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STATISTICS

Optimal plot size for experimental trials with *Opuntia* cactus pear

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ABSTRACT. The objective of the study with 'Gigante' cactus pear was to determine the size of plots that optimize the implementation of experiments with greater accuracy, spatial adequacy and efficiency of use of the experimental area by the Hatheway method (1961). The experiment was conducted in a uniform spacing of 2.0 x 0.2 m with 384 basic experimental units (BEUs). The vegetative descriptors were evaluated in the third production cycle. The coefficient of experimental variation (CVe) is the factor with the greatest influence for the experimental plot design; followed by the parameters - index d, which determines the difference to be detected between treatments; by the number of replications and, finally, by the number of treatments, which has the smallest effect on the plot size (BEUs). For the efficiency of use of the experimental area - EUEA, one can select larger plots (three BEU) with a lower number of repetitions (three) or smaller plots (two UEB) with a higher number of repetitions (10) with the same level of accuracy to evaluate the yield of 'Gigante' cactus pear. However, the selection criteria are based on the smallest experimental area, reflecting the maximum of EUEA. Useful plots with eight basic units are considered efficient for experiments with cactus pear.

Keywords: agronomic descriptors; experimental accuracy; basic experimental units.

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Introduction

Due to its high nutritional and energetic and hydric value, 'Gigante' cactus pear (*Opuntia ficus indica*, Mill) stands out as a strategic food source for ruminant nutrition (Aguiar et al., 2015). Additionally, because of morphological, anatomical and physiological characteristics, this plant combines efficient mechanisms for the use of water in semi-arid conditions (Dantas, Lima, & Mota, 2017). Thus, forage production is of particular importance in the composition of balanced diets, especially in an adverse ecosystem (Aguiar et al., 2015).

Recent studies with cactus pear have been developed to optimize agricultural resources for various technological levels. These works are associated with mineral fertilization (Silva et al., 2016), organic fertilization (Donato, Donato, Silva, Pires, & Silva Júnior, 2017), economic viability of irrigated and narrow rows (Dantas et al., 2017), harvest intensity and correct harvest management (Lima et al., 2016), animal feed (Aguiar et al., 2015), among others (Guimarães, Donato, Azevedo, Aspiazú, & Silva Junior, 2018).

These studies, despite the relevance to the semi-arid region, reveal some disagreements on the experimental arrangement, number of replications and size of the experimental unit used (Queiroz et al., 2015; Padilha Junior, Donato, Silva, Donato, & Souza, 2016; Silva et al., 2016). Thus, it is necessary to improve the agricultural research with cactus pear in order to obtain information on the number of replications, size and shape of the experimental plots to achieve results that allow detecting significant differences between tested treatments (Cargnelutti Filho, Storck, Lúcio, Toebe, & Alves, 2016; Cargnelutti Filho, Araujo, Gasparin, & Foltz, 2018).

The ideal size of the experimental plot can be established considering soil heterogeneity index - SHI (Smith, 1938; Cargnelutti Filho et al., 2016), genetic material or studied crop (Sousa, Silva, & Assis, 2016), balance between accuracy and costs (Cargnelutti Filho et al., 2016; Sousa et al., 2016), nature of the experimental material, number of replicates and evaluation methods (Cargnelutti Filho et al., 2018).

The estimation of plot sizes by the statistical proposal of Hatheway (1961) was investigated in several studies (Cargnelutti Filho, Toebe, Burin, Casarotto, & Alves, 2014; Schmildt, Schmildt, Cruz, Cattaneo, & Ferreguetti, 2016; Lavezo et al., 2017; Donato, Silva, Guimarães, & Silva, 2018) with wide recommendation for the use of smaller plots with a greater number of replications to reach the maximum experimental accuracy and, with this, a greater efficiency in the use of the area. These results reinforce the need to plan smaller and more efficient experiments on accuracy and costs. In addition, considering the essence of this method, the researcher can select convenient plot sizes, given the specific objectives, available resources and local conditions of the experimental field (Sousa et al., 2016).

However, there are no studies in the literature on estimates of the optimal experimental plot size for the evaluation of 'Gigante' cactus pear phenotype descriptors. Thus, the objective of this study was to determine, using the Hatheway method (1961), convenient plot sizes for optimization of experiments, aiming at greater accuracy, spatial adequacy and efficient use of the experimental area.

Material and methods

The experiment was conducted at the *Instituto Federal de Educação, Ciência e Tecnologia Baiano*, Campus Guanambi, State of Bahia, Brazil. The region is located at 14° 13' 30" S, 42° 46' 53" W, at an altitude of 525 m. The climate is considered as hot tropical semi-arid, according to Köeppen classification. The soil is a Lithic Neosol and the averages for annual rainfall and temperature are, respectively, 670.2 mm and 25.9°C.

The experiment was carried out in a uniformity test with cactus pear. These blank trials are characterized by not having treatments, and maintaining homogeneous cultural treatments in any experimental area (Ramalho, Ferreira, & Oliveira, 2012). The crop was planted in a spacing of 2.0 x 0.2 m, in a format of ten rows with 50 plants each. The eight central rows, with 48 plants per row, were considered as useful area, totaling 384 plants and a 153.6 m^2 area.

In the evaluations, each plant was considered as a basic experimental unit (BEU), thus, totaling 384 BEUs. These plants were combined by configuring 15 plot sizes, pre-established with rectangular shapes, and in rows, sufficient to cover all experimental space. The vegetative descriptors evaluated were: plant height (m), length (cm), width (cm) and thickness of the cladode (mm), number of cladodes (unit), mass of cladodes (kg), area of the cladode (cm^2) and the green mass yield of each plot (mg ha^{-1}) in the third production cycle.

For the determination of the Hatheway Method (1961), entitled as the appropriate size of the experimental plot, the complete grouping of the adjacent BEUs in the field was carried out, occupying the entire evaluation area. Based on the descriptors measured in the adjacent BEUs, to compose the plot formats, the measurements of statistical variability, soil heterogeneity index (Smith, 1938) and plot size (Hatheway, 1961) were determined by means of Microsoft - Excel® calculation worksheet, according to the model proposed by Donato et al. (2018).

Soil variability is expressed indirectly by the degree of correlation between the plot size and the variance of the adjacent BEUs, being this an inversely proportional relation. Thus, the soil heterogeneity index (b), established by the linear equation of Smith (1938), is plotted: logVx = logV1- b (log x), in which: Vx, variance of the descriptors measured in the third production cycle of the cactus pear for each corresponding plot size; V_1, variance between plots with one basic unit; b, soil heterogeneity index; and x, plot size in BEU.

To estimate suitable plot sizes, Hatheway (1961) added the coefficient of variation of the evaluated descriptors to Smith's SHI method (1938), in order to align the convenient plot size with the percentage difference between the means of the treatments to be detected. Accuracy levels α_1 = 5.0% and α_2 = 2 (1 – P), with P = 0.80 (80% probability), were considered for four, five and six replicates; five, 10, 15 and 20 treatments; and differences to be detected between the means of treatments, d, equal to 10, 20, 30, 40 and 50%. For the application of this method, the experimental design was randomized blocks.

For the determination of plot sizes, it was considered the Equation 1:

$$x^b = \frac{2(t_1 + t_2)^2\, cv^2}{rd^2} \qquad (1)$$

where:

x is plot size (BEU); CV^2 is squared coefficient of variation (%) of plots with 1 BEU; b, is Smith's heterogeneity index; t_1 is the critical value of the Student's distribution at the α_1 probability level; critical value of the Student's distribution at the α_2 = 2 (1-P) probability level, in which P is the selected probability of obtaining a significant result; r, number of replicates; d, difference to be detected, measured as a percentage of the mean. To estimate the detectable difference between treatment means (d), it was employed the Equation 2:

$$d = \sqrt{\frac{2(t_1 + t_2)^2 cv^2}{rx^b}} \quad (2)$$

Determined for each variable measured in the third cycle of cactus pear production, with 1, 2, 3, 4, 6, 8, 12, 16, 24, 32 and 48 BEUs, (0.4, 0.8, 1.2, 1.6, 2.4, 3.2, 4.8, 6.4, 9.6, 12.8 and 19.2 m²). The experiments were analyzed in randomized blocks, with five and ten treatments, and 3, 4, 5, 6 and 10; and, 3, 4 and 5 replicates, respectively (Hatheway, 1961).

Results and discussion

From the estimate of the index b, soil heterogeneity described by Smith (1938), the coefficients were determined to be 0.72; 0.85; 0.79; 0.94, respectively, for the descriptors, plant height (Figure 1A), total area of cladodes (Figure 1B), number of cladodes (Figure 1C), and green mass yield (Figure 1D), evaluated in the third production cycle. According to the description, values of b> 0.70 denote soils of a heterogeneous nature, with low correlation between the adjacent basic units (Smith, 1938).

Several factors that may favor the heterogeneity of the experimental area, such as the physical-chemical characteristics of the soils, agronomic material to be tested, crop management, intra- and inter-plot competition or failures during sampling (Ramalho et al., 2012). Cargnelutti Filho et al. (2014) emphasize that the experimental accuracy is mainly affected by soil heterogeneity and the material analyzed.

The regression coefficients 1.04; 0.94; 0.40 and 1.14 were associated with the variables area (Figure 2A), length (Figure 2B), thickness (Figure 2C) and width of cladodes (Figure 2D), respectively. The index b, because it is a negative value, must be considered in module. Normally, these values do not extrapolate a unit, as verified for these last two characteristics. However, it can be assumed, based on Donato et al. (2018), that the b estimation method is inserted into the category $0 < b < +\infty$. Thomas (1974) interprets the index b>1 as the reflection of the negative correlation between the confronting plots, if each plot is composed of a single BEU. Sousa et al. (2016) state that this argument is incomprehensible when the plot is formed by more than one BEU, since, normally, blank experimentation suggests competition between BEUs or high susceptibility of plants to environmental variations.

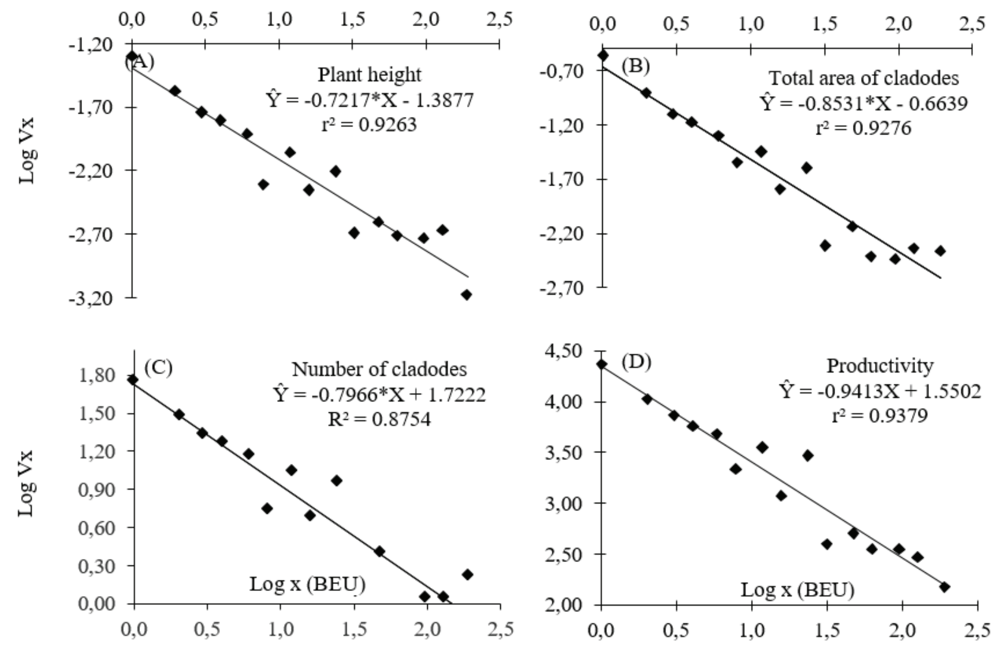

Figure 1. Regression equations between logarithm of variance and logarithm of plot size (BEU), for plant height (A), total area of cladodes (B), number of cladodes (C) and green mass yield (D), evaluated in the third production cycle in 'Gigante' cactus pear.

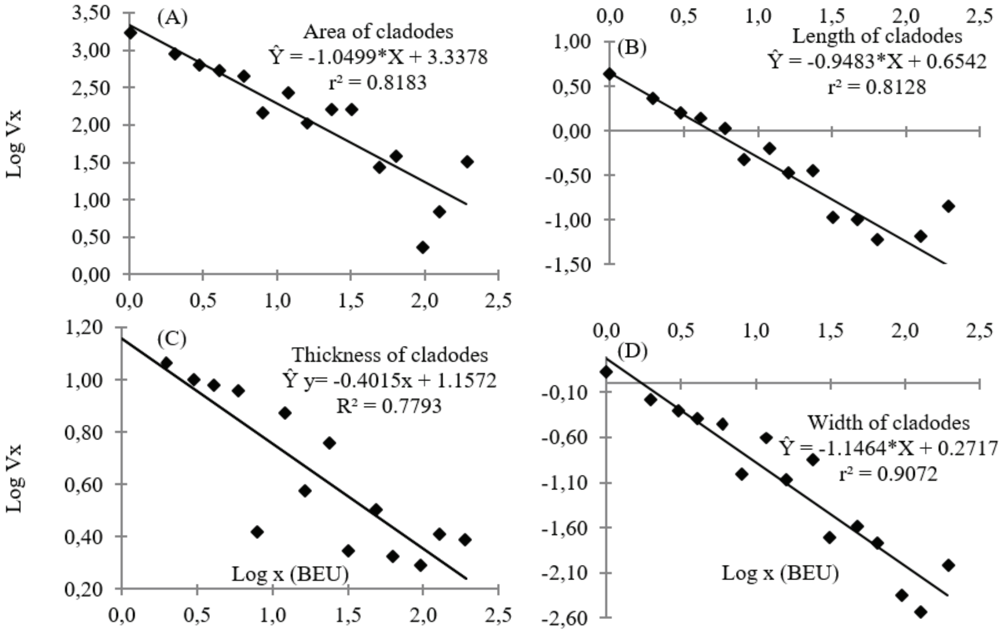

Figure 2. Regression equations between logarithm of variance and logarithm of plot size (BEU) for mean characteristics area of cladodes (A), length of cladodes (B), thickness of cladodes (C) and width of cladodes (D), evaluated in the third production cycle in 'Gigante' cactus pear.

In a similar study with the sunflower crop, Sousa et al. (2016) estimated an index b at 1.0585 for all cultivars tested, thus denoting high soil variability, through the nullity of correlation between the BEUs. Also, in this context, indices b > 1 have been observed in several agronomic studies (Lúcio, Haesbaert, Santos, Schwertner, & Brunes, 2012; Santos, Haesbaert, Lúcio, Storck, & Cargnelutti Filho, 2012; Donato et al., 2018).

According to Lavezo et al. (2017), the experimental design, applied in an efficient way, seeks to promote the adequate arrangement between statistical factors, treatments, replicates and plot size, in order to optimize the experimental area and achieve maximum accuracy for the evaluated parameters. Based on the Hatheway method (1961), a statistical matrix was obtained, making it possible to identify the ideal combination in the experimental plan between the vegetative characteristics (Table 1).

The coefficients of experimental variation (CVe) reflect the natural and specific variability in the evaluated characteristic. However, it can be influenced mainly by the soil conditions and the agricultural management of the BEU, which directly influences the experimental accuracy (Cargnelutti Filho et al., 2018). Pimentel-Gomes (2009) classified the experimental accuracy using CVe, so that values lower than 10%, between 10 and 20%, between 20.01 and 30% and greater than 30%, indicate, in this order, high, medium, low and very low experimental accuracy.

In this study, among the eight characteristics evaluated, the CVe values oscillated between 6.89 and 50.13% (Table 1), for the vegetative and yield characteristics. In 50, 12.5 and 37.5% of the evaluated parameters, CVe values were classified as very low, medium and high at the same time (Pimentel-Gomes, 2009).

The CVe presented a directly proportional relationship to the plot size, as expected, since the greater percentage variation of the evaluated characteristic indicates the need for a larger experimental area to detect a significant difference between the treatments (Cargnelutti Filho et al., 2018).

Thus, CVe is the factor with the greatest influence on the experimental plot dimension, followed by the index d, which determines the difference to be detected between treatments; the number of replicates and, finally, the number of treatments, with smaller effect on the plot size. Similar sequence on the order of importance of the factors was reported by Sousa et al. (2016), Oliveira, Mello, Lima, Scolforo, and Oliveira (2011), Muniz, Aquino, Simplicio, and Soares (2009) and Donato et al. (2018) for sunflower, candeia, eucalyptus and banana crops, respectively.

For the variables yield and cladode length, considering values close to the soil heterogeneity index b = 0.9413 (Figure 1) and b = 0.9483 (Figure 2), with the factors set at d = 10%, t = 5 treatments and r = 4 replicates, the composition of 151.62 and 2.22 basic units is visualized, in this sequence, to detect the mean difference between the treatments of the aforementioned characteristics. It is worth considering that such discrepancies between the sizes of the BEUs are reflections of the CVe of the evaluated characteristic.

Table 1. Estimates of plot size, in BEU, for the characteristics evaluated in the third production production cycle in 'Gigante' cactus pear, for the combinations of number of replicates (r), treatments (t), percentual difference of the mean to be detected (d) and values of coefficient of experimental variation (CVe).

	d	CVe (%)	r = 4				r = 5				r = 6			
			t =5	t = 10	t = 15	t = 20	t = 5	t = 10	t = 15	t = 20	t = 5	t = 10	t = 15	t = 20
	10	18.69	45.39	41.25	39.99	39.38	31.75	29.58	28.91	28.58	23.97	22.66	22.25	22.05
	20	18.69	6.65	6.04	5.86	5.77	4.65	4.33	4.23	4.19	3.51	3.32	3.26	3.23
PH	30	18.69	2.16	1.96	1.90	1.88	1.51	1.41	1.38	1.36	1.14	1.08	1.06	1.05
	40	18.69	0.97	0.89	0.86	0.84	0.68	0.63	0.62	0.61	0.51	0.49	0.48	0.47
	50	18.69	0.52	0.48	0.46	0.46	0.37	0.34	0.33	0.33	0.28	0.26	0.26	0.25
	10	39.96	149.7	138.1	134.5	132.8	110.7	104.2	102.2	101.2	87.2	83.2	81.9	81.3
	20	39.96	29.49	27.20	26.49	26.15	21.79	20.53	20.13	19.94	17.18	16.38	16.13	16.01
TAC	30	39.96	11.40	10.51	10.24	10.11	8.42	7.93	7.78	7.71	6.64	6.33	6.24	6.19
	40	39.96	5.81	5.36	5.22	5.15	4.29	4.04	3.96	3.93	3.38	3.23	3.18	3.15
	50	39.96	3.44	3.17	3.09	3.05	2.54	2.40	2.35	2.33	2.01	1.91	1.88	1.87
	10	36.50	170.2	156.0	151.7	149.6	123.1	115.5	113.1	111.9	95.4	90.7	89.2	88.5
	20	36.50	29.86	27.38	26.62	26.25	21.60	20.26	19.84	19.64	16.74	15.91	15.65	15.52
NC	30	36.50	10.79	9.89	9.62	9.49	7.80	7.32	7.17	7.09	6.05	5.75	5.66	5.61
	40	36.50	5.24	4.80	4.67	4.61	3.79	3.56	3.48	3.45	2.94	2.79	2.75	2.72
	50	36.50	2.99	2.74	2.67	2.63	2.16	2.03	1.99	1.97	1.68	1.59	1.57	1.56
	10	50.13	151.6	140.9	137.6	135.9	115.3	109.2	107.3	106.3	92.9	89.0	87.8	87.2
	20	50.13	34.77	32.31	31.55	31.18	26.43	25.04	24.60	24.38	21.31	20.41	20.13	19.99
P	30	50.13	14.69	13.65	13.33	13.17	11.17	10.58	10.39	10.30	9.00	8.62	8.50	8.44
	40	50.13	7.97	7.41	7.23	7.15	6.06	5.74	5.64	5.59	4.89	4.68	4.61	4.58
	50	50.13	4.96	4.61	4.50	4.45	3.77	3.57	3.51	3.48	3.04	2.91	2.87	2.85
	10	13.58	7.50	7.02	6.87	6.80	5.86	5.59	5.50	5.46	4.83	4.65	4.59	4.56
	20	13.58	2.00	1.87	1.84	1.82	1.57	1.49	1.47	1.46	1.29	1.24	1.23	1.22
CA	30	13.58	0.92	0.87	0.85	0.84	0.72	0.69	0.68	0.67	0.60	0.57	0.57	0.56
	40	13.58	0.53	0.50	0.49	0.48	0.42	0.40	0.39	0.39	0.34	0.33	0.33	0.33
	50	13.58	0.35	0.33	0.32	0.32	0.27	0.26	0.26	0.25	0.23	0.22	0.21	0.21
	10	6.89	2.22	2.07	2.02	2.00	1.69	1.61	1.58	1.56	1.37	1.31	1.29	1.28
	20	6.89	0.52	0.48	0.47	0.46	0.39	0.37	0.37	0.36	0.32	0.30	0.30	0.30
CC	30	6.89	0.22	0.20	0.20	0.20	0.17	0.16	0.16	0.15	0.13	0.13	0.13	0.13
	40	6.89	0.12	0.11	0.11	0.11	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.07
	50	6.89	0.07	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04
	10	28.96	8418	7089	6704	6522	4428	3900	3741	3665	2671	2415	2337	2299
	20	28.96	266.5	224.4	212.3	206.5	140.2	123.4	118.5	116.1	84.59	76.49	74.01	72.80
CT	30	28.96	35.38	29.79	28.18	27.41	18.61	16.39	15.72	15.40	11.23	10.15	9.82	9.66
	40	28.96	8.44	7.11	6.72	6.54	4.44	3.91	3.75	3.68	2.68	2.42	2.34	2.31
	50	28.96	2.78	2.34	2.21	2.15	1.46	1.29	1.23	1.21	0.88	0.80	0.77	0.76
	10	8.03	2.53	2.38	2.34	2.31	2.02	1.93	1.91	1.89	1.69	1.63	1.62	1.61
	20	8.03	0.76	0.71	0.70	0.69	0.60	0.58	0.57	0.56	0.51	0.49	0.48	0.48
CW	30	8.03	0.37	0.35	0.34	0.34	0.30	0.28	0.28	0.28	0.25	0.24	0.24	0.24
	40	8.03	0.23	0.21	0.21	0.21	0.18	0.17	0.17	0.17	0.15	0.15	0.14	0.14
	50	8.03	0.15	0.14	0.14	0.14	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.10

EC = evaluated characteristic; P = Yield; PH = Plant height; NC = number of cladodes; TAC= Total area of cladodes; CA = Cladode area; CC = Cladode length; CT = Cladode thickness; CW = Cladode width.

Equivalent proportion between the assessed characteristic, CVe and plot size was determined by Cargnelutti Filho et al. (2014), Sousa et al. (2016) and Donato et al. (2018), for turnip, sunflower and banana crops, respectively. This shows that the researcher can make use of experimental plots according to focus, model, arrangement and purpose of the research. In addition, the researcher must be careful about the size of plots presented by the Hatheway model (1961), since some combinations of factors (CVe, d, t and r) can result in extreme plot sizes with low practical application (Sousa et al., 2016).

In this respect, it can be observed when the detectable difference in the number of cladodes and plant height is set at 10% (Table 1), because of the high discrepancy between the CVe of these characteristics (36.50 and 18.69%), despite the similarity between index b 0.7966 (Figure 1C) and 0.7217 (Figure 1A) and number of treatments (five) and repetitions (four), reflected in the extreme composition of 170.22 and 45.39 basic units (Table 1), in this sequence.

The inverse is true when we consider variables with closer CVe and index b, both for the number of cladodes (CVe = 36.50%, b = 0.7966, BEU = 170.16) and total area of cladodes (CVe = 39.96%, b = 0.8531 and BEU = 149.74), as for the variables cladode length (CVe = 6.89%, b = 0.9483 and BEU = 2.22) and cladode width (CVe = (Table 1), for the same values of d = 10%, t = 5 treatments and r = 4 replicates, the formation of basic units is similar.

The dimensioning of the plots from the basic unit formation components, CVe, index b, d, t and r, establish similarity between the variables, mainly due to the influence of the CVe and the difference to be detected - d, since it configures a direct relationship between the variability of the data and the size of the plot (Smith, 1938; Hatheway, 1961), a fact supported in several studies (Schmildt et al., 2016; Sousa et al., 2016; Lavezo et al., 2017; Cargnelutti Filho et al., 2018). However, the lower required experimental accuracy - d, implies reduced BEUs.

Among the factors for dimensioning the basic experimental units, the number of replicates stands out with singular importance, as it directly reflects the accuracy and the experimental arrangement to be used. For this parameter, there is a direct effect between the increase in number of replicates and the decrease in plot size. On the other hand, the increase in the number of treatments showed no similar effect. While the addition of two replicates, from four to six, decreased the base units by 38.71% (151.62 to 92.92 BEU), the increase from five to 20 treatments reduced only 10% the basic units, 151.62 to 135.98 BEU, for green mass yield (Table 1).

With this practice, it is possible to achieve greater experimental efficiency in the detection of percentage differences between treatments with smaller plots and greater number of replications, instead of larger plots and fewer replicates (Sousa et al., 2016). Cargnelutti Filho et al. (2016) argue that the increase in number of replicates is effective to enhance experimental accuracy, provided that the soil heterogeneity index ($b < 0.2$) is observed.

Also, in relation to plant height, number of cladodes, total area of cladodes and yield of green mass, it can be highlighted, in this order, a reduction of 47.19; 43.92; 41.74 and 38.71% in the number of BEUs, respectively, by adding two replicates, from four to six (Table 1). This same analysis, for thickness, length, area and cladodes width, showed decreases of the BEUs similar to the direct variables, with values of 31.73; 38.28; 35.60 and 33.20%, respectively (Table 1).

Low expression was observed in the reduction of the BEU by increasing the number of treatments, with similar mean values for all evaluated characteristics. However, when analyzing the addition of treatments by replicate category, there was a decrease in treatment effect with increasing number of replicates, with mean reduction values of 11.64, 8.83 and 7.21% of the BEUs for the four, five and six replicate levels, sequentially.

The vegetative variables plant height and cladode area (Table 1), when subjected to an increase in the number of replicates, from four to six, presented the best adjustments in the decrease of plots, 45.39 to 23.97 and 7.50 to 4.83 basic units, in that order. A similar efficacy was also found by several researchers (Oliveira et al., 2011; Sousa et al., 2016; Donato et al., 2018).

For yield, the experimental evaluation with 15 (Queiroz et al., 2015), 32 (Silva et al., 2016) and 36 basic units (Padilha Junior et al., 2016) are frequently carried out in experiments with cactus pear. However, Donato et al. (2018) describe that excessive size, especially without focus on the tested effect, maximizes costs in implementation of the experiment, without significant gains in experimental accuracy. Nevertheless, plots equivalent to $^1/_2$, $^1/_4$ and $^1/_5$ of the aforementioned sizes, respectively, provide the same accuracy, with expressive optimization of the experimental resources.

These and other relationships with the studied variables can be observed in Figure 3 and 4, with the arrangements of five and 10 treatments and five replicate levels, three, four, five, six and 10, even for the most discrepant descriptors - yield of green mass (Figure 3) and mean cladode thickness (Figure 4).

Differences of 50, 30 and 15% between treatment means can be detected with two, five and eight basic units, respectively (Figure 3 and 4). However, significant differences below 15% are not achieved with the increase in the number of BEUs, or even, little effect is set on distinguishing treatments with the addition of BEUs. For the analyzed variables, plots larger than eight BEUs do not guarantee experimental accuracy.

Regarding yield, height, number of cladodes and total area of cladodes, the plots with eight BEUs allow to visualize, in this order, 11 ± 0.4, 5.2 ± 1.2, 10 ± 3 and 10 ± 3% of variation between treatment means. The intraclass variation ($\pm$) occurs as a function of the number of replicates to be adopted in the experiment (Figure 3).

As for the characteristics length, width and thickness of the cladode, high stability is observed for the first variables, and low uniformity for the latter (Table 1). This phenotypic behavior has a direct influence on the size of the plot to be used in the field, in addition to allowing the researcher to detect smaller (length - 6.89% and width - 8.03%) or larger (thickness – 28.96%) differences, for the same number of BEUs (Figure 4).

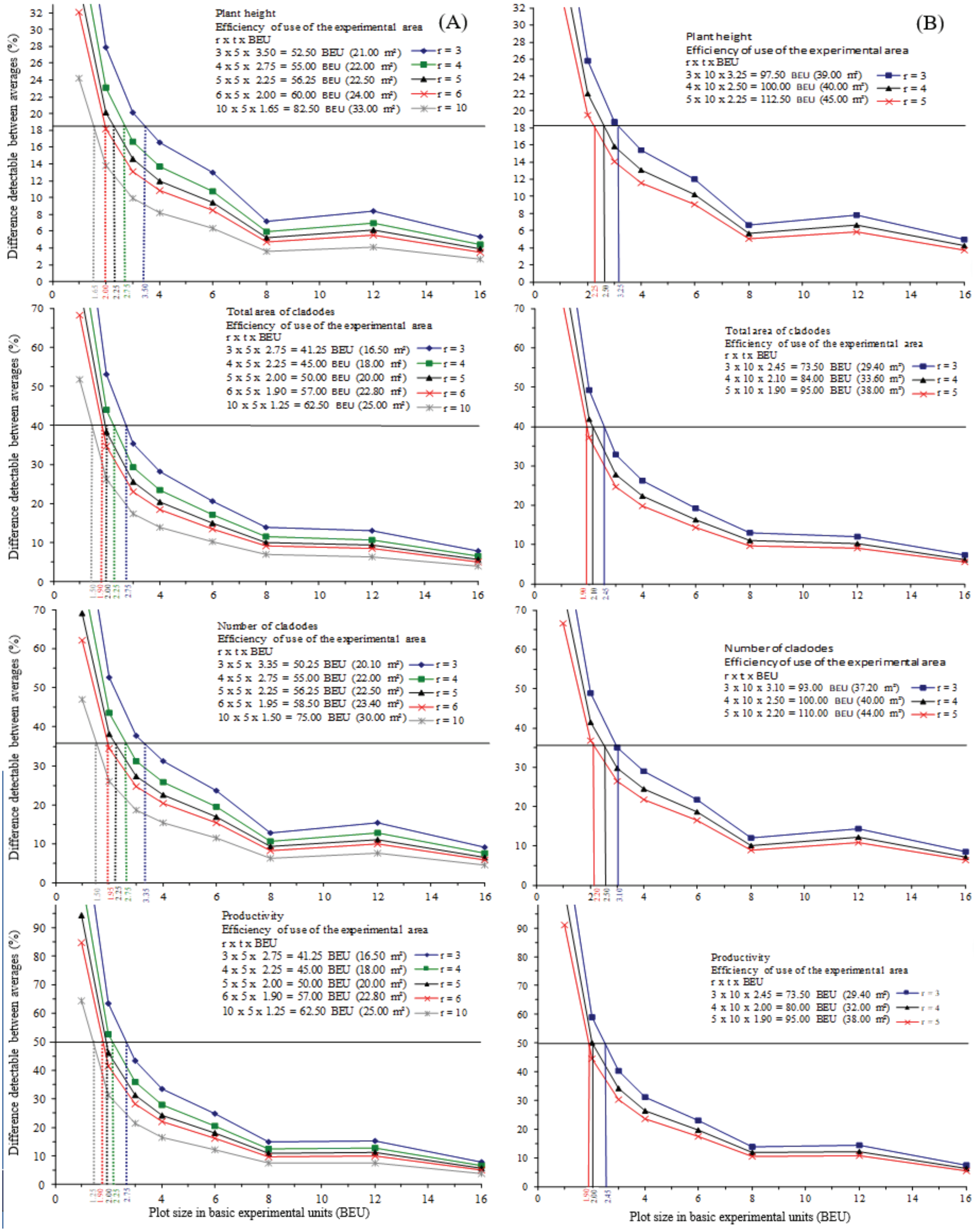

Figure 3. Relationship between plot size and detectable difference between two treatments (% of means), with five replicate options and five treatments (A) and three replicate options and ten treatments (B), for the characteristics plant height, total area of cladodes, number of cladodes and yield, evaluated in the third production cycle in 'Gigante' cactus pear.

For the aforementioned variables, when setting the size of the BEUs at eight, it is possible to obtain minimum differences between treatment means of 1.8 ± 0.4, 1.2 ± 0.4 and 15 ± 5%, for length, width and thickness of cladodes, respectively. The intraclass variation (±) occurs as a function of the number of replicates to be adopted in the experiment (Figure 4).

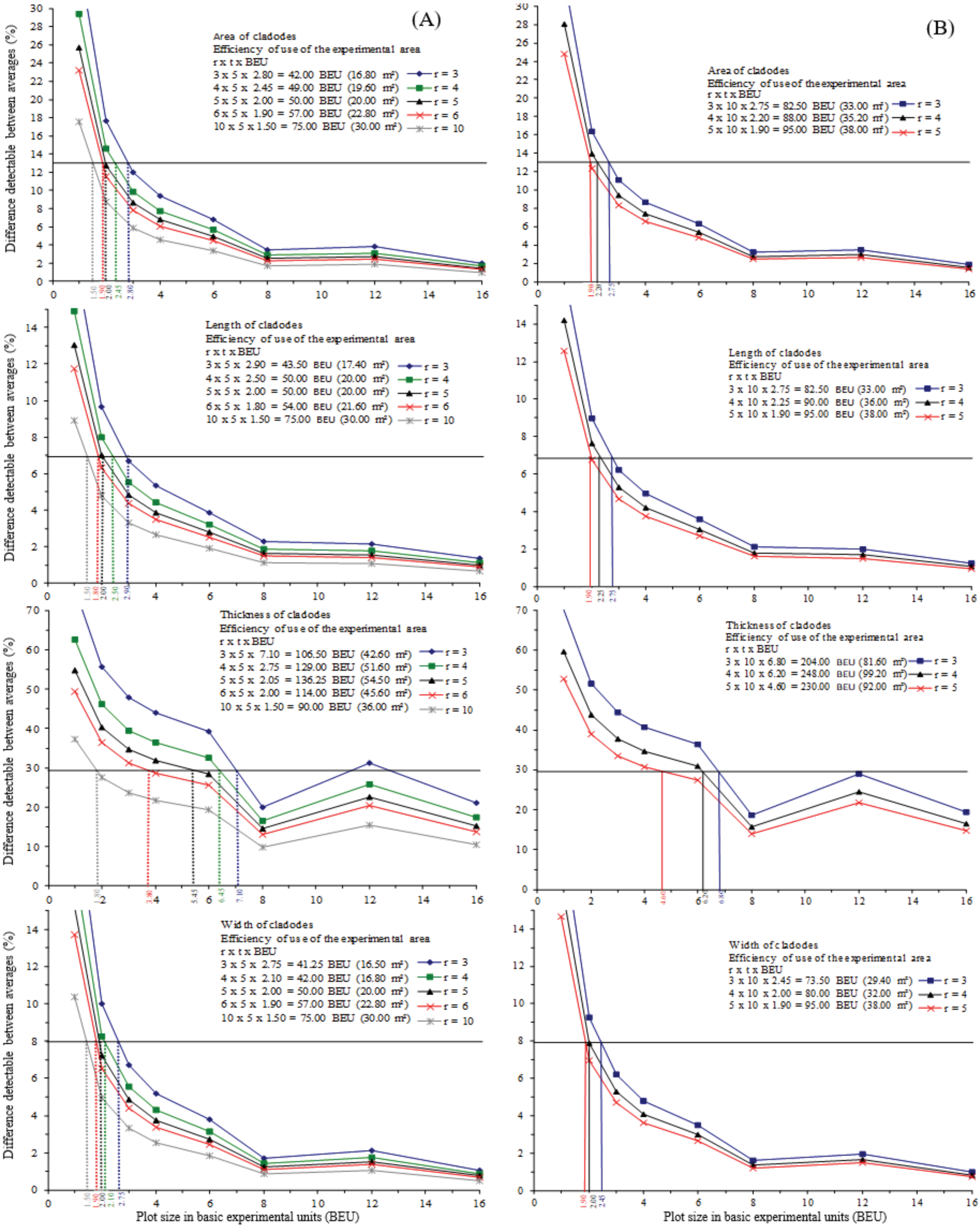

Figure 4. Relationship between plot size and detectable difference (% of means) between two treatments, with five replicate options and five treatments (A) and three replicate options and ten treatments (B), for the means of the characteristics cladode area, cladode length, cladode thickness and cladodes width, evaluated in the third production cycle of 'Gigante' cactus pear.

Table 1 and Figure 3 and 4 provide the researcher with information that is relevant to agricultural planning, especially as to the level of accuracy to be achieved in the experimental area, based on the arrangement between plot size and number of replicates. In order to select these statistical parameters, it should be observed the appropriate size of the unit to be evaluated, in terms of area, sampling, inputs, human and financial resources, as well as the requirements for number of degrees of freedom and residue (Pimentel-Gomes, 2009).

Furthermore, as a support for the diverse agricultural trials with *Opuntia* cactus pear, Figure 3 and 4 provide the analysis of the efficiency of use of the experimental area - EUEA. By means of this, the descriptors measured in the third production cycle were estimated. In this plan, the BEUs and the number of replicates were organized to detect a difference (d) of 50.13, 18.69, 36.50 and 39.96% of the mean for the variables green mass yield, height, number of cladodes and total area of cladodes, respectively. With respect to the variables related to the cladode, the difference (d) of 13.58, 6.89, 28.96 and 8.03% of the mean for area, length, thickness and width were considered in this sequence. By the specificity of the methodology proposed by Hatheway (1961), the detectable difference between the means of the treatments should be greater than the CVe.

Conclusion

1) The numerous basic experimental units, obtained through combinations of plot size and number of replicates, allow the researcher efficient planning and experimental evaluations in *Opuntia* cactus pear.

2) Useful plots with eight basic units are considered efficient for experiments with cactus pear.

3) Larger plots (three BEU) with fewer replicates (three) or smaller plots (two BEU) with a higher number of replications (ten) can be selected with the same level of accuracy to evaluate the yield of 'Gigante' cactus pear.

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