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Plot size related to numbers of treatments and replications, and experimental precision in dwarf pigeon pea

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ABSTRACT: The aim of this study was to determine the optimum plot size to evaluate the fresh matter of aerial part of dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), in scenarios formed by combinations of numbers of treatments, number of replications, and precision levels. The fresh matter of aerial part was weighed on basic experimental units of 1 m × 1 m in three uniformity trials with size of 24 m × 12 m (288 m^2 in each trial). The soil heterogeneity index of Smith was estimated. Also, the optimum plot size was determined by Hatheway's method in scenarios formed by combinations of i treatments (i = 5, 10, 15, and 20), r replications (r = 3, 4, 5, 6, 7 8, 9, and 10), and d precision levels (d = 5%, 10%, 15%, 20%, 25%, and 30%). In experiments designed on randomized block design with 5 to 20 treatments and four replications, plots with 9 m^2 were enough to identify significant differences among treatments regarding the fresh matter of aerial part in dwarf pigeon pea at 5% probability of 30% of the experiment overall mean.

Key words: *Cajanus cajan* L., fresh matter of aerial part, uniformity trial, experimental design, cover crops.

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INTRODUCTION

The dwarf pigeon pea (*Cajanus cajan* (L.) Millsp) belongs to the Fabaceae family. It is a woody plant with annual or perennial cycle and height of 1 to 1.5 m. It is used as cover crop due to its nitrogen fixation capacity. Moreover, in some continents, such as Africa and Asia, it is used as feed and food (Castro 1984).

Studies with an important cultivar of dwarf pigeon pea (IAPAR 43, Aratã) focusing on aspects related to crop rotation (Ferrari Neto et al. 2012), soil compaction (Farias et al. 2013), influence on soil characteristics (Cardoso et al. 2014), and nitrogen fixation (Rufini et al. 2014) showed promising characteristics of this pea. Dwarf pigeon pea's fresh matter of 23.80 $t \cdot ha^{-1}$ at 92 days after sowing demonstrates its potential as a cover crop (Pereira et al. 2016).

In the area of Agricultural Sciences, it is important that field experiments are planned adequately in order to have reliability on research results. Thus, from the number of treatments and available experimental area, it is necessary to define the experimental design according to the homogeneity of the area. Subsequently, it is necessary to adjust the plot size and number of replications in order to obtain the desired experimental precision.

With data collected from basic experimental units (BEU) of uniformity trials (experiments without treatments), it is possible to estimate the coefficient of variation (CV) between BEU and the soil heterogeneity index (b) of Smith (1938). The optimum plot size (Xo) can be determined by the method of Hatheway (1961), according to experimental design, number of treatments, number of replications, and precision levels.

This approach has been used for crop traits, such as cassava (Viana et al. 2003), maize (Alves and Seraphin 2004), wheat (Henriques Neto et al. 2004), and common bean (Mayor-Durán et al. 2012). Moreover, it has also been used to evaluate the fresh matter of soil cover crops, such as velvet bean (Cargnelutti Filho et al. 2014a) and forage turnip (Cargnelutti Filho et al. 2014b). In addition, the plot size and number of replications for pigeon pea (cultivar 'BRS Mandarim') have been investigated by Santos et al. (2016). It is possible that the experimental design for cultivar 'IAPAR 43 (Aratã)' is distinct from the one for cultivar 'BRS Mandarim', mainly by the distinct height of these cultivars.

The aim of this study was to determine the optimum plot size to evaluate the fresh matter of aerial part of dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), in scenarios formed by combinations of numbers of treatments, number of replications, and precision levels.

MATERIAL AND METHODS

Three uniformity trials (experiments without treatments, in which the crop and all procedures performed during the experiment are homogeneous in the experimental area) were carried out with dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), in an area of 30 m × 54 m (1620 m^2) located in southern Brazil at lat 29º42'S, long 53º49'W, and altitude of 95 m. According to Köppen climate classification, the climate is Cfa, humid subtropical with warm Summers and without a dry season defined (Heldwein et al. 2009).

Each uniformity trial was carried out on an experimental area of 30 m × 18 m (540 m^2). Basic fertilization of 25 $kg \cdot ha^{-1}$ of N, 100 $kg \cdot ha^{-1}$ of P_2O_5, and 100 $kg \cdot ha^{-1}$ of K_2O (only NPK in proportion of 05-20-20) and sowing were performed on January 13, 2016. The area one, 30 m × 18 m (uniformity trial one), was sown with broadcast sowing; areas two, 30 m × 18 m (uniformity trial two), and three, 30 m × 18 m (uniformity trial three), were sown with row sowing. There was a 0.5 m spacing between rows. As recommended for uniformity trials by Storck et al. (2016), cultural practices were carried out homogeneously in the experimental area.

In each uniformity trial, the central area with size of 24 m × 12 m (288 m^2) was divided into 288 BEU of 1 m × 1 m, forming a matrix with 24 rows and 12 columns. In the crop flowering period – i.e., on April 16, 2016 (94 days after broadcast sowing) for uniformity trial one, on April 16, 2016 (94 days after row sowing) for uniformity trial two, and on April 30, 2016 (108 days after row sowing) for uniformity trial three –, the plants were cut at the soil surface in each BEU of 1 m^2. Hereafter, the fresh matter of aerial part (FM) was obtained by weighing in $g \cdot m^{-2}$. The number of plants was counted in each BEU. The plant density obtained was 322,535 $plants \cdot ha^{-1}$, 191,181 $plants \cdot ha^{-1}$, and 180,868 $plants \cdot ha^{-1}$, for uniformity trials one, two, and three, respectively.

In each uniformity trial, plots with X_R adjacent BEU in the row and X_C adjacent BEU in the column were designed based on FM data of 288 BEU. The plots with different sizes and/or shapes were designed as ($X = X_R \times X_C$), i.e., (1×1), (1×2), (1×3), (1×4), (1×6), (2×1), (2×2), (2×3), (2×4), (2×6), (3×1), (3×2), (3×3), (3×4), (3×6), (4×1), (4×2), (4×3), (4×4), (4×6), (6×1), (6×2), (6×3), (6×4), (6×6), (8×1), (8×2), (8×3), (8×4), (8×6), (12×1), (12×2), (12×3), (12×4), and (12×6). Abbreviations X_R, X_C and X represent respectively the number of adjacent BEU in the row, number of adjacent BEU in the column, and plot size in number of BEU.

Hereafter, n – number of plots with X BEU of size (n = 288/X), $M_{(X)}$ – mean of plots with X BEU of size, $V_{(X)}$ – variance between plots with X BEU of size, $CV_{(X)}$ – coefficient of variation (in percentage) between plots with X BEU of size, and $VU_{(X)}$ – variance by BEU between plots with X BEU of size [$VU_{(X)} = V_{(X)}/X^2$] – were determined for each plot size (X).

Subsequently, two parameters were estimated: V1 (estimate of variance by BEU between plots with one BEU size) and b (estimate of soil heterogeneity index). Moreover, the coefficient of determination (r^2) of the function $VU_{(X)} = V1/X^b$ of Smith (1938) was also determined. These parameters were estimated by logarithmic transformation and, consequently, linearization of the function $VU_{(X)} = V1/X^b$, i.e., $\log VU_{(X)} = \log V1 - b \log X$, whose estimation is weighed by the degrees of freedom (DF = n-1) associated to each plot size. The observed values of dependent [$VU_{(X)}$] and independent (X) variables and the function $VU_{(X)} = V1/X^b$ (Smith 1938) were plotted.

Experimental designs were simulated in a randomized block design (commonly used in field experiments) for scenarios formed by combinations of i treatments (i = 5, 10, 15, and 20), r replications (r = 3, 4, 5, 6, 7, 8, 9, and 10), and d differences between treatment means, detected as significant at 5% probability and expressed as a percentage of the mean, i.e., different precision levels (d = 5%, 10%, 15%, 20%, 25%, and 30%). In this case, d = 5% indicates more precision and the other extreme d = 30% indicates smaller precision.

Xo was calculated, in number of BEU (rounded to the greater whole number), using the Equation 1 (Hatheway 1961):

$$Xo = \sqrt[b]{2(t_1 + t_2)^2 CV^2 / r d^2} \quad (1)$$

where b is the estimate of soil heterogeneity index; t_1 is the critical value of Student's t distribution for the significance level of the test (type I error) of α = 5% (5% of two-tailed test) with DF; t_2 is the critical value of Student's t distribution, corresponding to 2(1-P) (two-tailed test), P is the probability of obtaining significant result, i.e., the test power (P = 0.80, in this study), with DF; CV is the estimate of coefficient of variation between plots of one BEU size, in percentage; r is the number of replications; and d is the difference between treatment means detected as significant at 5% probability and expressed as a percentage of the overall mean of the experiment (precision). The DF to obtain the critical values (tabulated) of Student's t distribution were obtained by the equation DF = (i-1)(r-1), where i is the number of treatments and r is the number of replications. In this study, values of t_1 and t_2 were obtained with Microsoft Office Excel® application, through the functions t_1 = INVT(0.05; DF) and t_2 = INVT(0.40; DF), respectively. Statistical analysis were performed using Microsoft Office Excel® application.

RESULTS AND DISCUSSION

The mean of the fresh matter of aerial part in dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), between 288 BEU of 1 m^2 in uniformity trial one (21.2776 $t \cdot ha^{-1}$) was higher than the means in uniformity trials two (15.4097 $t \cdot ha^{-1}$) and three (16.1748 $t \cdot ha^{-1}$) (Table 1). The greater plant density in uniformity trial one (322,535 $plants \cdot ha^{-1}$) when compared to uniformity trials two (191,181 $plants \cdot ha^{-1}$) and three (180,868 $plants \cdot ha^{-1}$) can explain the greater fresh matter values obtained in uniformity trial one. These elevated amounts of fresh matter similar to the 23.80 $t \cdot ha^{-1}$ obtained in study performed by Pereira et al. (2016) suggest proper growth and development of dwarf pigeon pea. Furthermore, they also reveal the importance of continuing studies on the feasibility of dwarf pigeon pea, cultivar IAPAR 43 (Aratã), use as a cover crop specie, as already performed by Ferrari Neto et al. (2012), Farias et al. (2013), Cardoso et al. (2014), and Rufini et al. (2014).

The CV of fresh matter of aerial part among the 288 BEU of 1 m^2 was 27.54%, 31.12%, and 33.28%, respectively, for uniformity trials one, two, and three (Table 1). These values were relatively higher than the CV of 21.78% observed in the evaluation of fresh matter of aerial part of velvet bean (Cargnelutti Filho et al. 2014a). Meanwhile, they were similar to the CV of 30.54% obtained by Pereira et al. (2016) in the evaluation of fresh matter of dwarf pigeon pea and other five cover crop species. Variability among the 288 BEU where the →

FM was evaluated is important to study the optimum plot size and it reflects the real conditions of field areas. Therefore, proper growth and development of dwarf pigeon pea plants in the three uniformity trials and the wide variability among the BEU provide credibility to this database for the proposed study.

Soil heterogeneity index (b) of Smith (1938) was 1.0474, 0.7716, and 0.8558, respectively, for trials one, two, and three

Table 1. Designed plot size ($X = X_R \times X_C$) in basic experimental units (BEU) with X_R adjacent BEU in the row and X_C adjacent BEU in the column; number of plots with X BEU of size (n = 288/X); mean of plots with X BEU of size [$M_{(X)}$], in grams; and coefficient of variation (in percentage) between plots with X BEU of size [$CV_{(X)}$]. Data of fresh matter of aerial part of dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), in three uniformity trials with 288 BEU of 1.00 m^2.

X_R	X_C	X	n	Uniformity trial one[1]		Uniformity trial two[2]		Uniformity trial three[3]	
				$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$
1	1	1	288	2127.76	27.54	1540.97	31.12	1617.48	33.28
1	2	2	144	4255.53	18.76	3081.94	21.92	3234.97	21.72
1	3	3	96	6383.29	15.14	4622.92	18.24	4852.45	18.26
1	4	4	72	8511.06	14.03	6163.89	15.85	6469.93	16.94
1	6	6	48	12766.58	10.61	9245.83	13.59	9704.90	11.55
2	1	2	144	4255.53	19.61	3081.94	22.45	3234.97	26.64
2	2	4	72	8511.06	12.80	6163.89	15.82	6469.93	16.62
2	3	6	48	12766.58	9.73	9245.83	12.83	9704.90	13.69
2	4	8	36	17022.11	8.72	12327.78	11.53	12939.86	13.31
2	6	12	24	25533.17	6.39	18491.67	10.16	19409.79	8.44
3	1	3	96	6383.29	17.44	4622.92	19.70	4852.45	24.98
3	2	6	48	12766.58	10.76	9245.83	13.96	9704.90	14.29
3	3	9	32	19149.88	7.64	13868.75	10.82	14557.34	12.02
3	4	12	24	25533.17	6.75	18491.67	9.87	19409.79	12.47
3	6	18	16	38299.75	3.73	27737.50	9.05	29114.69	7.36
4	1	4	72	8511.06	15.96	6163.89	18.70	6469.93	23.21
4	2	8	36	17022.11	10.37	12327.78	13.35	12939.86	12.96
4	3	12	24	25533.17	6.54	18491.67	10.51	19409.79	10.52
4	4	16	18	34044.22	6.21	24655.56	9.31	25879.72	11.04
4	6	24	12	51066.33	3.83	36983.33	8.85	38819.58	5.98
6	1	6	48	12766.58	14.52	9245.83	16.66	9704.90	22.46
6	2	12	24	25533.17	8.97	18491.67	12.28	19409.79	12.50
6	3	18	16	38299.75	5.92	27737.50	9.42	29114.69	9.43
6	4	24	12	51066.33	5.69	36983.33	8.81	38819.58	11.51
6	6	36	8	76599.50	2.25	55475.00	8.20	58229.38	6.25
8	1	8	36	17022.11	13.55	12327.78	15.13	12939.86	21.19
8	2	16	18	34044.22	8.63	24655.56	11.65	25879.72	10.40
8	3	24	12	51066.33	5.21	36983.33	9.48	38819.58	6.72
8	4	32	9	68088.44	5.29	49311.11	8.66	51759.44	9.46
8	6	48	6	102132.67	2.19	73966.67	8.37	77639.17	1.89
12	1	12	24	25533.17	11.75	18491.67	14.91	19409.79	21.00
12	2	24	12	51066.33	7.36	36983.33	11.48	38819.58	10.77
12	3	36	8	76599.50	4.50	55475.00	8.79	58229.38	6.76
12	4	48	6	102132.67	4.29	73966.67	8.63	77639.17	10.18
12	6	72	4	153199.00	2.13	110950.00	7.89	116458.75	3.23

[1]Uniformity trial one - broadcast sowing was carried out on January 13, 2016 and harvest in April 16, 2016; [2]Uniformity trial two - row sowing was carried out on January 13, 2016 and harvest in April 16, 2016; [3]Uniformity trial three - row sowing was carried out on January 13, 2016 and harvest in April 30, 2016.

(Figure 1). Alves and Seraphin (2004) have discussed that in the Equation 2 (Hatheway 1961),

$$Xo = \sqrt[b]{2(t_1 + t_2)^2 CV^2 / r d^2} \quad (2)$$

where b interferes differently in the estimate of Xo.

Visually, for the three uniformity trials, accentuated decreases of variance per BEU [$VU_{(X)}$] in plots of six BEU (6 m^2), intermediate decreases between six and 12 BEU, and stabilization trend with plots greater than 12 BEU (Figure 1) were observed. Similar behavior was observed in velvet bean (Cargnelutti Filho et al. 2014a) and forage turnip (Cargnelutti Filho et al. 2014b). Therefore, in order to evaluate the fresh matter of aerial part of dwarf pigeon pea, plots of up to 12 BEU (12 m^2) are suggested because the gain in experimental precision (decrease of $VU_{(X)}$) with incremental increases in plot sizes from 12 BEU was inexpressive.

In the three uniformity trials, Xo in BEU for a fixed number of treatments (i) and replications (r) increases with increased desired precision (d). With fixed number of i and d, Xo decreases with the increase in number of r. Meanwhile, with fixed values of r and d, there is a reduction of Xo with increased number of i (Table 2). These findings agree with inferences of Cargnelutti Filho et al. (2014 a,b). These authors explained that the larger the number of

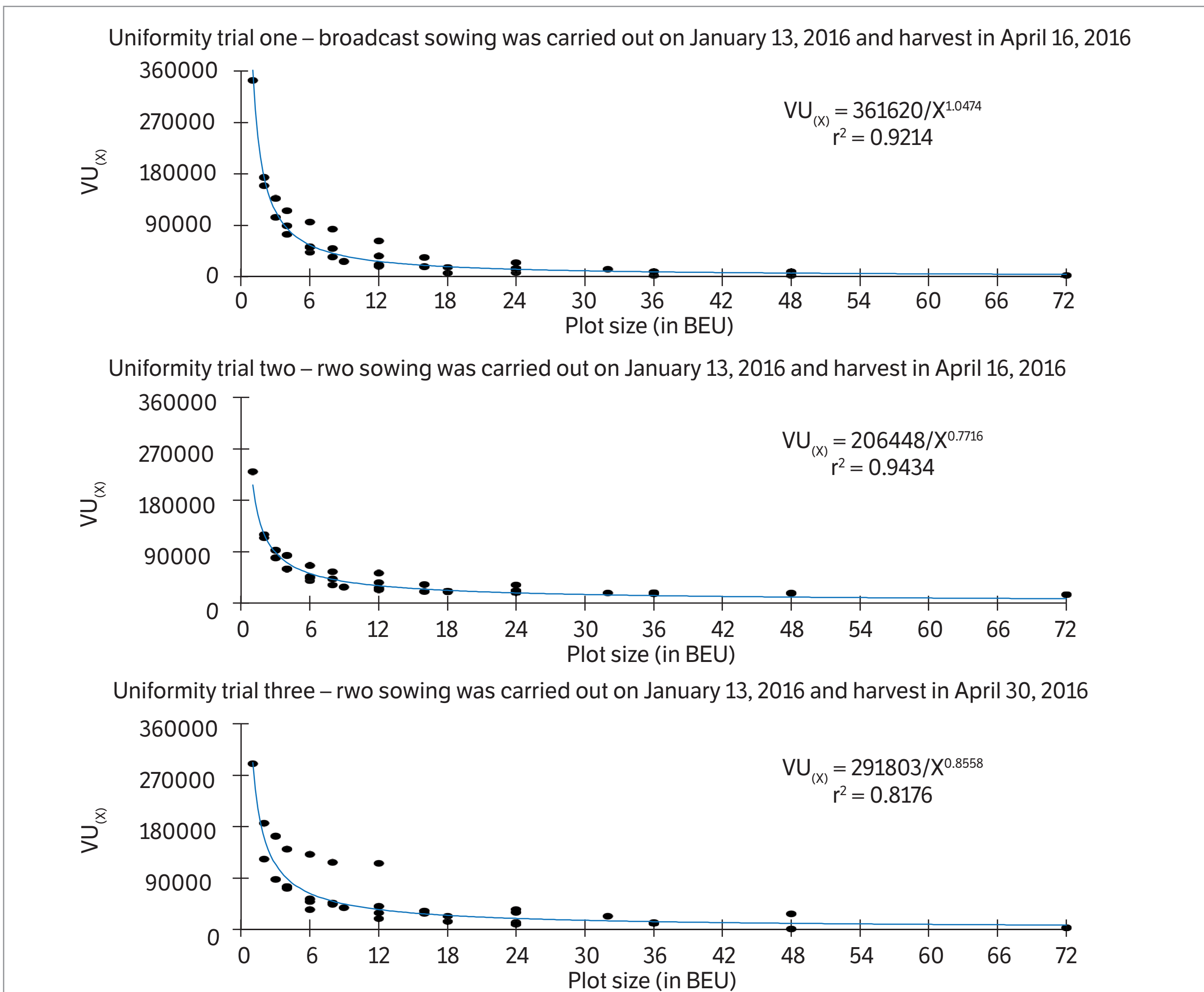

Figure 1. Graphical representation of the relation between the variance by basic experimental unit (BEU) among plots with X BEU size [$VU_{(X)} = V_{(X)}/X^2$] and the designed plot size (X) in BEU and estimates of the function parameters $VU(x) = V1/X^b$ of Smith (1938). Data of fresh matter of aerial part of dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), in three uniformity trials with 288 BEU of 1.00 m^2 in each trial.

Table 2. Optimum plot size (Xo) in basic experimental units of 1 m^2, estimated by Hatheway's method (1961), for experimental design in randomized blocks in scenarios formed by combinations of i treatments, r replications, and d differences between treatment means to be detected as significant at 5% probability, expressed as a percentage of the experiment overall mean (d = 5%, 10%, 15%, 20%, 25%, and 30%) for data of fresh matter of aerial part of dwarf pigeon pea (*Cajanus cajan* (L.) Millsp), cultivar IAPAR 43 (Aratã), in three uniformity trials.

i	r	Uniformity trial one[1]						Uniformity trial two[2]						Uniformity trial three[3]					
		5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%	5%	10%	15%	20%	25%	30%
5	3	163	44	20	12	8	6	1373	228	80	38	22	14	789	157	61	31	19	12
5	4	113	31	14	8	6	4	840	140	49	24	13	9	507	101	39	20	12	8
5	5	88	24	11	7	5	3	594	99	35	17	10	6	371	74	29	15	9	6
5	6	72	20	9	6	4	3	453	76	27	13	7	5	291	58	23	12	7	5
5	7	61	17	8	5	3	2	363	61	22	10	6	4	238	48	19	10	6	4
5	8	53	15	7	4	3	2	301	50	18	9	5	3	201	40	16	8	5	4
5	9	47	13	6	4	3	2	255	43	15	8	4	3	173	35	14	7	5	3
5	10	43	12	6	3	2	2	221	37	13	7	4	3	152	31	12	6	4	3
10	3	141	38	18	10	7	5	1130	188	66	32	18	11	662	131	51	26	16	11
10	4	103	28	13	8	5	4	741	123	43	21	12	8	453	90	35	18	11	7
10	5	82	22	11	6	4	3	541	90	32	15	9	6	341	68	27	14	8	6
10	6	68	19	9	5	4	3	421	70	25	12	7	5	272	54	21	11	7	5
10	7	59	16	8	5	3	2	342	57	20	10	6	4	226	45	18	9	6	4
10	8	51	14	7	4	3	2	286	48	17	8	5	3	192	38	15	8	5	3
10	9	46	13	6	4	3	2	244	41	15	7	4	3	166	33	13	7	4	3
10	10	41	11	6	3	2	2	212	36	13	6	4	3	147	29	12	6	4	3
15	3	136	36	17	10	7	5	1071	178	63	30	17	11	631	125	49	25	15	10
15	4	101	27	13	8	5	4	715	119	42	20	12	7	439	87	34	18	11	7
15	5	81	22	10	6	4	3	528	88	31	15	9	6	333	66	26	14	8	6
15	6	67	18	9	5	4	3	413	69	24	12	7	4	267	53	21	11	7	5
15	7	58	16	8	5	3	2	336	56	20	10	6	4	222	44	18	9	6	4
15	8	51	14	7	4	3	2	282	47	17	8	5	3	189	38	15	8	5	3
15	9	45	12	6	4	3	2	241	40	14	7	4	3	165	33	13	7	4	3
15	10	41	11	5	3	2	2	210	35	13	6	4	3	145	29	12	6	4	3
20	3	133	36	17	10	7	5	1045	174	61	29	17	11	617	123	48	25	15	10
20	4	100	27	13	8	5	4	704	117	41	20	11	7	432	86	34	17	11	7
20	5	80	22	10	6	4	3	521	87	31	15	9	6	330	66	26	13	8	6
20	6	67	18	9	5	4	3	409	68	24	12	7	4	265	53	21	11	7	5
20	7	58	16	8	5	3	2	333	56	20	10	6	4	221	44	17	9	6	4
20	8	51	14	7	4	3	2	280	47	17	8	5	3	188	38	15	8	5	3
20	9	45	12	6	4	3	2	240	40	14	7	4	3	164	33	13	7	4	3
20	10	41	11	5	3	2	2	209	35	13	6	4	3	145	29	12	6	4	3

[1]Uniformity trial one - broadcast sowing was carried out on January 13, 2016 and harvest in April 16, 2016; [2]Uniformity trial two - row sowing was carried out on January 13, 2016 and harvest in April 16, 2016; [3]Uniformity trial three - row sowing was carried out on January 13, 2016 and harvest in April 30, 2016.

treatments and number of replications, the greater is the number of degrees of freedom of error and, consequently, the lower is the estimate of the residual variance (mean square error), i.e., the greater is the experimental precision.

Among the uniformity trials for the same i, r, and d, Xo was decreasing in the following order: trial two, trial three, and trial one (Table 2). Thus, opting for the experimental design based on trial two (greater plot size) is an appropriate procedure. For example, in order to evaluate the FM in an experiment with five treatments (i = 5) and three replications (r = 3), aiming that in 80% of the experiments (power = 0.80) differences among treatments (d = 30%) of the experiment overall mean (lower precision) are detected as significant at 5% probability, the plot size should be 14 BEU (14 m^2). This plot size is suitable in field experiments but the experimental precision is low. Thus, in these same conditions, at the other extreme, plots with 1373 BEU (1373 m^2) would be necessary for d = 5% (greater precision). The experimental precision is greater in this situation but performing a field experiment with plot size of 1373 m^2 is impracticable. Therefore, high experimental precisions (low percentages of d) are difficult to obtain due to the elevated plot size (Cargnelutti Filho et al. 2014 a,b).

The method of Hatheway (1961) is based on the fixed value of the soil heterogeneity index (b) of Smith (1938); Xo is dependent on the number of treatments (i), number of replications (r), and precision (d). Therefore, based on the number of treatments and the desired precision, a researcher can use the information from this study to plan the plot size and number of replications to be used. For example, if the researcher wants to evaluate the FM of ten treatments with precision of 25%, among the various options, plots of 18 BEU (18 m^2) and three replications, 12 BEU (12 m^2) and four replications, 9 BEU (9 m^2) and five replications, or 7 BEU (7 m^2) and six replications can be used (Table 2). In these four options, the experimental area would be respectively 540, 480, 450, and 420 m^2. Thus, for the same precision (d = 25% in this case), smaller plots and more replications are more efficient in the experimental area use, as discussed in Alves and Seraphin (2004), Henriques Neto et al. (2004), Cargnelutti Filho et al. (2014 a,b), and Storck et al. (2016). It is important to consider that with increased number of replications, larger number of evaluations are required, and being the trait difficult to measure and/or of high cost to be assessed, the use of larger plot sizes and lower replications can be advantageous, as there is enough experimental area. Therefore, the researcher should investigate considering the available experimental area, the number of treatments to be evaluated, and the desired precision, which combination of plot size and number of replications is more appropriate.

The information provided in this study enable these investigations for 192 scenarios consisting of combinations of i treatments (i = 5, 10, 15, and 20), r replications (r = 3, 4, 5, 6, 7, 8, 9, and 10), and d differences among treatment means to be detected as significant at 5% probability (d = 5%, 10%, 15%, 20%, 25%, and 30%) (Table 2). Alternatively, from uniformity trial two, other scenarios can be simulated by the Eq. 3 (Hatheway 1961) based on the estimates of b = 0.7716 index of soil heterogeneity of Smith (1938) (Figure 1) and on the coefficient of variation (CV = 31.12%) among the 288 BEU (Table 1).

$$Xo = \sqrt[b]{2(t_1 + t_2)^2 CV^2 / r d^2} \quad (3)$$

For example, in order to evaluate the FM of eight treatments with four replications, and d = 25% in a randomized block design (RBD), it is obtained: b = 0.7716; DF = (8-1)(4-1) = 21; t_1 = INVT(0.05;21) = 2.07961383; t_2 = INVT(0.40;21) = 0.85907403; CV = 31.12%; r = 4; and d = 25%. Therefore:

$$Xo = \sqrt[0.7716]{2(2.07961383 + 0.85907403)^2 31.12^2 / 4 \times 25^2} = \\ = 11.74 \cong 12 \ \text{BEU} \quad (4)$$

In order to simulate scenarios in a completely randomized design (CRD), only the equation for calculating the number of degrees of freedom changes, i.e., for this design, DF = i(r-1), where i is the number of treatments and r is number of replications. For this example: b = 0.7716; DF = (8)(4-1) = 24; t_1 = INVT(0.05;24) = 2.06389854; t_2 = INVT(0.40;24) = 0.85685545; CV = 31.12%; r = 4; and d = 25%. Thus:

$$Xo = \sqrt[0.7716]{2(2.06389854 + 0.85685545)^2 31.12^2 / 4 \times 25^2} = \\ = 11.55 \cong 12 \ \text{BEU} \quad (5)$$

CONCLUSION

In experiments designed on randomized block design with 5 to 20 treatments and four replications, plots with 9 m^2 are enough to identify significant differences among treatments regarding the fresh matter of aerial part in dwarf pigeon pea at 5% probability of 30% of the experiment overall mean.

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