTELHAS, PC; GONÇALVES, JLM; SPAROVEK, G. 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22: 711-728.

AZEVEDO, VR; WADT, LHO; PEDROZO, CA; RESENDE, MDV. 2020. Coeficiente de repetibilidade para produção de frutos e seleção de matrizes de *Bertholletia excelsa* (Bonpl.) em castanhais nativos do estado do Acre. *Ciência Florestal* 30: 135.

CANELLA, DS; LOUZADA, MLDC; CLARO, RM; COSTA, JC; BANDONI, DH; LEVY, RB; MARTINS, APB. 2018. Consumo de hortaliças e sua relação com os alimentos ultraprocessados no Brasil. *Revista Saude Publica* 52: 50-61.

CARGNELUTTI FILHO, A; ALVES, BM; BURIN, C; KLEINPAUL, JA; NEU, IMM; SILVEIRA, DL; SIMÕES, FM; SPANHOLI, R; MEDEIROS, LB. 2015. Tamanho de parcela e número de repetições em ervilha forrageira. *Ciência Rural* 45: 1174-1182.

CARPES, RH; LÚCIO, AD; LOPES, SJ; BENZ, V; HAESBAERT, F; SANTOS, D. 2010. Variabilidade produtiva e agrupamentos de colheitas de abobrinha italiana cultivada em ambiente protegido. *Ciência Rural* 40: 294-301.

CQFS - COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO, 2016. *Manual de calagem e adubação para os Estados de Rio Grande do Sul e de Santa Catarina.* Sociedade Brasileira de Ciência do Solo, Viçosa.

CRUZ, CD; CARNEIRO, PCS; REGAZZI, AJ. 2014. *Modelos biométricos aplicados ao melhoramento genético*, 3ª. ed. Viçosa: Editora Viçosa. 668p.

CRUZ, CD; REGAZZI, AJ; CARNEIRO, PCS. 2012. *Modelos biométricos aplicados ao melhoramento genético*, 4th ed. Editora UFV, Viçosa: Editora Viçosa. 514p.

DELLA BRUNA, E; MORETO, AL; DALBÓ, MA. 2012. Uso do coeficiente de repetibilidade na seleção de clones de pessegueiro para o litoral sul de Santa Catarina. *Revista Brasileira de Fruticultura* 34: 206-215.

DIEL, MI; LÚCIO, AD; OLIVOTO, T; PINHEIRO, MVM; KRYSCZUN, DK; SARI, BG; SCHMIDT, D. 2020a. Repeatability coefficients and number of measurements for evaluating traits in strawberry. *Acta Scientiarum. Agronomy* 42: 1-9.

DIEL, MI; LÚCIO, AD; VALERA, OVS; SARI, BG; OLIVOTO, T; PINHEIRO, MVM; MELO, PJ; TARTAGLIA, FL; SCHMIDT, D. 2020b. Production of biquinho pepper in different growing seasons characterized by the logistic model and its critical points. *Ciência Rural* 50: 1-11.

DUTRA FILHO, JA; CALSA JÚNIOR, T; SIMÕES NETO, DE; SOUTO, LS; LUNA, RG; SOUZA, AS. 2020. Eficiência de métodos de repetibilidade nas fases finais do melhoramento genético da cana-de-açúcar. *Research, Society and Development* 9: 9.

KRYSCZUN, DK; LÚCIO, ADC; SARI, BG; DIEL, MI; OLIVOTO, T; SANTANA, CS; UBESSI, C; SCHABARUM, DE. 2018. Sample size, plot size and number of replications for trials with *Solanum melongena* L. *Scientia Horticulture* 233: 220-224.

LÚCIO, AD; BENZ, V. 2017. Accuracy in the estimates of zucchini production related to the plot size and number of harvests. *Ciência Rural* 47: 54-61.

LÚCIO, AD; LAMBRECHT, DM; SARI, BG; KRYSCZUN, DK; UBESSI, C. 2020. Experimental planning for conducting experiments with cucumber. *Horticultura Brasileira* 38: 112-116.

MANFIO, CE; MOTOIKE, SY; SANTOS, CEM; PIMENTEL, LD; QUEIROZ, V; SATO, AY. 2011. Repetibilidade em características biométricas do fruto de macaúba. *Ciência Rural* 41: 70-76.

MUNIZ, PHPC; PEIXOTO, GHS; MARQUES, MG; TEIXEIRA, MPM; RODRIGUES, F; CARVALHO, DDC. 2018. Análise cienciométrica das principais doenças da ervilha. *Revista Biotecnologia & Ciência* 7: 1-7.

PAGOTO, SN; LAUDETE, AA; NEVES, GJ; DEGASPARI, LA; ARAUJO, LM; ANDRADE, FR. 2020. Pollination techniques in zucchini production in the presence of boron fertilization. *Comunicata Scientiae*. 11: 1-5.

R DEVELOPMENT CORE TEAM, 2019. R: *A language and environment for statistical computing.* R Foundation for Statistical Computing version 3.5.3 (software).

RESENDE, MDV. 2002. *Genética biométrica e estatística no melhoramento de plantas perenes.* Brasília: Embrapa Informação Tecnológica. 975p.

SANTOS, D; LÚCIO, ADC; FILHO, AC; STORCK, L; LORENTZ, LH; SCHABARUM, DE. 2014. Efeito de vizinhança e tamanho de parcela em experimentos com culturas olerícolas de múltiplas colheitas. *Pesquisa Agropecuaria Brasileira* 49: 257-264.

SEDIYAMA, MA; NASCIMENTO, JL; LOPES, IP; LIMA, PC; VIDIGAL, SM. 2014. Tipos de poda em pepino dos grupos aodai, japonês e caipira. *Horticultura Brasileira* 32: 491-496.

STRECK, EV; KÄMPF, N; DALMOLIN, RSD; KLAMT, E; NASCIMENTO, PC; SCHNEIDER, P; GIASSON, E; PINTO, LFS. 2008. *Solos do Rio Grande do Sul*, 2nd ed. 222p.

ZÁRATE, NAH; GASSI, RP; VIEIRA, MC; TABALDI, LA; TORALES, EP; FACCIN, FC. 2012. Espaçamentos entre plantas e cobertura do solo com cama-de-frango na produção de ervilhas. *Bragantia* 71: 43-46.