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Optimal plot size for cabbage experiments

Tamanho ideal de parcela para experimentos de repolho

Tamaño de parcela óptimo para experimentos con repollo

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Vinicius de Freitas Mateus
ORCID: https://orcid.org/0000-0003-1962-3550
Federal Institute of Education Science and Technology of Espírito Santo, Brazil
E-mail: viniciusfreitas20@yahoo.com.br
Gisele Rodriguês Moreira
ORCID: https://orcid.org/0000-0001-9442-7504
University Federal of Espírito Santo, Brazil
E-mail: gisele.moreira@ufes.br
Mario Euclides Pechara da Costa Jaeggi
ORCID: https://orcid.org/0000-0002-2984-2995
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: mariopechara@hotmail.com
Richardson Sales Rocha
ORCID: https://orcid.org/0000-0003-2814-0091
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: richardson_sales@hotmail.com
Rita de Kássia Guarnier da Silva
ORCID: https://orcid.org/0000-0001-5927-9980X
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: kassiaguarnier@gmail.com
Israel Martins Pereira
ORCID: https://orcid.org/0000-0002-3713-4796
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: israelmartins80@gmail.com
Tâmara Rebecca Albuquerque de Oliveira
ORCID: https://orcid.org/0000-0002-3713-4796
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: tamara_rebecca@hotmail.com

Derivaldo Pureza da Cruz

ORCID: https://orcid.org/0000-0003-2042-0697

State University of North Fluminense Darcy Ribeiro, Brazil

E-mail: deri.engineer@gmail.com

Thiago Blunck Rezende Moreira

ORCID: https://orcid.org/0000-0001-9591-0987

Federal Institute of Education Science and Technology of Espírito Santo, Brazil

E-mail: tbrmoreira@hotmail.com

Wagner Bastos dos Santos Oliveira

ORCID: https://orcid.org/0000-0002-5384-9636

University Federal of Espírito Santo, Brazil

E-mail: wagnerbastos@yahoo.com

Jaídson Gonçalves da Rocha

ORCID: https://orcid.org/0000-0002-9933-526

State University of North Fluminense Darcy Ribeiro, Brazil

E-mail: jaidsongr@yahoo.com.br

Edevaldo de Castro Monteiro

ORCID: https://orcid.org/ 0000-0002-5091-1449

University Federal Rural of Rio de Janeiro, Brazil

E-mail: ecmonteiro@hotmail.com

Alexandre Gomes de Souza

ORCID: https://orcid.org/0000-0001-7528-179X

State University of North Fluminense Darcy Ribeiro, Brazil

E-mail: alexander.souza.agronomo@gmail.com

Camila Queiroz da Silva Sanfim de Sant'Anna

ORCID: https://orcid.org/0000-0003-2430-1740

State University of North Fluminense Darcy Ribeiro, Brazil

E-mail: agro.camilaqs@gmail.com

Geraldo de Amaral Gravina

ORCID: https://orcid.org/0000-0002-1044-5041

State University of North Fluminense Darcy Ribeiro, Brazil

E-mail: gravina@uenf.br

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Rogério Figueiredo Daher
ORCID: https://orcid.org/0000-0002-4218-8828
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: rogdaher@uenf.br
Rogério Rangel Rodrigues
ORCID: https://orcid.org/0000-0001-8589-0740
University Federal of Lavras, Brazil
E-mail: rogeriorr7@hotmail.com
Magno do Carmo Parajara
ORCID: https://orcid.org/0000-0001-6266-883X
University Federal of Viçosa, Brazil
E-mail: magnocp1@hotmail.com
Josimar Nogueira Batista
ORCID: https://orcid.org/0000-0001-5129-7092
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: josimarbatista.agro@gmail.com
Samyra de Araújo Capetini
ORCID: https://orcid.org/0000-0001-8084-207X
State University of North Fluminense Darcy Ribeiro, Brazil
E-mail: samyracapetini@gmail.com

Abstract

Among the factors that influence the detection of minimum significant differences between treatments in conventional experiments is the size of the plot, whose correct determination allows the reduction of experimental error, consequently, increases the precision of the experiment and the reliability of the interpretations and conclusions obtained. There are different methods to estimate the optimal plot size, which relate plot size and residual variation, highlighting among these the methods of maximum curvature, maximum modified curvature, maximum curvature of the coefficient of variation and regression with plateau response. In addition to these, there is the Hatheway method that takes into account factors such as number of treatments, repetitions and levels of significance. Since there is little work to estimate the optimal plot size in experiments with species of the genus Brassica, the present study aimed to increase the experimental precision in experiments with cabbage in the municipality of Alegre - ES by determining the optimal plot size with based on Hatheway's methods, maximum curvature, maximum curvature of the coefficient of variation and plateau regression. The work was carried out by means of a blank test carried out in the experimental area of the Center for Agricultural Sciences of the Federal University of Espírito Santo, Alegre - ES, in which both productive and growth variables were evaluated. At the end of the project, propose the optimal plot size to be used in experiments with cabbage in order to increase the experimental precision and the reliability of the results obtained in future experiments.

Keywords: Brassica oleracea L. var. capitata L.; Experimental planning; Hatheway; Maximum curvature; Maximum curvature of the coefficient of variation; Plateau regression.

Resumo

Entre os fatores que influenciam na detecção de diferenças mínimas significativas entre tratamentos em experimentos convencionais está o tamanho da parcela, cuja correta determinação permite a redução do erro experimental, consequentemente, aumenta a precisão do experimento e a confiabilidade das interpretações e conclusões obtidas. Existem diferentes métodos para estimar o tamanho ótimo de parcela, que relacionam tamanho de parcela e variação residual, destacando-se entre eles os métodos de curvatura máxima, curvatura máxima modificada, curvatura máxima do coeficiente de variação e regressão com resposta de platô. Além desses, existe o método de Hatheway que leva em consideração fatores como número de tratamentos, repetições e níveis de significância. Como há poucos trabalhos para estimar o tamanho ótimo de parcela em experimentos com espécies do gênero Brassica, o presente estudo teve como objetivo aumentar a precisão experimental em experimentos com repolho no município de Alegre - ES por meio da determinação do tamanho ótimo de parcela com base em Hatheway's. métodos, curvatura máxima, curvatura máxima do coeficiente de variação e regressão de platô. O trabalho foi realizado por meio de um teste em branco realizado na área experimental do Centro de Ciências Agrárias da Universidade Federal do Espírito Santo, Alegre - ES, no qual foram avaliadas as variáveis produtivas e de crescimento. Ao final do projeto, propor o tamanho ótimo de parcela a ser utilizado em experimentos com repolho, a fim de aumentar a precisão experimental e a confiabilidade dos resultados obtidos em experimentos futuros.

Palavras-chave: Brassica oleracea L. var. capitata L.; Planejamento experimental; Hatheway; Curvatura máxima; Curvatura máxima do coeficiente de variação; Regressão de platô.

Resumen

Entre los factores que influyen en la detección de diferencias mínimas significativas entre tratamientos en experimentos convencionales se encuentra el tamaño de la parcela, cuya correcta determinación permite la reducción del error experimental, en consecuencia, aumenta la precisión del experimento y la confiabilidad de las interpretaciones y conclusiones obtenidas. Existen diferentes métodos para estimar el tamaño óptimo de parcela, que relacionan tamaño de parcela y variación residual, destacando entre estos los métodos de máxima curvatura, máxima curvatura modificada, máxima curvatura del coeficiente de variación y regresión con respuesta meseta. Además de estos, existe el método de Hatheway que toma en cuenta factores como número de tratamientos, repeticiones y niveles de significancia. Dado que hay poco trabajo para estimar el tamaño óptimo de parcela en experimentos con especies del género Brassica, el presente estudio tuvo como objetivo aumentar la precisión experimental en experimentos con repollo en el municipio de Alegre - ES mediante la determinación del tamaño óptimo de parcela con base en el estudio de Hatheway. métodos, máxima curvatura, máxima curvatura del coeficiente de variación y regresión meseta. El trabajo se realizó mediante una prueba en blanco realizada en el área experimental del Centro de Ciencias Agropecuarias de la Universidad Federal de Espírito Santo, Alegre - ES, en la que se evaluaron tanto variables productivas como de crecimiento. Al final del proyecto, proponer el tamaño de parcela óptimo para ser utilizado en experimentos con repollo con el fin de aumentar la precisión experimental y la confiabilidad de los resultados obtenidos en experimentos futuros.

Palabras clave: Brassica oleracea L. var. capitata L.; Planificación experimental; Hatheway; Curvatura máxima; Curvatura máxima del coeficiente de variación; Regresión meseta.

1. Introduction

Among the most consumed vegetables in Brazil, brassicas are one of the most consumed, only behind Solanaceae, such as potatoes and tomatoes. In Europe, Portugal and Spain have the highest per capita consumption. In Brazil, the preference for these vegetables is not different, with cabbage (Brassica oleracea L. var. Capitata L.) being the most consumed brassica. Obtaining new information in various areas of study, including agronomy, is often obtained by conducting scientific experiments. In planning and carrying out these, several factors such as the size and shape of the plot, the number of repetitions, the experimental design, among others, directly influence the variability inherent in the experiment. This variability interferes with the results of the statistical analysis of the data, inflating the estimate of the experimental error, and consequently leading the researcher to interpretations and conclusions with low precision and experimental reliability.

Regarding the plot, there is no single size defined for all the experiments, but rather an optimal size, which is affected by several factors, such as soil characteristics and climatic conditions (Oliveira & Steffanel, 1995).

Different methods have been used to obtain the optimal plot size in different crops, such as tomatoes (Lúcio et al., 2012), sweet pepper (Lúcio et al., 2003), zucchini (Lúcio et al., 2008), radish (Silva et al., ., 2008). ., 2012) green beans (Haesbaert et al., 2011), wheat (Henriques Neto et al., 2009), cassava (Paranaíbaet al., 2009a; Paranaíba et al., 2009b). Guarçoni et al. (2017) studied the optimal plot size of experimental cabbage for characteristics of mass, diameter and compactness. The linear response regression method was 16, 7 and 5 plants per plot, respectively, for characteristics of mass, diameter and compactness. . Since the linear response regression method was adequate to determine the optimal size of experimental plots for the three characteristics studied.

The objective of this work is to determine the optimal plot size using the Hatheway method, modified maximum curvature, maximum curvature of the coefficient of variation and plateau regression and to compare the methods and recommend the optimal plot size in future experiments with cabbage.

2. Materials and Methods

A blank test was carried out with the cabbage crop in the experimental area of the Center for Agricultural Sciences of the Federal University of Espírito Santo (CCAUFES), Alegre - ES.

The plants used in the experiment were obtained by seeds, being the transplant to the field, as well as the sowing time, the cultivation treatments and the control of pests and diseases carried out according to what is recommended for the crop.

On August 1, 2013, cabbage seeds were sown in the Green Valley cultivar. At 18 days, the seedlings were transplanted to the field in the experimental area. The spacing used was 0.3 m between each other and 0.6 between lines, totaling 10 lines each with 24 plants. On September 11, 2013, straw was placed on the cultivation line to control weeds and improve the soil moisture condition, and the next day fertilization with 20-00-20 fertilizer (10 g / plant) was carried out. On October 9, 2013, an insecticide was applied to control pests, and on

October 21, 2012, weeding and a second fertilization with 20-00-20 fertilizer (10g / plant) were carried out. Before harvest, the rainy season (December / 2013) impaired head formation for data collection, which resulted in the decision to redo the experiment, with the sowing carried out in 128-cell Styrofoam trays in February 2014, and due to the malformation of the seedling, the sowing was carried out again in April 2014.

In transplantation, the plants were arranged in six rows of 5.0 m in length, 0.6 m and 0.3 m spaced between plants, using the five central lines as useful, from which the two plants at each end will be discarded. The basic units (SU) will be formed by each plant of the cultivation lines, excluding the first and last plants. The number of SUs per plot will be simulated based on multiples of the number of plants in each crop line.

In August 2014, data was collected on the following characteristics: cycle: represented by the period between sowing and harvesting the cabbage. The harvest took place when more than 80% of the plants in the plot had a compact head and the outer edge of the cabbage leaf began to detach, expressed in days; number of leaves: after harvesting the heads, the number of leaves of the plant was counted and the average was obtained, expressed in leaves / plant; Leaf area: determined on the day of harvest, passing the leaves of the plants in an electronic leaf area meter, expressed in cm2 / plant; Leaf area index: obtained by the relationship between the leaf area of a plant and the area available for the plant; dry mass of leaves external to the head: after harvesting the heads, the leaves were evaluated and the foliar area was washed and packed in paper bags, dried in an oven with air circulation, at 65ºC, until reaching constant masses and heavy, expressed in g / plant; mass of fresh ears: after harvesting, the ears of the useful area of the plot were weighed individually and the average value was obtained, expressed in grams; cabbage head diameters: the longitudinal (DL) and transverse (DT) diameters of the heads of the useful area of the plot were evaluated. The measurements were made with the help of a ruler and the value expressed in centimeters; heart length (WC): measurement of a head of the useful area of the plot with the help of a caliper, expressed in centimeters; CC / DL ratio: expresses the relationship between the length of the heart in relation to the longitudinal diameter of the head; Cabbage shape index: is the ratio of the longitudinal diameter to the transverse diameter; Productivity: obtained by adding the mass of cabbage produced by all the plants harvested in the useful area of the plot and expressed in kg / m2. As análises estatísticas para a estimação do tamanho ótimo de parcela, ainda em análise, são:

Method described by Hatheway (1961), cited by Oliveira et al. (2011), by the expression:

$$X_0 = \left\{ \frac{[2CV^2(t_1 + t_2)^2]}{(rd^2)} \right\}^{\frac{1}{b}}$$

Where, is the optimal size of the plot; b is the soil heterogeneity index; d is the minimum significant difference to be detected between the means of treatments I (% of the mean); r is the number of repetitions to detect differences of d%; CV is the estimate of the coefficient of variation for the plots composed of a SU (%); t_1 is the tabulated value of the t distribution at the level of significance α1 and degree of freedom gl = (I – 1) (r – 1) for random block design; t_2 is the tabulated value of the t distribution at the significance level α2 = 2(1 – p) e gl = (I – 1) (r – 1), where p corresponds to the probability of obtaining significant results.

Modified maximum curvature method, described by Lessman and Atkins (1963) and adapted by Meier and Lessman (1971), cited by Silva et al. (2012), the point where the curvature is maximum in the curve that relates the coefficient of variation with the size of the plot with X basic units will be determined algebraically. This relationship will be estimated according to the model $Y_i = a / X^b + \varepsilon_i$, where Y represents the variability index and X corresponds to the size of the plot in basic units.

The minimum plot size limit (X_0), which consists of the abscissa value corresponding to the point of maximum curvature, will be estimated by the expression:

$$X_0 = \left\{ \frac{a^2 b^2 (2b+1)}{(b+2)} \right\}^{\frac{1}{(2b+2)}}$$

In which, a and b are the model parameters corresponding to the regression constant and the regression coefficient, respectively.

Maximum curvature of the coefficient of variation (CM) method proposed by Paranaíba et al. (2009b) the size of the plot will be estimated using the following expression:

$$\hat{X}_0 = \frac{10\sqrt[3]{2(1-\hat{p}^2)S^2\bar{Z}}}{\bar{Z}}$$

In which, S^2 is the sample variance, $\overline{Z}$ is the sample mean and $\hat{p}$ is the first-order spatial autocorrelation coefficient estimated by $\hat{p} = \frac{\sum_{i=1}^{rc}(\hat{\varepsilon}_i - \overline{\varepsilon})(\hat{\varepsilon}_{i-1})}{\sum_{i=1}^{rc}(\hat{\varepsilon}_i - \overline{\varepsilon})}$. In which, $\hat{\varepsilon}$ is the experimental error associated with the observation $Z_i(Y_i)$.

The plateau regression method will be used, the linear model and the quadratic model (Silva et al., 2012). In the segmented linear response model method, the model consists of two segments; the first describes a decreasing line up to a certain constant P, which is the plateau, and the second refers to the plateau, which after a certain value of the coefficient of variation (CV) assumes a constant value. The model considered will be the one shown below:

$$CV(X_i) = \begin{cases} \beta_0 + \beta_1 X_i + \varepsilon_i, \text{se } \mathrm{X}_1 < \mathrm{X}_0 \\ p + \varepsilon_i, \text{se } \mathrm{X}_1 > \mathrm{X}_0 \end{cases}$$

The method of the segmented quadratic response model will be defined by:

$$CV(X_i) = \begin{cases} \beta_0 + \beta_1 X_i + \beta_1 X_i^2 + \varepsilon_i, \text{se } \mathrm{X}_1 < \mathrm{X}_0 \\ p + \varepsilon_i, \text{se } \mathrm{X}_1 > \mathrm{X}_0 \end{cases}$$

All simulations and calculations are being carried out on EXCEL spreadsheets (Microsoft Office 2007), except those referring to the plateau regression method, which will be carried out with the help of the statistical application SAEG (Universidade Federal de Viçosa - UFV, version 2013).

3. Results and Discussion

Tables 1, 2, 3, 4, 5, 6, 7, 8 and 9 present the convenient sizes of the experimental parchment plots, using the method of Hatheway (1961).

Table 1. Convenient sizes of experimental cabbage plot for Foliar Area in aviation carried out with 80% of closed heads.

			FOLIAR AREA (AF)								
			Xc (UB)								
Evaluation	DMS	Bloks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
	5%	4	106	71	63	59	57	56	55	55	54
	10%	4	29	19	17	16	16	15	15	15	15
CV% = 20,42	15%	4	13	9	8	8	7	7	7	7	7
	20%	4	8	5	5	4	4	4	4	4	4
	5%	5	70	54	48	46	45	44	44	44	43
	10%	5	19	15	13	13	12	12	12	12	12
	15%	5	9	7	6	6	6	6	6	6	6
	20%	5	5	4	4	3	3	3	3	3	3
	5%	6	52	42	39	38	37	37	37	36	36
b = 1,06479	10%	6	14	11	11	10	10	10	10	10	10
	15%	6	7	5	5	5	5	5	5	5	5
	20%	6	4	3	3	3	3	3	3	3	3
	5%	7	42	35	33	32	32	32	31	31	31
	10%	7	11	10	9	9	9	9	9	8	8
	15%	7	5	4	4	4	4	4	4	4	4
	20%	7	3	3	2	2	2	2	2	2	2
	5%	8	35	30	29	28	28	28	28	27	27
	10%	8	10	8	8	8	8	8	7	7	7
	15%	8	4	4	4	4	4	4	3	3	3
	20%	8	3	2	2	2	2	2	2	2	2

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For variable leaf area (FA) (Table 1), with 4 blocks, 10% DMS, between 5 and 10 treatments, feasible plots of 15 to 16 plants were obtained. Source: Authors.

Table 2. Convenient experimental plot sizes for cabbage for the length of the heart being evaluated with 80% of the heads closed.

			HEART LENGTH (HL)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
CV% = 18,82	5%	4	119	77	68	64	62	61	60	59	58
	10%	4	30	19	17	16	16	15	15	15	15
	15%	4	13	9	8	7	7	7	7	7	7
	20%	4	8	5	4	4	4	4	4	4	4
	5%	5	76	58	51	49	48	47	46	47	46
	10%	5	19	15	13	12	12	12	12	12	12
	15%	5	9	6	6	6	5	5	5	5	5
	20%	5	5	4	3	3	3	3	3	3	3
	5%	6	56	44	41	40	39	39	39	38	38
b = 1,00473	10%	6	14	11	10	10	10	10	10	10	10
	15%	6	6	5	5	5	4	4	4	4	4
	20%	6	4	3	3	3	2	2	2	2	2
	5%	7	44	37	35	34	33	33	33	33	32
	10%	7	11	9	9	8	8	8	8	8	8
	15%	7	5	4	4	4	4	4	4	4	4
	20%	7	3	2	2	2	2	2	2	2	2
	5%	8	37	31	30	29	29	29	29	28	28
	10%	8	9	8	8	7	7	7	7	7	7
	15%	8	4	4	3	3	3	3	3	3	3
	20%	8	2	2	1	2	2	2	2	2	2

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For the variable heart length (CC) (Table 2), with 4 blocks, 10% DMS, between 5 and 10 treatments, the number of practicable plots with a range of 15 to 16 plants was obtained, repeating the behavior of the variable previous. Source: Authors.

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Table 3. Convenient experimental plot sizes for cabbage for Longitudinal Diameter in an evaluation carried out with 80% of the heads closed.

			LONGITUDINAL DIAMETER (DL)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
CV% = 8,94	5%	4	91	50	42	39	37	36	35	34	34
	10%	4	14	8	6	6	6	5	5	5	5
	15%	4	5	3	2	2	2	2	2	2	2
	20%	4	2	1	1	1	1	1	1	1	1
	5%	5	49	34	29	27	26	25	25	25	25
	10%	5	7	5	4	4	4	4	4	4	4
	15%	5	2	2	1	1	1	1	1	1	1
	20%	5	1	1	1	1	1	1	1	1	1
b = 0,73558	5%	6	32	23	21	20	20	20	19	19	19
	10%	6	5	4	3	3	3	3	3	3	3
	15%	6	2	1	1	1	1	1	1	1	1
	20%	6	1	1	0	0	0	0	0	0	0
	5%	7	23	18	17	16	16	16	15	15	15
	10%	7	4	3	3	2	2	2	2	2	2
	15%	7	1	1	1	1	1	1	1	1	1
	20%	7	1	0	0	0	0	0	0	0	0
	5%	8	18	15	14	13	13	13	13	13	13
	10%	8	3	2	2	2	2	2	2	2	2
	15%	8	1	1	1	1	1	1	1	1	1
	20%	8	0	0	0	0	0	0	0	0	0

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For variable longitudinal diameter (DL) (Table 3), with 4 blocks, 10% DMS and with a variation of 4 to 10 treatments, practical plots of 5 to 6 plants were obtained. Source: Authors.

Table 4. uitable sizes of experimental plot for cabbage for Transverse diameter in evaluation carried out with 80% of the heads closed.

			TRANSVERSE DIAMETER (CT)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
CV% = 10,26	5%	4	97	56	48	44	42	41	40	39	39
	10%	4	17	10	8	7	7	7	7	7	7
	15%	4	6	3	3	3	3	2	2	2	2
	20%	4	3	2	1	1	1	1	1	1	1
	5%	5	55	39	33	31	30	30	29	29	29
	10%	5	9	7	6	5	5	5	5	5	5
	15%	5	3	2	2	2	2	2	2	2	2
	20%	5	2	1	1	1	1	1	1	1	1
b = 0,78482	5%	6	37	27	25	24	23	23	23	23	23
	10%	6	6	5	4	4	4	4	4	4	4
	15%	6	2	2	2	1	1	1	1	1	1
	20%	6	1	1	1	1	1	1	1	1	1
	5%	7	27	22	20	19	19	19	19	18	18
	10%	7	5	4	3	3	3	3	3	3	3
	15%	7	2	1	1	1	1	1	1	1	1
	20%	7	1	1	1	1	1	1	1	1	1
	5%	8	22	18	17	16	16	16	16	15	15
	10%	8	4	3	3	3	3	3	3	3	3
	15%	8	1	1	1	1	1	1	1	1	1
	20%	8	1	1	0	0	0	0	0	0	0

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For variable transverse diameter (DT) (Table 4), 10% DMS, 4 blocks and with a variation between 5 and 10 treatments, a practicable portion of 7 plants was obtained. Source: Authors.

Table 5. Convenient experimental plot sizes for cabbage for Number of leaves outside the head in an evaluation carried out with 80% of the heads closed.

			N ° OF EXTERNAL BLADES TO HEAD (NFEC)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
	5%	4	4	125	77	67	62	60	58	57	56
	10%	4	4	26	16	14	13	12	12	12	12
CV% = 14,34	15%	4	4	10	6	6	5	5	5	5	5
	20%	4	4	5	3	3	3	3	3	2	2
	5%	5	75	56	48	46	45	44	43	43	43
	10%	5	16	12	10	10	9	9	9	9	9
	15%	5	6	4	4	4	4	4	4	4	4
	20%	5	3	2	2	2	2	2	2	2	2
	5%	6	6	53	41	38	36	35	35	35	34
b = 0,88168	10%	6	6	11	8	8	8	7	7	7	7
	15%	6	6	4	3	3	3	3	3	3	3
	20%	6	6	2	2	2	2	2	2	1	1
	5%	7	41	33	31	30	29	29	29	29	28
	10%	7	8	7	6	6	6	6	6	6	6
	15%	7	3	3	3	2	2	2	2	2	2
	20%	7	2	1	1	1	1	1	1	1	1
	5%	8	33	27	26	25	25	25	25	24	24
	10%	8	7	6	5	5	5	5	5	5	5
	15%	8	3	2	2	2	2	2	2	2	2
	20%	8	1	1	1	1	1	1	1	1	1

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For the variable number of external leaves on the head (NFEC) (Table 5), with 10% DMS, 4 blocks and number of treatments ranging from 6 to 10, it was possible to obtain practicable plots of 12 plants. Source: Authors.

Table 6. Convenient Cabbage Experimental Plot Sizes for Head Weight in an Evaluation Conducted with 80% of Head Closed.

			HEAD WEIGHT (PC)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
CV% = 24,64	5%	4	114	78	70	66	64	63	62	61	60
	10%	4	33	23	20	19	19	18	18	18	18
	15%	4	16	11	10	9	9	9	9	9	9
	20%	4	10	7	6	6	5	5	5	5	5
	5%	5	77	60	54	52	51	50	49	49	49
	10%	5	22	18	16	15	15	15	14	14	14
	15%	5	11	8	8	7	7	7	7	7	7
	20%	5	7	5	5	4	4	4	4	4	4
	5%	6	58	47	45	43	42	42	42	41	41
b = 1,12761	10%	6	17	14	13	13	12	12	12	12	12
	15%	6	8	7	6	6	6	6	6	6	6
	20%	6	5	4	4	4	4	4	4	4	4
	5%	7	47	40	38	37	37	36	36	36	36
	10%	7	14	12	11	11	11	11	11	11	10
	15%	7	7	6	5	5	5	5	5	5	5
	20%	7	4	3	3	3	3	3	3	3	3
	5%	8	40	35	33	33	32	32	32	32	32
	10%	8	12	10	10	10	9	9	9	9	9
	15%	8	6	5	5	5	5	5	5	5	5
	20%	8	3	3	2	3	3	3	3	3	3

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For variable head weight (BW) (Table 6), with 15% DMS, blocks ranging from 4 to 8, number of treatments from 4 to 10, it was possible to obtain practicable plots of 5 to 10 plants. Source: Authors.

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Table 7. Suitable sizes of experimental plot for cabbage for Dry Weight of Leaves in evaluation carried out with 80% of the heads closed.

			MASS OF FRESH EARS (PSF)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
CV% = 49,97	5%	4	176	126	115	109	107	105	103	102	102
	10%	4	61	44	40	38	37	36	36	35	35
	15%	4	33	24	21	20	20	20	19	19	19
	20%	4	21	15	14	13	13	13	12	12	12
	5%	5	125	102	92	89	88	86	85	85	85
	10%	5	43	35	32	31	30	30	30	30	29
	15%	5	23	18	17	17	16	16	16	16	16
	20%	5	15	12	11	11	10	10	10	10	10
	5%	6	99	82	78	76	75	74	74	74	73
b = 1,30661	10%	6	34	28	27	26	26	26	26	25	25
	15%	6	18	15	15	14	14	14	14	14	14
	20%	6	12	10	9	9	9	9	9	9	9
	5%	7	82	71	68	67	66	66	65	65	65
	10%	7	28	25	24	23	23	23	23	22	22
	15%	7	15	13	13	12	12	12	12	12	12
	20%	7	10	9	8	8	8	8	8	8	8
	5%	8	71	63	61	60	59	59	59	58	58
	10%	8	25	22	21	21	21	20	20	20	20
	15%	8	13	12	11	11	11	11	11	11	11
	20%	8	9	8	6	7	7	7	7	7	7

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For variable foliar dry weight (PSF) (Table 7), with 15% DMS, 4 blocks and variation from 5 to 10 treatments, it was possible to obtain practicable plots of 19 to 20 plants. Source: Authors.

Table 8. Convenient experimental plot sizes for cabbage for Heart Length and Longitudinal Diameter Ratio in evaluation carried out with 80% of the heads closed.

			RELATIONSHIP CC/DL(RCC/DL)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
CV% = 15,01	5%	4	122	76	66	61	59	58	57	56	55
	10%	4	26	16	14	13	13	13	12	12	12
	15%	4	11	7	6	5	5	5	5	5	5
	20%	4	6	4	3	3	3	3	3	3	3
	5%	5	5	75	55	48	46	45	44	43	43
	10%	5	5	16	12	10	10	10	9	9	9
	15%	5	5	7	5	4	4	4	4	4	4
	20%	5	5	3	2	2	2	2	2	2	2
b = 0,90528	5%	6	53	41	38	36	36	35	35	35	34
	10%	6	11	9	8	8	8	8	8	7	7
	15%	6	5	4	3	3	3	3	3	3	3
	20%	6	2	2	2	2	2	2	2	2	2
	5%	7	82	71	68	67	66	66	65	65	65
	10%	7	28	25	24	23	23	23	23	22	22
	15%	7	15	13	13	12	12	12	12	12	12
	20%	7	10	9	8	8	8	8	8	8	8
	5%	8	33	28	26	26	25	25	25	25	25
	10%	8	7	6	6	6	6	5	5	5	5
	15%	8	3	2	2	2	2	2	2	2	2
	20%	8	2	1	1	1	1	1	1	1	1

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For the relationship between heart length and longitudinal diameter (RCC / DL) (Table 8), with 10% DMS, 4 blocks and treatments ranging from 5 to 10, practical plots of 12 to 13 plants were obtained. Source: Authors.

Table 9. Suitable experimental plot sizes for cabbage for the cabbage shape index in evaluation performed with 80% closed heads.

			FORMAT INDEX CABBAGE (IFR)								
			Xc (UB)								
Evaluation	DMS	Blocks	Treatments								
	(d)	(r)	2	3	4	5	6	7	8	9	10
	5%	4	4	90	45	36	33	31	30	29	29
	10%	4	4	10	5	4	4	3	3	3	3
CV% = 6,87	15%	4	4	3	1	1	1	1	1	1	1
	20%	4	4	1	1	0	0	0	0	0	0
	5%	5	5	44	28	23	22	21	20	19	19
	10%	5	5	5	3	2	2	2	2	2	2
	15%	5	5	1	1	1	1	1	1	1	1
	20%	5	5	0	0	0	0	0	0	0	0
	5%	6	6	26	18	16	15	15	15	14	14
b = 0,62006	10%	6	6	3	2	2	2	2	2	2	2
	15%	6	6	1	1	0	0	0	0	0	0
	20%	6	6	0	0	0	0	0	0	0	0
	5%	7	18	13	12	12	11	11	11	11	11
	10%	7	2	1	1	1	1	1	1	1	1
	15%	7	1	0	0	0	0	0	0	0	0
	20%	7	0	0	0	0	0	0	0	0	0
	5%	8	13	10	10	9	9	9	9	9	9
	10%	8	1	1	1	1	1	1	1	1	1
	15%	8	0	0	0	0	0	0	0	0	0
	20%	8	0	0	0	0	0	0	0	0	0

Xc = convenient plot size (UB); DMS = minimum significant difference to detect between average treatments (%).For the cabbage shape index variable (IFR) (Table 9), with 10% DMS, 4 blocks and treatments ranging from 2 to 10, it was possible to obtain practicable plots of 3 to 10 plants. Source: Authors.

Table 10. Optimal size of experimental cabbage plots using the Meier and Lessman method for the variables analyzed, in an evaluation carried out with 80% of the heads closed.

Variáveis	*X0* (UB)
AF	1
CC	1
DL	1
DT	1
NFEC	2
PC	2
PSF	1
RCC/DL	1
IFR	1

X0 = convenient plot size (UB). By the Meier and Lesman method (Table 10), the convenient plot size for the variables AF, CC, DL, DT, NFEC, RCC / DL and IFR is equal to 1 and for PC and PSF it is equal to 2. Source: Authors.

The soil heterogeneity coefficients (b) for AF, CC, DL, DT, NFEC, PC, PSF, RCC / DL and IFR are respectively 1.06479, 1.00473, 0.73558, 0.78482, 0.88168, 1.122761, 1.30661, 0.90528 and 0.62006.

According to Smith (1938), the b index is a unique value that quantifies the correlation between contiguous plots, ranging from zero to one, where the zero value corresponds to identical plots (perfect correlation between them), while the unit corresponds to productions plot randomizations, without any correlation between plots. Values greater than unity do not have a defined interpretation and are interpreted by Thomas (1974) and Storck et al. (2006) as the existence of a negative correlation between adjacent plots, which indicates that there was competition between plants within the plot.

Lin and Binns (1986) stated that in the case of b greater than 0.7 an increase in plot size is more effective in improving experimental precision than an increase in the number of repetitions.

In Hatheway's method (1961), the reduction in the convenient size of the experimental plot (Xc) is given by an increase in the number of repetitions (r), an increase in the number of treatments (I), an increase in the difference to detect between treatments (d) and when reducing the coefficient of variation (CV), which shows a clear relationship between the size of the plot and the variables.

The Coefficient of Variation (CV), followed by Precision (b), Number of Blocks (d) and finally the Number of treatments, are the variables that have the greatest influence on the size of the plot. The method of Meier and Lessman (1971) does not present a consistent plot size, so Chaves (1985) stated that the values found by this method should be interpreted as the minimum limit of plot size and not as an optimal size.

4. Conclusions

We conclude that the optimal size of the cabbage plot by the method of Hatheway (1961) presents several possibilities for the variables under analysis, so that what should be considered for the choice of the experimental plot is the availability of space in the place where the experiment is installed, the desired precision, being sensible to use a DMS less than 15% so that the precision of the experiment is not sacrificed, and the field conditions. The size of the experimental plots, found by the method of Meier & Lessman (1971), of a plant tends to limit the optimal number, so the value must be higher than that found, with the need to try other methods to estimate this value.

The work has as a suggestion for readers to inform the ideal repetition number for each variable when working with an experiment for the cultivation of cabbage.

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Percentage of contribution of each author in the manuscript

Vinicius de Freitas Mateus – 10%

Gisele Rodriguês Moreira – 5%

Mario Euclides Pechara da Costa Jaeggi – 5%

Richardson Sales Rocha – 5%

Rita de Kássia Guarnier da Silva – 5%

Israel Martins Pereira – 5%

Tâmara Rebecca Albuquerque de Oliveira – 5%

Derivaldo Pureza da Cruz – 5%

Thiago Blunck Rezende Moreira – 5%

Wagner Bastos dos Santos Oliveira – 5%

Jaídson Gonçalves da Rocha – 5%

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Alexandre Gomes de Souza – 5%

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Josimar Nogueira Batista – 2,5%

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