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Optimal plot size in single or intercropping sorghum and showy rattlebox

Alberto Cargnelutti Filho[1]*, Ismael Mario Márcio Neu[1], Vinicius Severo Trivisiol[1], Lucas Fillipin Osmari[1], Vithória Morena Ortiz[1]

[1] Universidade Federal de Santa Maria, Santa Maria, RS, Brasil, E-mail: alberto.cargnelutti.filho@gmail.com; ismaelmmneu@hotmail.com; vinicius_trivisiol@hotmail.com; lucasfosmari@gmail.com; vithoria.ortiz159@gmail.com

ABSTRACT: The objective of this study was to determine the optimal plot size to evaluate fresh matter productivity of sorghum (*Sorghum bicolor* (L.) Moench) and showy rattlebox (*Crotalaria spectabilis* Roth.). Fifteen uniformity trials (blank experiments) with sorghum and showy rattlebox, in single or intercropping, were carried out. The fresh matter productivity was evaluated in 540 basic experimental units (BEU) of 1 × 1 m (15 trials × 36 BEU per trial). The plot size was determined by the method of Hatheway (1961), in scenarios formed by combinations of treatment numbers, repetitions numbers, and levels of experimental precision. To evaluate the fresh matter productivity of sorghum and showy rattlebox, in single or intercropping, with 5 to 30 treatments and with five repetitions, plots of 10 m² of useful area are sufficient for differences between treatments of 24% of the overall average of the experiment to be considered significant at 0.05 probability.

Key words: *Crotalaria spectabilis* Roth.; experimental dimensions; soil cover crop; *Sorghum bicolor* (L.) Moench.

Tamanho ótimo de parcela em cultivo solteiro e consorciado de sorgo e crotalária spectabilis

RESUMO: O objetivo deste trabalho foi determinar o tamanho ótimo de parcela para avaliar a produtividade de matéria fresca de sorgo (*Sorghum bicolor* (L.) Moench) e crotalária spectabilis (*Crotalaria spectabilis* Roth.). Foram realizados quinze ensaios de uniformidade (experimentos em branco) com sorgo e crotalária spectabilis, em cultivo solteiro e consorciado. Foi avaliada a produtividade de matéria fresca em 540 unidades experimentais básicas (UEB) de 1 × 1 m (15 ensaios × 36 UEB por ensaio). Foi determinado o tamanho de parcela, por meio do método de Hatheway (1961), em cenários formados por combinações de números de tratamentos, números de repetições e níveis de precisão experimental. Para avaliar a produtividade de matéria fresca de sorgo e crotalária spectabilis, em cultivo solteiro ou consorciado, com 5 a 30 tratamentos e com cinco repetições, parcelas de 10 m² de área útil são suficientes para que diferenças entre tratamentos de 24% da média geral do experimento sejam consideradas significativas a 0,05 de probabilidade.

Palavras-chave: *Crotalaria spectabilis* Roth.; dimensionamentos experimentais; cultura de cobertura de solo; *Sorghum bicolor* (L.) Moench.

* Alberto Cargnelutti Filho - E-mail: alberto.cargnelutti.filho@gmail.com (Corresponding author)
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Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) and showy rattlebox (*Crotalaria spectabilis* Roth.) have been evaluated for phytomass production (Pereira et al., 2012; Torres et al., 2014; Santos et al., 2020), the interference of these species on corn and bean grain yields (Torres et al., 2014), and on soil chemical and physical attributes (Passos et al., 2017). In these surveys, the number of treatments evaluated ranged from six to fifteen. Four repetitions and plots of 37.5 m^2 (Pereira et al., 2012), 63 m^2 (Torres et al., 2014), and 50 m^2 (Passos et al., 2017) were used. However, the criteria used to define the plot size were not mentioned.

The plot size should be properly sized in order to minimize experimental error and, consequently, increase the accuracy of inferences regarding the treatments evaluated. Uniformity trials (blank experiments), that is, without treatments, make it possible to generate data for sizing in future experiments.

Methodologies from Smith (1938) and Hatheway (1961) can be applied to calculate the optimal plot size according to the number of treatments, number of repetitions, and experimental precision. These methodologies have been used in grain sorghum (Lopes et al., 2005; Brum et al., 2008), sunflower (Sousa et al., 2016), banana (Donato et al., 2018), forage palm (Guimarães et al., 2020), buckwheat (Cargnelutti Filho et al., 2020a), and tomato (Oliveira et al., 2021). It has still been used, in single and intercropped cultivation of black oat + vetch (Cargnelutti Filho et al., 2020b), millet + slender leaf rattlebox (Cargnelutti Filho et al., 2021a), millet + showy rattlebox (Cargnelutti Filho et al., 2021b), and intercropping of black oat + common vetch + forage turnip (Cargnelutti Filho et al., 2022).

Thus, the objective of this study was to determine the optimal plot size to evaluate the fresh matter productivity of sorghum (*S. bicolor* (L.) Moench) and showy rattlebox (*C. spectabilis* Roth.) in scenarios formed by combinations of treatment numbers, repetitions numbers, and levels of experimental precision.

Materials and Methods

Fifteen uniformity trials with sorghum (*S. bicolor* (L.) Moench) cultivar Nutribem (S) and showy rattlebox (*C. spectabilis* Roth.) (CS), were conducted in an experimental area located at 29º 42’ S, 53º 49’ W, and 95 m of altitude. The climate at this site is Cfa humid subtropical, according to the Köppen-Geiger classification, with hot summers and no dry season (Alvares et al., 2013). The soil is Arenic Dystrophic Red Argissolo (Santos et al., 2018).

The following compositions of sowing densities of S and CS crops were arranged: 100% of S (15 kg ha^{-1}); 75% of S (11.25 kg ha^{-1}) + 25% of CS (5.625 kg ha^{-1}); 50% of S (7.5 kg ha^{-1}) + 50% of CS (11.25 kg ha^{-1}); 25% of S (3.75 kg ha^{-1}) + 75% of CS (16.875 kg ha^{-1}); and 100% of CS (22.5 kg ha^{-1}). For each composition, three uniformity trials (repetitions) were conducted. On October 28, 2020, in all trials, 35 kg ha^{-1} of N, 135 kg ha^{-1} of P_2O_5, and 135 kg ha^{-1} of K_2O were incorporated into the soil, and then sowing was carried out by broadcast.

In each uniformity trial, a 6 × 6 m (36 m^2) area was demarcated. This area was divided into 36 basic experimental units (BEU) of 1 × 1 m (1 m^2), forming a matrix of six rows and six columns. At 79 days after sowing, when the sorghum plants were in flowering (reproductive stage) and the showy rattlebox plants in the vegetative stage, fresh matter (FM) productivity was evaluated. For this, in each BEU, the plants were cut near the soil surface and then the fresh matter was weighed on a digital scale (accuracy: 1 g), obtaining the FM in g m^{-2}.

With FM data from the 36 BEU, plots with X_R BEU adjacent in the row and X_C BEU adjacent in the column were planned. The plots with distinct sizes and/or shapes were planned as ($X = X_R \times X_C$), i.e., (1×1), (1×2), (1×3), (1×6), (2×1), (2×2), (2×3), (2×6), (3×1), (3×2), (3×3), (3×6), (6×1), (6×2), and (6×3). The abbreviations X_R, X_C, and X, stand for number of adjacent BEU in the row, number of adjacent BEU in the column, and plot size in number of BEU, respectively.

For each plot size (X) were determined: n - number of plots with X BEU size (n = 36/X); $M_{(X)}$ - average of the plots with X BEU size; $V_{(X)}$ - variance among plots of X BEU size; $CV_{(X)}$ - coefficient of variation (in %) among plots of X BEU size; and $VU_{(X)}$ – variance per BEU among the plots of X BEU size [$VU_{(X)} = V_{(X)}/X^2$].

The parameters V1 (variance per BEU among the plots of a BEU size), b (index of heterogeneity), and the coefficient of determination (r^2) of the function $VU_{(X)} = V1/X^b$ of Smith (1938) were estimated. These parameters were estimated by logarithmic transformation and linearization of the function $VU_{(X)} = V1/X^b$, i.e., $\log VU_{(X)} = \log V1 – b \log X$, whose estimation was weighted by the degrees of freedom (DF = n – 1), associated with each plot size, as applied by Sousa et al. (2016).

For each of the five compositions of sowing densities, 176 scenarios were planned formed by combinations of i treatments (i = 5, 10, 15, and 20), r repetitions (r = 3, 4, 5, and 6), and d differences between treatment averages to be detected as significant at 0.05 probability, expressed as a percentage of the overall average of the experiment, that is, in precision levels [d = 10 (highest precision), 12, 14, 16, 18, 20, 22, 24, 26, 28, and 30% (lowest precision)]. Subsequently, for the single crop composition of showy rattlebox (100% of CS) the scenarios for i = 25 and 30 and r = 7, 8, 9, and 10 were added, totaling 528 scenarios for this composition. In addition, for these 528 scenarios the experiment size was calculated.

For each scenario, the optimal plot size (Xo), in number of BEU, was calculated using the expression

$$Xo = \sqrt[b]{\frac{2(t_1 + t_2)^2 CV^2}{rd^2}} \quad (\text{Hatheway, 1961}).$$

In this expression b is the estimate of the soil heterogeneity index (in this study, for each composition, the average of b from the three uniformity trials was considered); t_1 is the critical value of Student t-distribution for the significance level of the test (type I error) of α = 5% (two-sided test at 5%), with DF degrees of freedom; t_2 is the critical value of Student t-distribution, corresponding to 2(1-P) (two-sided test), where P is the probability of obtaining a significant result, that is, the power of the test (P = 0.80, in this study), with DF degrees of freedom; CV is the estimate of the coefficient of variation among the plots of a BEU size (in this study, for each composition, the average CV of the three uniformity trials was considered), in percent; r is the number of repetitions; and d is the difference between treatment averages to be detected as significant at 0.05 probability, expressed as a percentage of the overall average of the experiment (precision). The degrees of freedom (DF) for obtaining the critical values (tabulated) of Student t-distribution were obtained by the expression DF = (i)(r-1), where i is the number of treatments and r is the number of repetitions. The values of t_1 and t_2 were obtained with the Microsoft Office Excel® application, using the functions t_1 = INVT(0.05;DF) and t_2 = INVT(0.40;DF), respectively. The statistical analyses were performed with the help of Microsoft Office Excel® application.

Results and Discussion

In the 15 uniformity trials, formed by compositions of sowing densities of sorghum (*S. bicolor* (L.) Moench) cultivar Nutribem (S) and showy rattlebox (*C. spectabilis* Roth.) (CS), the fresh matter (FM) productivity ranged between 2,174 and 4,016 g m^{-2}, i.e., 21.74 and 40.16 Mg ha^{-1}, respectively (Table 1).

The average of FM of the three intercrop compositions (3,413 g m^{-2}) did not differ from the average of the sorghum single crop (3,158 g m^{-2}; t = 0.905135; p-value = 0.386682; with 10 degrees of freedom) and was higher than the average of the showy rattlebox single crop (2,271 g m^{-2}; t = 4.042117; p-value = 0.002353; with 10 degrees of freedom). Among the single crops the FM of sorghum was higher than that of showy rattlebox (t = 7.114031; p-value = 0.002063; with 4 degrees of freedom).

For sorghum and showy rattlebox crops, 31.9 and 16.5 Mg ha^{-1} of FM were obtained by Torres et al. (2014), 25.74 and 33.9 Mg ha^{-1} by Passos et al. (2017), and 38.00 and 17.05 Mg ha^{-1} by Santos et al. (2020), respectively. Therefore, the superior FM ratio of sorghum, obtained in this study, was

Table 1. Planned plot size ($X = X_R \times X_C$), in basic experimental units (BEU), with X_R BEU adjacent in the row and X_C BEU adjacent in the column; number of plots with X BEU size (n = 36/X); average of the plots with X BEU size [$M_{(X)}$], in g; and coefficient of variation (in %) among plots of X BEU size [$CV_{(X)}$]. Fresh matter productivity data at sowing densities of sorghum (*Sorghum bicolor* (L.) Moench) (S) and showy rattlebox (*Crotalaria spectabilis* Roth.) (CS).

$E^{(1)}$	X_R	X_C	X	n	100% of S		75% of S + 25% of CS		50% of S + 50% of CS		25% of S + 75% of CS		100% of CS	
					$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$
1	1	1	1	36	3,044	18.08	3,497	22.47	3,077	27.26	2,604	37.28	2,174	31.09
1	1	2	2	18	6,088	15.51	6,993	18.55	6,154	20.33	5,207	27.93	4,348	17.95
1	1	3	3	12	9,131	12.71	10,490	10.16	9,231	20.88	7,811	24.51	6,523	21.10
1	1	6	6	6	18,263	8.63	20,980	9.07	18,462	7.85	15,622	18.95	13,045	10.70
1	2	1	2	18	6,088	16.16	6,993	20.25	6,154	25.04	5,207	25.16	4,348	27.69
1	2	2	4	9	12,175	13.84	13,987	17.20	12,308	18.82	10,415	15.57	8,697	15.15
1	2	3	6	6	18,263	12.28	20,980	8.57	18,462	19.69	15,622	13.30	13,045	19.18
1	2	6	12	3	36,526	8.14	41,961	8.42	36,923	4.00	31,244	7.25	26,091	11.49
1	3	1	3	12	9,131	9.73	10,490	18.43	9,231	23.93	7,811	24.88	6,523	26.38
1	3	2	6	6	18,263	6.65	20,980	17.46	18,462	18.16	15,622	13.46	13,045	15.37
1	3	3	9	4	27,394	6.86	31,471	10.20	27,693	19.78	23,433	11.59	19,568	19.64
1	3	6	18	2	54,789	3.08	62,941	10.66	55,385	7.17	46,866	3.44	39,136	12.30
1	6	1	6	6	18,263	5.50	20,980	15.51	18,462	22.69	15,622	17.12	13,045	24.56
1	6	2	12	3	36,526	5.18	41,961	15.70	36,923	18.86	31,244	6.13	26,091	11.50
1	6	3	18	2	54,789	5.33	62,941	0.92	55,385	23.10	46,866	13.77	39,136	19.83
2	1	1	1	36	3,321	19.13	3,616	18.54	2,966	23.50	3,324	29.78	2,183	26.61
2	1	2	2	18	6,643	10.35	7,231	15.69	5,933	17.12	6,648	20.78	4,365	22.04
2	1	3	3	12	9,964	10.18	10,847	11.40	8,899	16.57	9,972	15.80	6,548	16.24
2	1	6	6	6	19,928	6.70	21,693	11.51	17,798	9.29	19,943	14.79	13,096	14.04
2	2	1	2	18	6,643	16.26	7,231	14.51	5,933	17.26	6,648	25.88	4,365	20.60
2	2	2	4	9	13,285	8.00	14,462	13.84	11,865	15.27	13,295	18.89	8,730	16.34
2	2	3	6	6	19,928	8.80	21,693	9.55	17,798	15.62	19,943	14.35	13,096	10.91
2	2	6	12	3	39,855	5.38	43,386	10.23	35,596	6.62	39,886	15.30	26,191	9.15
2	3	1	3	12	9,964	13.61	10,847	12.91	8,899	16.47	9,972	23.49	6,548	17.90
2	3	2	6	6	19,928	7.13	21,693	11.46	17,798	13.79	19,943	17.23	13,096	14.15
2	3	3	9	4	29,892	7.13	32,540	2.47	26,697	14.56	29,915	11.33	19,644	10.44
2	3	6	18	2	59,783	5.48	65,080	2.25	53,394	4.28	59,829	13.21	39,287	11.02
2	6	1	6	6	19,928	11.26	21,693	11.07	17,798	13.55	19,943	21.66	13,096	15.50
2	6	2	12	3	39,855	6.23	43,386	11.32	35,596	13.63	39,886	14.94	26,191	12.14
2	6	3	18	2	59,783	5.01	65,080	0.76	53,394	16.57	59,829	4.24	39,287	6.29

Continued on next page

Continuation of Table 1

$E^{(1)}$	X_R	X_C	X	n	100% of S		75% of S + 25% of CS		50% of S + 50% of CS		25% of S + 75% of CS		100% of CS	
					$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$	$M_{(X)}$	$CV_{(X)}$
3	1	1	1	36	3,109	20.18	3,959	21.99	4,016	21.79	3,661	26.25	2,455	30.55
3	1	2	2	18	6,218	15.68	7,918	18.31	8,031	15.43	7,321	21.99	4,911	22.46
3	1	3	3	12	9,326	12.82	11,877	14.45	12,047	10.59	10,982	21.23	7,366	21.57
3	1	6	6	6	18,653	11.14	23,753	11.10	24,094	6.57	21,964	14.57	14,733	16.13
3	2	1	2	18	6,218	17.92	7,918	16.13	8,031	16.45	7,321	20.53	4,911	26.39
3	2	2	4	9	12,435	14.47	15,836	12.48	16,062	10.43	14,642	18.07	9,822	18.29
3	2	3	6	6	18,653	12.45	23,753	9.82	24,094	7.75	21,964	18.25	14,733	18.81
3	2	6	12	3	37,306	12.20	47,507	6.89	48,187	6.90	43,927	11.62	29,465	12.94
3	3	1	3	12	9,326	14.80	11,877	15.01	12,047	11.76	10,982	14.34	7,366	19.75
3	3	2	6	6	18,653	12.58	23,753	13.80	24,094	5.07	21,964	9.76	14,733	13.52
3	3	3	9	4	27,979	9.60	35,630	11.07	36,141	5.67	32,945	12.71	22,099	14.03
3	3	6	18	2	55,959	10.68	71,260	4.19	72,281	3.47	65,891	0.95	44,198	11.79
3	6	1	6	6	18,653	12.09	23,753	9.48	24,094	7.10	21,964	6.07	14,733	13.54
3	6	2	12	3	37,306	10.48	47,507	7.39	48,187	4.62	43,927	2.80	29,465	9.62
3	6	3	18	2	55,959	3.66	71,260	3.14	72,281	4.01	65,891	1.39	44,198	7.70

(1) Each uniformity trial of size 6.0 × 6.0 m (36.0 m^2) was divided into 36 BEU of 1.0 × 1.0 m (1.0 m^2), forming a matrix of six rows and six columns.

also observed by Torres et al. (2014) and Santos et al. (2020). On the other hand, Passos et al. (2017) found FM superiority of showy rattlebox. Also, Pereira et al. (2012) obtained 39.10 Mg ha^{-1} of FM of showy rattlebox. The fact that these studies were conducted under different environmental conditions, cultural management, and evaluation times makes comparisons with the results of this study difficult.

The coefficient of variation (CV) of FM, obtained among the 36 BEU in each of the 15 uniformity trials, ranged from 18.08 to 37.28%, with an average of 24.97% (Table 1). The averages of CV, from the three trials of each composition were 19.13, 21.00, 24.18, 31.10, and 29.42%, for the compositions of 100% of S; 75% of S + 25% of CS; 50% of S + 50% of CS; 25% of S + 75% of CS; and 100% of CS, respectively. Most of these coefficients are considered high according to Pimentel-Gomes (2009) classification, i.e., they are in the 20.0 to 30.0% range. In experiments with sorghum, showy rattlebox, and other species, CV of 39.78% (Pereira et al., 2012), 12.46% (Torres et al., 2014), 37.73% (Passos et al., 2017), and 16.33% (Santos et al., 2020) were obtained, therefore similar to those obtained in these 15 uniformity trials.

Smith (1938) heterogeneity index (b) ranged from 0.6042 to 1.2571 (Figure 1). The averages of b, from the three trials for each composition were 0.8179, 0.8514, 0.8350, 0.9899, and 0.7345 for the compositions of 100% of S, 75% of S + 25% of CS, 50% of S + 50% of CS, 25% of S + 75% of CS, and 100% of CS, respectively. Values of b close to unity were also obtained in grain sorghum (Lopes et al., 2005; Brum et al., 2008), sunflower (Sousa et al., 2016), forage palm (Guimarães et al., 2020), and in species with potential for ground cover, such as: buckwheat (Cargnelutti Filho et al., 2020a); black oat + vetch (Cargnelutti Filho et al., 2020b); millet + slender leaf rattlebox (Cargnelutti Filho et al., 2021a); millet + showy rattlebox (Cargnelutti Filho et al., 2021b); and black oat + common vetch + forage turnip (Cargnelutti Filho et al., 2022).

When $b > 0.7$, it is recommended to increase the plot size, when $b < 0.2$, one should increase the number of repetitions, and in cases of $0.2 \leq b \leq 0.7$ it is appropriate to investigate the best combination of plot size and number of repetitions (Lin & Binns, 1986). Therefore, the high values of b (Figure 1) indicate that sorghum and showy rattlebox experiments, in single or intercropping, should prioritize the use of larger plots.

With increasing the planned plot size (X), there was a decrease in the coefficient of variation [$CV_{(X)}$] and the variance per BEU among plots [$VU_{(X)}$] (Table 1 and Figure 1), which means improvement in experimental precision. Sharp decreases in $VU_{(X)}$ were observed with plots up to four BEU (4 m^2), intermediate between four and ten BEU, and a stabilizing trend with plots larger than ten BEU (10 m^2). Thus, it is suggested to use plots up to 10 m^2, because the gain in experimental precision (decrease of $VU_{(X)}$), from ten BEU, was inexpressive. Similar pattern was observed in buckwheat (Cargnelutti Filho et al., 2020a); black oat + common vetch (Cargnelutti Filho et al., 2020b); millet + slender leaf rattlebox (Cargnelutti Filho et al., 2021a); millet + showy rattlebox (Cargnelutti Filho et al., 2021b); and black oat + common vetch + forage turnip (Cargnelutti Filho et al., 2022).

In the five compositions of S and CS sowing densities, it is observed that with fixed values of i and r, Xo increased with increasing precision (d); with fixed values of i and d, Xo decreased with increasing r; and with fixed values of r and d, there was a decrease in Xo with increasing i (Figures 2 and 3). This pattern is in agreement with the results obtained by Cargnelutti Filho et al. (2020a, 2020b, 2021a, 2021b, 2022).

For fixed values of i, r, and d, the 100% of CS composition, with soil heterogeneity index b = 0.7345 and CV = 29.42%, showed larger plot sizes compared to the other compositions (100% of S; 75% of S + 25% of CS; 50% of S + 50% of CS; and 25% of S + 75% of CS) (Figures 2 and 3). Therefore, the results of this composition can be used as a reference for defining the plot size and number of repetitions, in order to ensure sufficient experimental precision for experiments with sorghum and showy rattlebox, in single and intercropping.

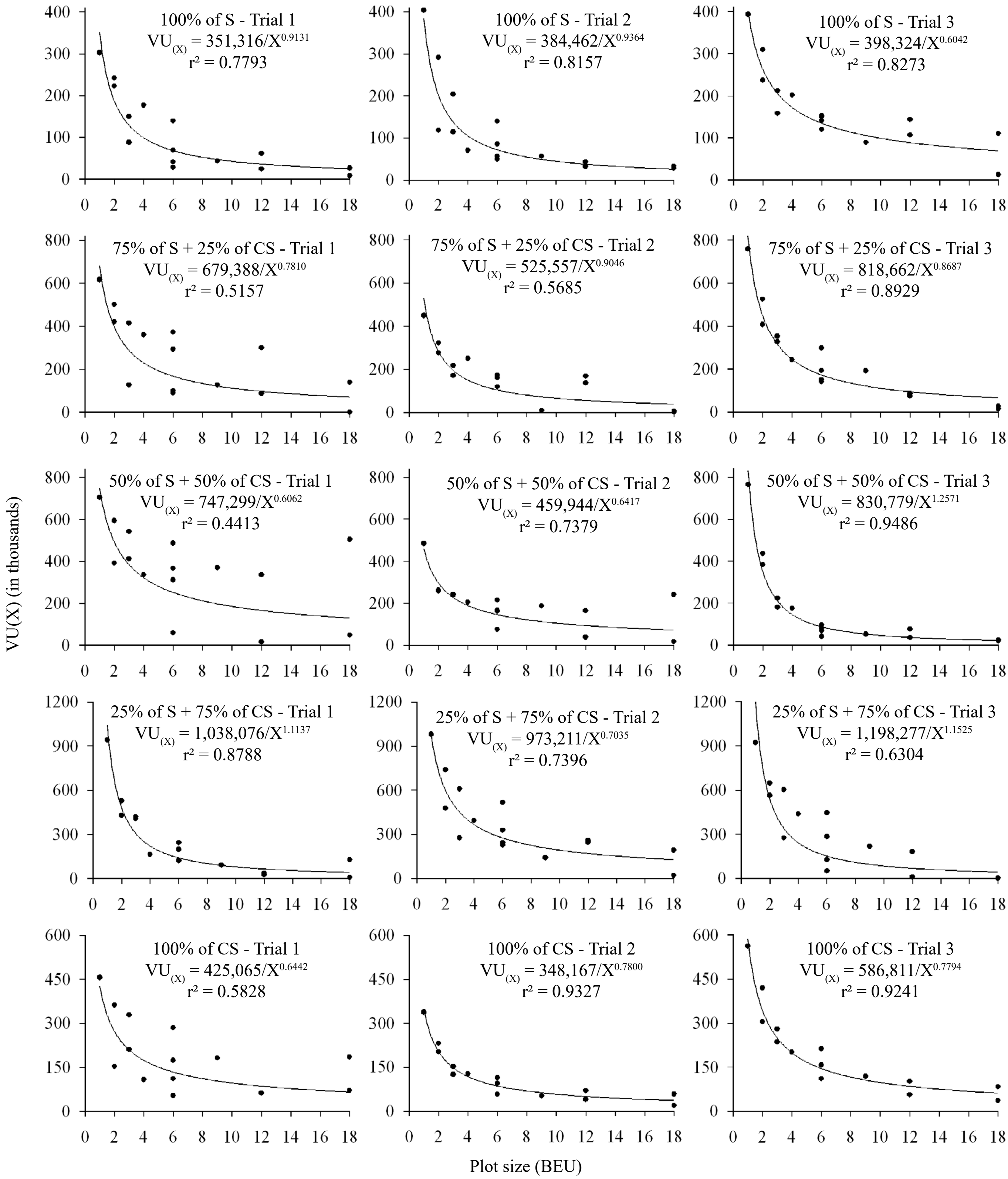

Figure 1. Relationship between the variance per basic experimental unit (BEU) between X BEU plot sizes [$VU_{(x)} = V_{(x)}/X^2$] and the planned plot size (X), in BEU, and the parameter estimates of the function $VU_{(x)} = V1/X^b$ of Smith (1938). Fresh matter productivity data obtained in uniformity trials, with 36 BEU of 1.0 m², formed by compositions of sowing densities of sorghum (*Sorghum bicolor* (L.) Moench) (S) and showy rattlebox (*Crotalaria spectabilis* Roth.) (CS).

In addition to the plot sizes, calculated for the combinations of i, r, and d (Figures 2 and 3), numerous other scenarios can be simulated using the expression

$$Xo = \sqrt[b]{\frac{2(t_1 + t_2)^2 CV^2}{rd^2}} \quad \text{(Hatheway, 1961)},$$

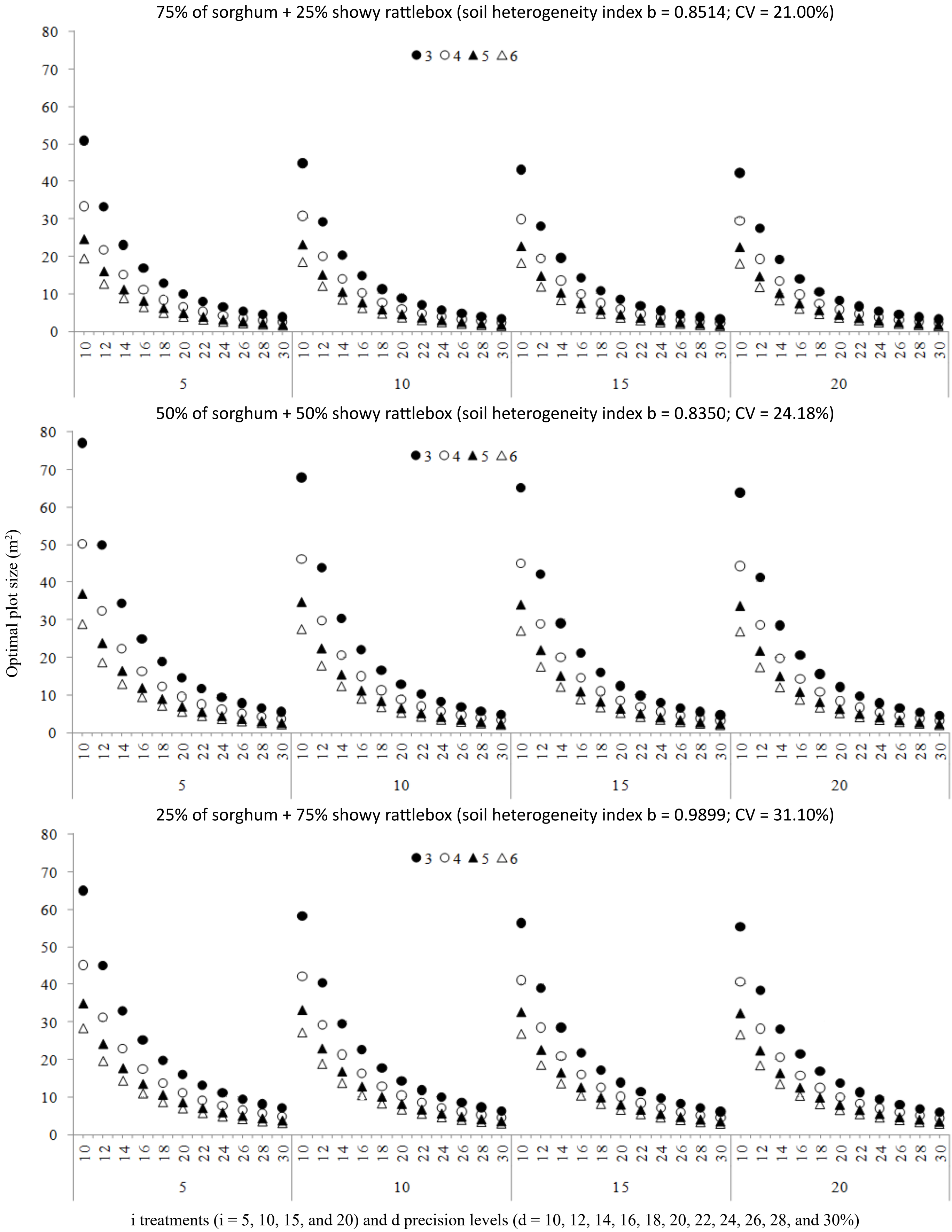

Figure 2. Optimal plot size, in m², for combinations of i treatments (i = 5, 10, 15, and 20), r repetitions (r = 3, 4, 5, and 6), and d precision levels (d = 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, and 30%), for the fresh matter productivity in intercrops of sorghum (*Sorghum bicolor* (L.) Moench) and showy rattlebox (*Crotalaria spectabilis* Roth.).

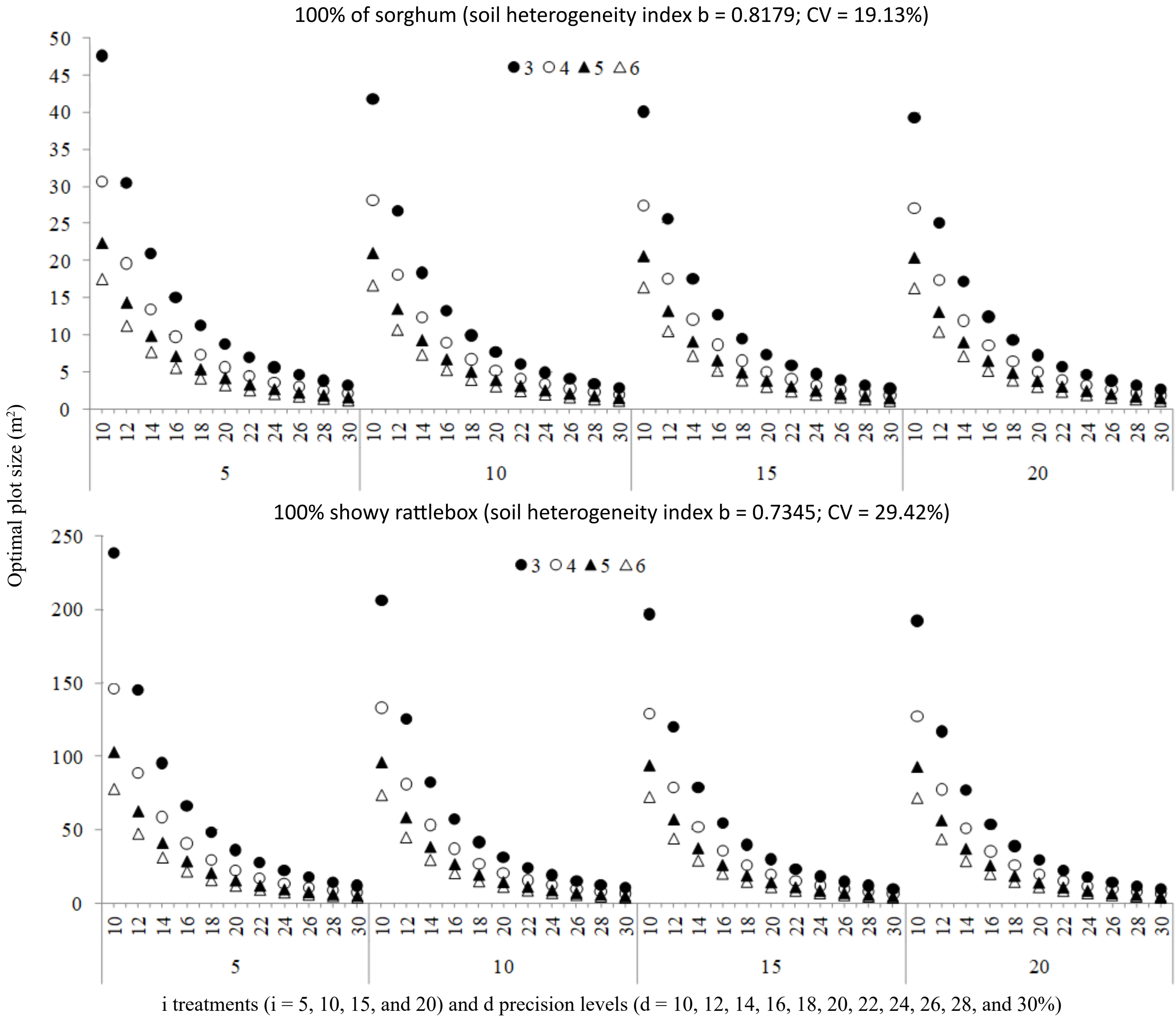

Figure 3. Optimal plot size, in m², for combinations of i treatments (i = 5, 10, 15, and 20), r repetitions (r = 3, 4, 5, and 6), and d precision levels (d = 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, and 30%), for fresh matter productivity in single crops of sorghum (*Sorghum bicolor* (L.) Moench) and showy rattlebox (*Crotalaria spectabilis* Roth.).

based on the average soil heterogeneity index (b) of the Smith (1938) function and the average coefficient of variation (CV) of FM, from the three trials of each composition. Thus, the following estimates would be used for the compositions: 100% of S (b = 0.8179; CV = 19.13%), 75% of S + 25% of CS (b = 0.8514; CV = 21.00%), 50% of S + 50% of CS (b = 0.8350; CV = 24.18%), 25% of S + 75% of CS (b = 0.9899; CV = 31.10%), and 100% of CS (b = 0.7345; CV = 29.42%) (Table 2).

As an example, to evaluate the FM of six treatments of the 100% of CS composition, with five repetitions and with d = 24%, one has: b = 0.7345; DF = (6)(5-1) = 24; t_1 = INVT(0.05;24) = 2.063898547; t_2 = INVT(0.40;24) = 0.856855458; CV = 29.42%; r = 5; d = 24%. Soon,

$$Xo = \sqrt[0.7345]{\frac{2\left(2.063898547 + 0.856855458\right)^2 29.45^2}{5 \times 24^2}} = 9.26 \text{ BEU.}$$

Therefore, using the criterion of rounding up to the next whole number, the plot size for this example would be 10 m². Following this example, 528 scenarios were generated and the optimal plot size and experiment size calculated to serve as a reference for planning future experiments (Table 2).

This size of 10 m² is relatively larger than those established for grain sorghum that were 3.2 m² (Lopes et al., 2005) and 0.5 m² (Brum et al., 2008), equal to the 10 m² established for the single and intercropped crops of black oat + common vetch (Cargnelutti Filho et al, 2020b), millet + slender leaf rattlebox (Cargnelutti Filho et al., 2021a), and millet + showy rattlebox (Cargnelutti Filho et al., 2021b). Additionally, this size of 10 m² is relatively smaller than those used in experiments with sorghum and showy rattlebox, along with other ground cover species, by Pereira et al. (2012), Torres et al. (2014), and Passos et al. (2017), which ranged between 37.5 and 63.0 m².

Table 2. Optimal plot and experiment sizes, in m², for combinations of i treatments, r repetitions, and d precision levels (%), for fresh matter productivity of single showy rattlebox (*Crotalaria spectabilis* Roth.), based on the soil heterogeneity index b = 0.7345 and CV = 29.42%.

		d (%)																					
i	r	10	12	14	16	18	20	22	24	26	28	30	10	12	14	16	18	20	22	24	26	28	30
		Optimal plot size (m²)											Experiment size (m²)										
5	3	238.3	145.0	95.3	66.3	48.1	36.1	27.8	22.0	17.7	14.4	12.0	3,574	2,175	1,430	994	721	541	418	329	265	217	179
	4	146.1	88.9	58.4	40.6	29.5	22.1	17.1	13.5	10.8	8.8	7.3	2,921	1,778	1,169	812	589	442	341	269	217	177	147
	5	102.8	62.6	41.1	28.6	20.7	15.6	12.0	9.5	7.6	6.2	5.2	2,570	1,564	1,028	715	519	389	300	237	191	156	129
	6	78.0	47.5	31.2	21.7	15.7	11.8	9.1	7.2	5.8	4.7	3.9	2,339	1,424	936	651	472	354	273	216	173	142	117
	7	62.1	37.8	24.8	17.3	12.5	9.4	7.3	5.7	4.6	3.8	3.1	2,172	1,322	869	604	438	329	254	200	161	132	109
	8	51.1	31.1	20.4	14.2	10.3	7.7	6.0	4.7	3.8	3.1	2.6	2,043	1,243	817	568	412	309	239	188	151	124	103
	9	43.1	26.2	17.2	12.0	8.7	6.5	5.0	4.0	3.2	2.6	2.2	1,939	1,180	776	539	391	294	227	179	144	117	97
	10	37.0	22.5	14.8	10.3	7.5	5.6	4.3	3.4	2.7	2.2	1.9	1,852	1,127	741	515	374	281	216	171	137	112	93
10	3	206.1	125.4	82.4	57.3	41.6	31.2	24.1	19.0	15.3	12.5	10.3	6,182	3,763	2,473	1,719	1,247	936	722	570	458	375	310
	4	133.0	80.9	53.2	37.0	26.8	20.1	15.5	12.3	9.9	8.1	6.7	5,318	3,237	2,128	1,479	1,073	806	621	490	394	322	267
	5	95.9	58.4	38.4	26.7	19.4	14.5	11.2	8.8	7.1	5.8	4.8	4,795	2,919	1,918	1,333	968	726	560	442	356	291	241
	6	73.8	44.9	29.5	20.5	14.9	11.2	8.6	6.8	5.5	4.5	3.7	4,428	2,695	1,772	1,232	894	671	517	408	328	268	222
	7	59.3	36.1	23.7	16.5	12.0	9.0	6.9	5.5	4.4	3.6	3.0	4,151	2,526	1,660	1,154	838	629	485	383	308	251	208
	8	49.1	29.9	19.7	13.7	9.9	7.4	5.7	4.5	3.6	3.0	2.5	3,930	2,392	1,572	1,093	793	595	459	362	291	238	197
	9	41.6	25.3	16.7	11.6	8.4	6.3	4.9	3.8	3.1	2.5	2.1	3,748	2,281	1,499	1,042	756	568	438	346	278	227	188
	10	35.9	21.9	14.4	10.0	7.3	5.4	4.2	3.3	2.7	2.2	1.8	3,594	2,188	1,438	1,000	725	544	420	331	266	218	180
15	3	196.7	119.7	78.7	54.7	39.7	29.8	23.0	18.1	14.6	11.9	9.9	8,852	5,388	3,541	2,462	1,786	1,341	1,034	816	656	536	444
	4	129.0	78.5	51.6	35.9	26.0	19.5	15.1	11.9	9.6	7.8	6.5	7,738	4,710	3,095	2,152	1,561	1,172	904	713	574	469	389
	5	93.7	57.1	37.5	26.1	18.9	14.2	11.0	8.6	7.0	5.7	4.7	7,031	4,280	2,813	1,955	1,419	1,065	822	648	521	426	353
	6	72.5	44.1	29.0	20.2	14.6	11.0	8.5	6.7	5.4	4.4	3.6	6,524	3,971	2,610	1,814	1,316	988	762	601	484	395	328
	7	58.4	35.6	23.4	16.2	11.8	8.8	6.8	5.4	4.3	3.5	2.9	6,133	3,733	2,454	1,706	1,238	929	717	565	455	372	308
	8	48.5	29.5	19.4	13.5	9.8	7.3	5.7	4.5	3.6	2.9	2.4	5,819	3,542	2,328	1,618	1,174	881	680	537	431	353	292
	9	41.2	25.1	16.5	11.5	8.3	6.2	4.8	3.8	3.1	2.5	2.1	5,559	3,384	2,224	1,546	1,122	842	650	513	412	337	279
	10	35.6	21.7	14.2	9.9	7.2	5.4	4.2	3.3	2.6	2.2	1.8	5,338	3,249	2,135	1,484	1,077	809	624	492	396	323	268
20	3	192.2	117.0	76.9	53.5	38.8	29.1	22.5	17.7	14.3	11.6	9.7	11,535	7,021	4,614	3,208	2,328	1,747	1,348	1,063	855	699	579
	4	127.0	77.3	50.8	35.3	25.6	19.2	14.8	11.7	9.4	7.7	6.4	10,162	6,186	4,065	2,826	2,051	1,539	1,187	937	753	616	510
	5	92.7	56.4	37.1	25.8	18.7	14.0	10.8	8.5	6.9	5.6	4.7	9,270	5,643	3,708	2,578	1,871	1,404	1,083	855	687	562	465
	6	71.8	43.7	28.7	20.0	14.5	10.9	8.4	6.6	5.3	4.4	3.6	8,621	5,247	3,449	2,397	1,740	1,306	1,007	795	639	522	433
	7	58.0	35.3	23.2	16.1	11.7	8.8	6.8	5.3	4.3	3.5	2.9	8,117	4,941	3,247	2,257	1,638	1,229	948	748	602	492	408
	8	48.2	29.3	19.3	13.4	9.7	7.3	5.6	4.4	3.6	2.9	2.4	7,710	4,693	3,084	2,144	1,556	1,168	901	711	572	467	387
	9	40.9	24.9	16.4	11.4	8.3	6.2	4.8	3.8	3.0	2.5	2.1	7,371	4,487	2,949	2,050	1,487	1,116	861	680	546	447	370
	10	35.4	21.6	14.2	9.8	7.1	5.4	4.1	3.3	2.6	2.1	1.8	7,082	4,311	2,833	1,970	1,429	1,073	828	653	525	429	356
25	3	189.6	115.4	75.9	52.7	38.3	28.7	22.2	17.5	14.1	11.5	9.5	14,223	8,657	5,690	3,955	2,870	2,154	1,662	1,311	1,055	862	714
	4	125.9	76.6	50.4	35.0	25.4	19.1	14.7	11.6	9.3	7.6	6.3	12,589	7,663	5,036	3,501	2,540	1,907	1,471	1,161	933	763	632
	5	92.1	56.0	36.8	25.6	18.6	13.9	10.8	8.5	6.8	5.6	4.6	11,510	7,006	4,604	3,201	2,323	1,743	1,345	1,061	853	697	578
	6	71.5	43.5	28.6	19.9	14.4	10.8	8.3	6.6	5.3	4.3	3.6	10,718	6,524	4,288	2,981	2,163	1,623	1,252	988	795	649	538
	7	57.7	35.1	23.1	16.1	11.6	8.7	6.7	5.3	4.3	3.5	2.9	10,101	6,148	4,041	2,809	2,038	1,530	1,180	931	749	612	507
	8	48.0	29.2	19.2	13.3	9.7	7.3	5.6	4.4	3.6	2.9	2.4	9,601	5,844	3,841	2,670	1,937	1,454	1,122	885	712	582	482
	9	40.8	24.8	16.3	11.3	8.2	6.2	4.8	3.8	3.0	2.5	2.0	9,183	5,589	3,673	2,554	1,853	1,391	1,073	847	681	556	461
	10	35.3	21.5	14.1	9.8	7.1	5.3	4.1	3.3	2.6	2.1	1.8	8,827	5,373	3,531	2,455	1,781	1,337	1,031	814	654	535	443
30	3	187.9	114.4	75.2	52.3	37.9	28.5	22.0	17.3	13.9	11.4	9.4	16,914	10,295	6,766	4,704	3,413	2,562	1,976	1,559	1,254	1,025	849
	4	125.1	76.2	50.1	34.8	25.3	19.0	14.6	11.5	9.3	7.6	6.3	15,017	9,140	6,007	4,176	3,030	2,275	1,755	1,384	1,113	910	754
	5	91.7	55.8	36.7	25.5	18.5	13.9	10.7	8.5	6.8	5.6	4.6	13,750	8,369	5,501	3,824	2,775	2,083	1,607	1,268	1,019	833	690
	6	71.2	43.3	28.5	19.8	14.4	10.8	8.3	6.6	5.3	4.3	3.6	12,816	7,801	5,127	3,564	2,586	1,941	1,497	1,182	950	777	644
	7	57.5	35.0	23.0	16.0	11.6	8.7	6.7	5.3	4.3	3.5	2.9	12,085	7,356	4,835	3,361	2,439	1,830	1,412	1,114	896	732	607
	8	47.9	29.1	19.2	13.3	9.7	7.3	5.6	4.4	3.5	2.9	2.4	11,491	6,995	4,597	3,196	2,319	1,741	1,343	1,059	852	696	577
	9	40.7	24.8	16.3	11.3	8.2	6.2	4.8	3.8	3.0	2.5	2.0	10,995	6,692	4,398	3,058	2,219	1,665	1,285	1,014	815	666	552
	10	35.2	21.4	14.1	9.8	7.1	5.3	4.1	3.2	2.6	2.1	1.8	10,571	6,434	4,229	2,940	2,133	1,601	1,235	975	784	641	531

Conclusions

In experiments to evaluate the fresh matter productivity of sorghum and showy rattlebox, in single or intercropped cultivation, with 5 to 30 treatments and with five repetitions, plots of 10.0 m² of useful area are sufficient for differences between treatments of 24% of the overall average of the experiment to be considered significant at 0.05 probability.

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