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Experimental plan for radish culture

Tiago Mateus Rocha[1], Darlei Michalski Lambrecht[1], Jaqueline Sgarbossa[1]*, Iara Cristina Raddatz[2], Maria Inês Diel[3], Lana Bruna de Oliveira Engers[4], Alessandro Dal'Cól Lúcio[1]

[1]Universidade Federal de Santa Maria, Santa Maria-RS, Brasil
[2]Universidade Federal de Viçosa, Viçosa-MG, Brasil
[3]Universidade Federal de Santa Maria, Cachoeira do Sul-RS, Brasil
[4]Universidade Federal Fronteira Sul, Cerro Largo-RS, Brasil
*Corresponding author, e-mail: sgarbossa.jaqueline@ufsm.br

Abstract

One of the main stages of agricultural testing is experimental planning. This study aimed to propose an experimental plan, with estimates of plot size, sample size and number of repetitions in the radish crop. The uniformity sowing tests were carried out in three plots of 6.5 m in length, arranged in four rows with spacing of 0.20 m between them and 0.10 m between plants, totaling 64 plants per row. The cultivars used were Redondo Vermelho Gigante and Gigante Siculo. Each plant was considered a basic experimental unit, and the number of leaves, shoot length, root circumference, plant height, root mass and shoot mass were evaluated. For each line, the plot size was estimated by the method of maximum curvature of the coefficient of variation. Sample size estimation followed Cochran's methodology. To estimate the number of repetitions, the least significant difference from the Tukey test was used. It is recommended to use the largest plot size (13 plants) and sample size with twelve plants in the plot. For a minimum difference of 50% to be considered by Tukey's test, between six and twelve repetitions are necessary.

Keywords: number of repetitions, plot size, precision, *Raphanus sativus*, sample size

Introduction

The radish (*Raphanus sativus* L.) is a vegetable from the Brassicaceae family, with an annual cycle and small size (Filgueira, 2003). It is important among vegetable growers due to its characteristics of rusticity and short cultivation period, with the harvest carried out 25 to 35 days after sowing (Bonela et al., 2017; Filgueira, 2003). Taking it into consideration, the crop is an excellent option for vegetable producers, providing a quick financial return given that it can be grown throughout the year (Bonela et al., 2017; Boso et al., 2021).

Radish consumption has increased due to changes in the population's eating habits and awareness of healthy eating, as the edible tuber possesses medicinal properties, contains vitamins A, B1, B2, and minerals such as potassium, calcium, phosphorus, and sulfur. Additionally, it acts as a natural expectorant, and stimulant for the digestive system (Gamba et al., 2021; Shin et al., 2015). In Brazil, during the 2022 harvest, 3.76 million tons of radish tubers were produced, with the South of Brazil being the largest producer, accounting for 54.27% of national production (Conab, 2023).

Due to its nutritional importance and ease of cultivation throughout the year, there is now a demand for the development of studies and discussions aimed at improving crop management and promoting cultivation. Taking it into account, research on radish should focus on evaluating the performance of new genotypes, as well as exploring new cultivation techniques. Therefore, it is essential to carry out experiments with high experimental precision to obtain reliable results. To achieve such goals, researchers must follow the principles of experimentation (Lambrecht et al., 2022; Lúcio et al., 2020).

One of the main stages of experimentation is the correct experimental planning. In that stage, the researcher must define the appropriate plot size, sampling

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intensity, the experimental design to be used, and the number of repetitions. That way, there is a reduction in the experimental variability in such a way that it is in response to the different treatments tested in the experiment, and that the variability within each treatment is minimal, thus reducing the experimental error (Lúcio et al., 2020).

Sampling is important, as it causes a source of sampling variation, which is also known as experimental error, with the number of plants needed to compose the sample defined from the variation of data in relation to the mean. The greater the variation, the greater will be the number of plants needed (Silva et al., 2019). Thus, due to the increase in the reliability and precision of the results, the greater the number of plants sampled the researcher is benefited (Cargnelutti Filho et al., 2017).

In case the researcher does not perform the correct experimental planning, for example, if a very high size of plots, sample and number of repetitions is used, there will be a need for a greater demand of labor, material and financial support. On the other hand, if a very small size of plots, sample and number of repetitions is used, the experiment may be lost due to interferences, whether natural or mechanical. Therefore, it is important to have an ideal number of plots, neither too large nor too small (Lúcio & Sari, 2017).

For crops such as cucumber, pea, onion, studies on experimental design were also carried out (Lambrecht et al., 2022; Lúcio et al., 2020; Tartaglia et al., 2021). As for the cultivation of radish, there is a lack of information, since the number of studies with this crop is still small. Given the above, this study aimed to propose an experimental plan, with estimates of plot size, sample size and number of repetitions, with the purpose of increasing the precision and reliability of experiments with the radish crop.

Material and methods

Two uniformity trials were conducted during the 2019 harvest in Santa Maria, southern Brazil, at geographic coordinates 29° 42' 23'' S and 53° 43' 15'' W, altitude of 95 m above mean sea level. According to the Köppen climate classification, the region has a Cfa climate, characterized by an average air temperature of 19.1 °C, ranging from 0 °C to 38 °C, and accumulated rainfall of 2,040 mm (Alvares et al., 2013). The soil of the experimental area is classified as Argissolo Bruno-Acinzentado Alítico Úmbrico (Ultisol) (Santos et al., 2018).

Before sowing, the soil was prepared using a stonecutter coupled to a tractor. Base fertilization was conducted based on a chemical analysis of the soil, following the crop's recommended practices (CQFS, 2016). The other crop treatments adhered to technical guidelines in compliance with good agricultural practices.

Sowing was carried out on February 5, 2019, in three plots, each 6.5 m long each. Four rows were arranged in each bed, with a spacing of 0.20 m between rows and 0.10 m between plants, totaling 64 plants per row. After sowing, a drip irrigation system was installed, and irrigation was provided according to the water needs for the crop. The radish cultivars used were Redondo Vermelho Gigante – Horticeres (Cultivar 1), which has rounded roots, purplish-red external color, white pulp and commercial diameter of 3.5 – 4.0 cm, in addition to the cultivar Gigante Siculo - Isla® (Cultivar 2), which has round and flat roots, red in color, white pulp and a commercial diameter of 4 to 4.5 cm.

The harvest was carried out on March 9, 2019, where each plant was considered a basic experimental unit (BEU). In each BEU, the following variables were evaluated: number of leaves (NL), shoot length (SL in cm), root circumference (RC in cm), plant height (PH in cm), root mass (RM in g) and shoot mass (SM in g). NL was determined by counting the leaves. SL was measured from the base of the stem to the upper apex of the plant, while the total plant height was measured from the base of the tuber to the upper apex, using a graduated ruler. RCIR was measured with a digital caliper. RM and RC were determined by weighing on a precision scale (SM of 0.0001 g).

Initially, the data were subjected to homogeneity of variances test among the crop rows. The test was applied to each bed and each variable, following the methodology proposed by (Levene, 1960), as presented in Eq. 1:

$$W = \frac{(N-k)}{(k-1)} \cdot \frac{\sum_{i=1}^{k} Ni \left(Zi - Z\right)2}{\sum_{i=1}^{k} \sum_{i=1}^{Ni} (Nij - Zi)2} \quad (1)$$

Where k is the number of different groups to which the sampled cases belong, N_i is the number of cases I ° group, N is the total number of cases in all groups, Z_{ij} is the value of the variable measured for the j ° case of the I ° group, estimated by Eq. 2

$$Zij = \begin{cases} \left| Yij - \overline{Yi} \right| & \overline{Yi} \text{ it is the average group I} \\ \left| Yij - \widetilde{Yi} \right| & \widetilde{Yi} \text{ it is a median of group I} \end{cases} \quad (2)$$

For each crop row, the plot size (number of plants) was estimated using the method of maximum curvature of the coefficient of variation, proposed by (Paranaíba et al., 2009), by Eq. 3:

$$\widehat{X_0} = \frac{\sqrt[10^3]{2\left(1-\widehat{p}^2\right)s^2\overline{Y}}}{\overline{Y}} \quad (3)$$

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Where, $\widehat{X_0}$: is the appropriate plot size, s^2: is the variance in the crop row, $\bar{Y}$: is the average of the BEU in the crop row, $\hat{\rho}$: is the first-order spatial autocorrelation, which was estimated by Eq. 4:

$$\rho = \frac{\sum_{i=1}^{n}\left(\widehat{\varepsilon_i} - \bar{\varepsilon}\right)\left(\widehat{\varepsilon i - 1 \varepsilon}\right)}{\sum_{i-1}^{rc}\left(\widehat{\varepsilon_i}\,\bar{\varepsilon}\right)^2} \quad (4)$$

Where $\hat{\varepsilon}$: is the experimental error associated with the observation of each *i* BEU and $\bar{\varepsilon}$: mean of experimental errors. As for the experimental error, it was estimated by Eq.5:

$$\varepsilon_i = \rho\varepsilon_i - 1 + U_i \quad (5)$$

where o ρ is the first-order spatial autocorrelation coefficient, Ui is the "pure" experimental error, independent of Ui ~ N(0,σ^2) .

The estimate of the sample size (number of plants) for each crop row, through the methodology proposed by (Cochran, 1977), by Eq. 6:

$$n = \frac{t_\alpha^2/2(CV\%)^2}{(D\%)^2} \quad (6)$$

Where n is the sample size (in number of plants), $t_\alpha^2/2$ is the value of the student's t table with n-1 degrees of freedom at 5% error probability, CV% is the coefficient of variation of the considered variable calculated by Eq. 7:

$$CV\% - \frac{100\sqrt{s^2}}{\bar{x}} \quad (7)$$

Where s^2 is the sample variance, $\bar{x}$ is the mean of the variable and D% is the half-amplitude of the mean confidence interval (D%= 5, 10, 15 and 20). Corrections for finite population were performed according to (Cochran, 1977) recommendations. For that, Eq. 8:

$$nc = \frac{n}{1 + \frac{n}{N}} \quad (8)$$

Where *nc* is the adjusted sample size, *N* is the population size of each cultivation row, and n is the sample size for infinite population.

Tukey test was used, expressed as a percentage of the mean of the Eq test. 9.

$$d = \left(\frac{q_{\alpha(i;GLE)}\frac{\sqrt{QME}}{r}}{\bar{Y}}\right) \quad (9)$$

Where $q_{\alpha x(i;GLE)}$ is the critical value of the Tukey test at error probability level a (a=0.05 adopted in this research), i is the number of simulated treatments (2 to 20 treatments), GLE is the number of degrees of freedom of error for the randomized blocks design, that is, (i-1) (r-1). Each row of cultivation represented a block, as there was significant heterogeneity between the rows of cultivation. QME is the mean square of the error and $\bar{Y}$ is the mean of the experiment. Thus, substituting the expression of the experimental variation coefficient in percentage, in the expression for the calculation of d, and isolating r, we have Eq. 10:

$$r = \left(\frac{xq_{\alpha(i;GLE)}CV}{d}\right)^2 \quad (10)$$

In this study, the CV was expressed as a percentage, and corresponds to the CV X_0, as this is the expected CV for the experiment with the previously calculated plot size (X_0). With the highest coefficient of variation of the plot size (*CV* x_0) of the total grouping of harvests, the number of repetitions (r) was determined, by an iterative process up to the convergence for experiments in the randomized block design, in scenarios formed by the combinations of i (i=2, 3, 4, ..., 20) and D (D=5%, 10%, 15%, ..., 50%). All analyzes were performed using the R (R core team, 2023) and the Office Excel ® application.

Results and discussion

The results of the Levene variance homogeneity test performed among the variances of the rows showed that there was heterogeneity among the rows for both cultivars in some variables and cultivation plots (**Table 1**). Thus, totaling 22.22 and 16.66% of heterogeneity in cultivar 1 and 2, respectively. These results suggest that the experimental design to be adopted should be randomized blocks, in order to block this source of variation between rows of cultivation.

After the previous test of homogeneity of variances, it was verified that some rows of the uniformity test were heterogeneous. To justify this experimental variability, we can name several causes, such as, area with uneven fertility, incidence of diseases and weeds and occurrence of pests (Lúcio & Benz, 2017; Lúcio et al., 2010). Therefore, following the recommendation of (Lúcio & Sari, 2017), the experimental design to be used by researchers in future experiments is randomized blocks,

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Table 1. Levene's test p-value among the rows of each bed and cultivar, for the variables number of leaves (NL), shoot length (SL in cm), root circumference (RC in cm), plant height (PH in cm), root mass (RM in g) and shoot mass (SM in g) of radish in the year 2019

Cultivar	Plots	NL	SL	RC	PH	RM	SM
1	1	0.10513	0.73839	1.80×10^{-14}	0.87384	0.40112	1.20×10^{-37}
	2	0.63604	0.32967	0.04665	0.15913	0.05692	0.15506
	3	0.00726	0.40422	0.70504	0.31751	0.33188	0.15032
2	1	0.59646	0.18397	0.228234	0.70129	0.37435	0.62276
	2	0.62878	0.0294	0.785772	0.09097	0.42925	0.03678
	3	0.96954	0.25884	0.607604	0.27503	0.05949	0.01036

Redondo Vermelho Gigante (Cultivar 1) and Gigante Siculo (Cultivar 2); Number of leaves (NL), shoot length (SL), root circumference (RC), plant height (PH), root mass (RM) and shoot mass (SM).

Table 2. Plot size (X_0, in plants) and coefficient of variation in plot size between parentheses (CV X_0, in %) of each row in each bed, for the variables number of leaves (NL), part length aerial (SL in cm), root circumference (RC in cm), plant height (PH in cm), root mass (RM in g) and shoot mass (SM in g) of radish, for cultivar 1 and 2 in the year 2019

Cult.	Var.	Plot 1				Plot 2				Plot 3			
		F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
1	NL	5(11)	5(11)	5(11)	5(11)	10(23)	10(23)	11(25)	10(23)	6(13)	6(13)	6(13)	6(14)
	SL	3(8)	4(8)	3(7)	3(7)	4(9)	4(10)	3(8)	3(8)	4(8)	4(8)	4(8)	4(9)
	RC	9(20)	9(20)	9(19)	4(9)	5(11)	5(11)	5(12)	5(12)	5(11)	5(11)	5(11)	6(13)
	SM	7(16)	8(17)	8(17)	12(26)	8(17)	8(17)	8(17)	8(19)	7(15)	7(16)	8(17)	8(18)
	RM	8(18)	8(19)	9(20)	9(20)	9(20)	8(18)	9(21)	10(22)	9(21)	10(23)	11(24)	13(28)
	PH	5(11)	5(11)	5(11)	5(11)	10(23)	10(23)	11(25)	10(23)	6(14)	6(13)	6(13)	6(14)
2	NL	5(12)	6(12)	5(11)	6(13)	5(11)	5(11)	5(12)	5(11)	6(13)	6(13)	6(12)	6(13)
	SL	4(10)	4(10)	4(10)	5(10)	5(12)	5(12)	5(11)	5(11)	5(10)	4(10)	4(9)	4(10)
	RC	4(10)	4(10)	5(11)	4(10)	5(11)	5(11)	5(11)	5(10)	5(10)	5(10)	5(10)	5(11)
	SM	7(15)	7(15)	7(15)	7(16)	9(19)	8(18)	9(19)	8(18)	12(27)	12(26)	12(26)	10(23)
	RM	7(16)	7(16)	9(19)	8(17)	9(19)	8(18)	8(17)	7(17)	8(17)	8(18)	8(17)	8(17)
	PH	6(13)	6(13)	6(14)	6(13)	6(12)	5(12)	5(11)	5(12)	5(12)	6(13)	6(12)	6(12)

Cult., refers to cultivar and Var. refers to variable; F1, F2, F3 and F4 refer to the ranks; Number of leaves (NL), shoot length (SL), root circumference (RC), plant height (PH), root mass (RM) and shoot mass (SM).

where each block/repetition will be composed of a row of cultivation. So that, using this design, it is possible to reduce the experimental variability of the area, avoiding inflating the estimate of the experimental error and the coefficient of variation.

Regarding plot size, the largest sizes found in cultivars 1 and 2 were for the variables root mass and shoot mass (**Table 2**). In cultivar 1, the largest plot sizes observed in each variable were eleven, four, nine, twelve, thirteen and eleven plants, with a coefficient of variation in plot size of 25, 10, 20, 26, 28, and 25% respectively for the variables NL, SL, RC, SM, RM and PH. For cultivar 2, the largest plot sizes observed in each variable were 6, 5, 5, 12, 9 and 6, with coefficient of variation in plot size of 13, 12, 11,27, 19 and 14%, respectively for the variables NL, SL, RC, SM, RM and PH. Make a note that for the SL and SM variables, the number of plants needed to compose the plot is practically identical for both cultivars, but for the other variables, the largest plot sizes differ between cultivars.

One of the main factors that impact on plot size is the variability of the experimental area. Therefore, it is important to use the experimental design correctly, in order to minimize the effects of this variability. In this same line of research, several works have already been carried out by other researchers, even with other cultures, also indicating the use of a randomized block design, as in experiments with eggplant (Krysczun et al., 2018) and with cucumber (Lúcio et al., 2020).

In the case of experiments with the radish crop, it is recommended that in future studies the researcher use the largest plot sizes found in this study, namely: 11, 5, 9, 12, 13 and 11 plants to evaluate the variables NL, SL, RC, SM, RM and PH respectively for both cultivars. If the researcher's objective is to analyze all these variables in his experiment, it is recommended the use the largest plot size observed in this study (13 plants). By using the largest plot size, it is possible to cover all variability in the area, thus obtaining data that reflect the real effect of the treatments tested, generating good reliability in the database and, consequently, in the results (Boyhan et al., 2003).

On the other hand, other studies also carried out with the radish crop obtained divergent results, such as the work by (Silva et al., 2019), which recommends 99 plants per plot. These results with high discrepancy justify the need for further studies with the purpose of proposing experimental plans, in order to supplement the literature, as well as recommend new experimental plans for the culture of radish in other parts of the world.

The results of sample size in the plot (in number of plants) varied according to the analyzed variable, minimum differences between averages (D%) and rows of cultivation of each cultivar (**Table 3**). In cultivar 1 for D% equal to 5% of the mean, the largest sample sizes among the variables ranged from 4 to 12 plants, while for D% equal to 20%, the largest sample sizes ranged from 3 to 11 plants, which results in a reduction of 25 to 9.3% in the

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Table 3. Sample size in the plot (number of plants) and minimum differences between means (D= 5, 10, 15 and 20%), for each row in each bed for the variables number of leaves (NL), shoot length (SL in cm), root circumference (RC in cm), plant height (PH in cm), root mass (RM in g) and shoot mass (SM in g) of radish in the year 2019

Cultivar	Variables	D%	Plot 1				Plot 2				Plot 3			
			F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
1	NL	5	4	5	5	5	10	10	11	10	6	6	6	6
		10	4	4	4	4	10	10	11	10	5	5	5	6
		15	3	4	4	4	9	9	10	9	5	4	5	5
		20	3	3	3	3	9	9	9	9	4	4	4	4
	SL	5	3	3	3	3	4	4	3	3	3	3	3	4
		10	3	3	3	3	4	4	3	3	3	3	3	3
		15	3	3	3	3	3	4	3	3	2	2	2	3
		20	3	3	2	3	3	3	3	3	1	2	2	2
	RC	5	9	9	8	4	5	5	5	5	5	5	5	5
		10	8	8	8	3	4	4	5	5	4	4	4	5
		15	8	8	7	3	4	4	4	4	3	4	4	4
		20	7	7	7	2	3	3	3	4	3	3	3	4
	SM	5	7	7	8	11	8	7	7	8	7	7	8	8
		10	7	7	7	11	7	7	7	8	6	7	7	8
		15	6	6	7	11	7	6	6	7	5	6	6	7
		20	5	6	6	10	6	6	6	7	5	5	6	6
	RM	5	8	8	9	9	9	8	9	10	9	10	11	12
		10	8	8	9	8	8	8	9	9	9	10	10	12
		15	7	7	8	8	8	7	8	9	8	9	10	12
		20	6	7	7	7	7	6	8	8	8	9	9	11
	PH	5	4	5	5	5	10	10	11	10	6	6	6	6
		10	4	4	4	4	10	10	11	10	5	5	5	6
		15	3	4	4	4	9	9	10	9	5	4	5	5
		20	3	3	3	3	9	9	9	9	4	4	4	4
2	NL	5	5	5	5	5	5	5	5	5	6	6	5	6
		10	4	5	4	5	4	4	4	4	5	5	5	5
		15	4	4	4	4	4	4	4	4	4	4	4	4
		20	3	4	3	4	3	3	3	3	4	4	4	4
	SL	5	4	4	4	4	5	5	5	5	4	4	4	4
		10	4	3	4	4	5	4	4	4	4	4	3	4
		15	3	3	3	3	4	4	4	4	3	3	3	3
		20	3	3	3	3	3	3	3	3	3	3	2	3
	RC	5	4	4	5	4	5	5	5	4	4	4	4	4
		10	4	4	4	4	4	4	4	4	4	4	4	4
		15	3	3	3	3	4	3	3	3	3	3	3	3
		20	3	3	3	3	3	3	3	3	3	3	3	3
	SM	5	7	7	7	7	9	8	8	8	12	11	11	10
		10	7	6	6	6	8	7	8	8	12	11	11	10
		15	6	5	6	6	8	7	7	7	11	11	11	9
		20	5	5	5	5	7	6	7	6	11	10	10	9
	RM	5	7	7	8	8	9	8	8	7	7	8	8	8
		10	7	7	8	7	8	8	7	7	7	8	7	7
		15	6	6	8	7	8	7	7	6	6	7	7	6
		20	5	5	7	6	7	6	6	6	6	6	6	6
	PH	5	6	5	6	6	5	5	5	5	5	5	5	5
		10	5	5	5	5	5	5	4	5	5	5	5	5
		15	4	4	5	5	4	4	4	4	4	4	4	4
		20	4	4	4	4	4	4	3	4	4	4	4	4

Redondo Vermelho Gigante (Cultivar 1) and Gigante Siculo (Cultivar 2); F1, F2, F3 and F4 refer to the ranks; Number of leaves (NL), shoot length (SL), root circumference (RC), plant height (PH), root mass (RM) and shoot mass (SM).

number of plants needed to be sampled in this situation.

In cultivar 2, it is observed that for D% equal to 5% of the mean, the largest sample sizes among the variables ranged from 5 to 12 plants. For D% equal to 20% of the average, the largest sample sizes ranged from 3 to 11 plants, which results in a reduction of 60.0 to 9.3% in the number of plants needed to be sampled in this situation, depending on the variable to be analyzed.

For sample size, it is also recommended that the largest size found in this study in order to cover the maximum possible experimental variability and provide reliable information. As a single sample size recommendation, it is recommended that twelve plants be sampled in the plot for both cultivars, considering a half-amplitude of the confidence interval (D%) equal to 5% of the mean.

If the researcher does not have financial resources, evaluation time and available labor, he can opt for a smaller sample, such as a sample of eleven plants, with a semi-amplitude of the confidence interval (D%) equal to 20% of the average, which will result in a 9.1% reduction in the number of plants needed to be evaluated. Depending on the researcher's objective and the variables to be evaluated, smaller sample sizes can be used, as presented in this study.

To determine the number of repetitions, the largest plot size and its coefficient of variation were used. Between the two cultivated varieties, the largest plot size of each analyzed variable was used, with 11, 5, 9, 12, 13 and 11 plants for the various NL, SL, RC, SM, RM and PH with coefficient of variation of 25, 12, 20, 26, 28 and 25% respectively (**Table 4**).

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Table 4. Number of repetitions for experiments in randomized block design, in scenarios formed by combinations of i treatments (i=2, 3, 4, ..., 20) and d minimum differences between means of treatments to be detected as significant at 5% probability, by Tukey 's test , expressed as a percentage of the average of the experiment (D= 5, 10, 15, ..., 50%), starting from the largest plot size (X_o= 13 and 12 plants) and coefficient of variation in plot size (CV_{X0} = 28 and 27%) for cultivars 1 and 2 respectively, the number of repetitions for the radish crop in the year 2019 was calculated

Variables	D%	Number of treatments (i)									
		2	4	6	8	10	12	14	16	18	20
	10	232	150	151	156	161	169	172	174	181	188
	20	58	38	38	39	40	42	43	43	45	47
NL and PH	30	26	17	17	17	18	19	19	19	20	21
	40	14	9	9	10	10	11	11	11	11	12
	50	9	6	6	6	6	7	7	7	7	8
	10	53	35	35	36	37	39	40	40	42	43
	20	13	9	9	9	9	10	10	10	10	11
SL	30	6	4	4	4	4	4	4	4	5	5
	40	3	2	2	2	2	2	2	2	3	3
	50	2	1	1	1	1	2	2	2	2	2
	10	148	96	96	100	103	108	110	111	116	120
	20	37	24	24	25	26	27	28	28	29	30
RC	30	16	11	11	11	11	12	12	12	13	13
	40	9	6	6	6	6	7	7	7	7	8
	50	6	4	4	4	4	4	4	4	5	5
	10	251	162	163	168	174	183	186	188	196	203
	20	63	41	41	42	43	46	47	47	49	51
SM	30	28	18	18	19	19	20	21	21	22	23
	40	16	10	10	11	11	11	12	12	12	13
	50	10	6	7	7	7	7	7	8	8	8
	10	291	188	189	195	202	212	216	218	227	235
	20	73	47	47	49	50	53	54	54	57	59
RM	30	32	21	21	22	22	24	24	24	25	26
	40	18	12	12	12	13	13	14	14	14	15
	50	12	8	8	8	8	8	9	9	9	9

Number of leaves (NL), shoot length (SL), root circumference (RC), plant height (PH), root mass (RM) and shoot mass (SM).

In scenarios formed by combinations of i treatments (i=2, 4, 6, ..., 20) and d minimum differences between means of treatments (D= 10%, 20%, 30%, ..., 50%), to be detected as significant at 5% probability, by Tukey test, the number of repetitions necessary to evaluate the variables number of leaves, shoot length, root circumference, plant height, root mass and shoot mass among these variables, showed an oscillation between 2 (2 treatments with D=50%) and 291 repetitions (2 treatments with d=10%). The recommended values for the variables NL, PH, RC, SM and RM are nine, nine, six, ten and twelve repetitions, respectively, considering D= 50%. As for the SL variable with similar repetition values (six), d= 30% can be used (Table 4).

From the plot sizes, it is possible that the researcher can establish the relationship between i treatments, d differences between means of treatments and the number of repetitions. Considering the variables analyzed in the two cultivars (Table 4), with two treatments (i=2) it is possible to identify that for a minimum difference of 50% to be considered by the Tukey test, between twelve and six repetitions will be necessary.

According to the results presented, it is possible to observe that the researcher will be able to choose the number of repetitions according to the objective of his research, reducing or increasing the minimum difference between intended means. If he chooses to work with PH, RC, SM and RM, he will be working with d= 50%, but if he only intends to analyze SL, he can reduce his minimum difference between means to d= 30% with a number of repetitions similar to those of the other variables.

For studies with the purpose to prove statistically small minimum significant differences between treatments, it is recommended to adopt a higher number of repetitions and smaller plot sizes (Gonçalves et al., 2024; Henriques Neto et al., 2009; Lambrecht et al., 2024; Nagai et al., 1978). It is noteworthy that the greater the number of repetitions adopted, the smaller the minimum difference between means. Thus, there will be an increase in the precision of the experiment with a reduction in the experimental error, providing greater reliability in the obtained results (Rossetti, 2002).

Conclusions

For the radish crop, it is recommended that the plot size for the variables number of leaves, shoot length, root circumference, plant height, root mass and shoot mass be eleven, five, nine, twelve, thirteen and eleven plants, respectively.

The sample size for good reliability in the database, for the variables number of leaves, shoot length, root circumference, plant height, root mass and shoot mass is nine, three, seven, eleven, eleven and nine plants respectively, considering a semi-amplitude confidence interval (D%) equal to 20% of the mean.

As a recommendation for the number of

repetitions, nine, nine, six, ten and twelve repetitions should be used to evaluate the variable number of leaves, plant height, root circumference, shoot mass and root mass, respectively, so that minimal differences of 50% could be identified by the Tukey test. As for the shoot length variable with similar repetition values (six), it is possible to work with minimum differences of 30%.

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References

Alvares, C.A., Stape, J.L., Sentelhas, P.C., de Moraes Gonçalves, J.L., Sparovek, G. 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22: 711–728.

Bonela, G.D., dos Santos, W.P., Sobrinho, E.A., Gomes, E.J. da C. 2017. Produtividade e qualidade de raízes de rabanete cultivadas sob diferentes fontes residuais de matéria orgânica. *Revista Brasileira de Agropecuária Sustentável* 7: 66-74.

Boso, A.C.M.R., Cremasco, C.P., Putti, F.F., Gabriel Filho, L.R.A. 2021. Fuzzy modeling of the effects of different irrigation depths on the radish crop. Part i: productivity analysis. *Engenharia Agrícola* 41: 311–318.

Boyhan, G.E., Langston, D.B., Purvis, A.C., Hill, C.R. 2003. Optimum plot size and number of replications with short-day onions for yield, seedstem formation, number of doubles, and incidence of foliar diseases. *Journal of the American Society for Horticultural Science* 128: 409–424.

Cargnelutti Filho, A., Araujo, M.M., Gasparin, E., Foltz, D.R.B. 2017. Dimensionamento amostral para avaliação de altura e diâmetro de plantas de timbaúva. *Floresta e Ambiente* 25: e00121314.

Cochran, W.G. 1977. *Sampling Techniques*, John Wiley & Sons, New York, USA 428p.

Comissão de Química e Fertilidade do Solo – CQFS RS/SC. 2016. *Manual de adubação e calagem para os estados do Rio Grande do Sul e Santa Catarina*. Sociedade Brasileira de Ciência do Solo – Núcleo Regional Sul, Porto Alegre, Brazil. 376p.

CONAB. Companhia nacional de Abastaceimento. 2024. https://www.conab.gov.br/info-agro/hortigranjeiros-prohort <Acesso em 10 Jan. 2024>

Silva, M. S., Silva, S. O., Donato, S.L.R., Ledo, C.A., Sampaio Filho, O.M.S., Melo Araújo Silva, G., da Silva Conceição, A.L. 2019. Optimal experimental plot size for papaya cultivation. *Pesquisa Agropecuária Brasileira* 54: e00768.

Filgueira, F.A.R., 2003. *Novo manual de olericultura: agrotecnologia moderna na produção e comercialização de hortaliças*. UFV, Viçosa, Brazil. 402p.

Gamba, M., Asllanaj, E., Raguindin, P.F., Glisic, M., Franco, O.H., Minder, B., Bussler, W., Metzger, B., Kern, H., Muka, T. 2021. Nutritional and phytochemical characterization of radish (*Raphanus sativus*): A systematic review. *Trends in Food Science & Technology* 113: 205–218.

Gonçalves, G.R., Prins, C.L., Diel, M.I., Lúcio, A.D. 2024. Plot and sample sizes for biometric variables in lettuce seedlings. *Ciência Rural* 54: e20220471.

Henriques Neto, D., Seydiama, T., Alvares de Souza, M., Carvalho Leite, L.F., Fávaro Blanco, F. 2009. Tamanho de parcela para avaliação da produção em trigo irrigado, sob dois sistemas de plantio. *Revista Ciência Agronômica* 40: 86–93.

Krysczun, D.K., Lúcio, A.D., Sari, B.G., Diel, M.I., Olivoto, T., Santana, C.S., Ubessi, C., Schabarum, D.E. 2018. Sample size, plot size and number of replications for trials with *Solanum melongena* L. *Science Horticulturae* 233: 220–224.

Lambrecht, D.M., Diel, M.I., Lúcio, A.D., Tartaglia, F. de L., Tischler, A.L., Krysczun, D.K. 2022. Onion culture: experimental techniques for carrying out high precision experiments. *Bragantia* 81: e2422.

Lambrecht, D.M., Sgarbossa, J., Diel, M.I., Lúcio, A.D., Marques, L.E., Raddatz, I.C., Tischler, A.L., Tartaglia, F. de L., Engers, L.B. de O., Soncini, I.R., Kuhn, M.M. 2024. Experimental plan for carrot culture. *Ciência Rural* 54: e20230428

Levene, H. Robust tests for equality of variances. 1960. In: Olkin, I.; Hotelling, H. *Contributions to Probability and Statistics: Essays in Honor of Harold Hotelling*. Stanford University Press, California, USA, p.278–292.

Lúcio, A.D., Benz, V. 2017. Accuracy in the estimates of zucchuni production related to the plot size and number of harvests. *Ciência Rural* 47: 1–5.

Lúcio, A.D., Lambrecht, D.M., Sari, B.G., Krysczun, D.K., Ubessi, C. 2020. Experimental planning for conducting experiments with cucumber. *Horticultura Brasileira* 38: 112–116.

Lúcio, A.D., Sari, B.G. 2017. Planning and implementing experiments and analyzing experimental data in vegetable crops: problems and solutions. *Horticultura Brasileira* 35: 316–327.

Lúcio, A.D., Carpes, R.H., Storck, L., Zanardo, B., Toebe, M., Puhl, O.J., dos Santos, J.R.A. 2010. Agrupamento de colheitas de tomate e estimativas do tamanho de parcela em cultivo protegido. *Horticultura Brasileira* 28: 190–196.

Nagai, V., Passos, F.A., Scaranari, H.J., Martins, F.P. 1978. Tamanho da parcela e número de repetições em experimentos com morangueiro. *Bragantia* 37: p.71–81.

Paranaíba, P.F., Ferreira, D., Morais, A.R. 2009. Tamanho ótimo de parcelas experimentais: Proposição de métodos de estimação. *Revista Brasileira de Biometria* 27: 255–268.

R Core Team. 2024. R: A Language and Environment for Statistical Computing. R Foundation of Statistical Computing, Viena, Austria.

Rossetti, A.G. 2002. Influência da área da parcela e do número de repetições na precisão de experimentos com arbóreas. *Pesquisa Agropecuária Brasileira* 37: 433–438.

Santos, H.G., Jacomine, P.K.T., Anjos, L.H.C., Oliveira, V.A. 2018. *Sistema brasileiro de classificação de solos*. Embrapa, Brasília, Brazil. 356p.

Shin, T., Ahn, M., Kim, G.O., Park, S.U. 2015. Biological activity of various radish species. *Oriental Pharmacy and Experimental Medicine* 15: 105–111.

Tartaglia, F. de L., Lúcio, A.D., Diel, M.I., Tischler, A.L., Krysczun, D.K., Zemolin, J.A., Marques, L.E. 2021. Experimental plan for tests with pea. Agronomy Journal 113: 1394–1406.

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