academicJournals

Vol. 14(30), pp. 2361-2366, 29 July, 2015
DOI: 10.5897/AJB2014.13984
Article Number: EFB3F8754435
ISSN 1684-5315

http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Estimation of optimal size of plots for experiments with radiometer in beans

Roger Nabeyama Michels[1]*, Marcelo Giovanetti Canteri[2], Inês Cristina de Batista Fonseca[2], Marcelo Augusto de Aguiar e Silva[2] and José Alexandre de França[2]

[1]Universidade Tecnológica Federal do Paraná, Avenida dos Pioneiros, 3131, CEP 86036-370, Londrina, PR, Brasil.
[2]Programa de pós graduação em Agronomia, Universidade Estadual de Londrina, UEL/CCA, Rodovia Celso Garcia Cid, PR 445 km 380, Campus Universitário, Cx. Postal 10.011, CEP 86.057-970, Londrina-PR, Brasil.

Received 13 June, 2014; Accepted 13 July, 2015

An experimental error can lead to rework and, consequently, to the loss of financial and human resources. One way to reduce this problem is the estimation of the optimum size of experimental plot to carry out the treatments. The objective of this study was to estimate the optimal size of plots for reflectance measurements in beans by the modified maximum curvature method and the maximum distance method. Reflectance readings were made on bean plants with the aid of the GreenSeeker® equipment, obtaining basic units of 0.45 m² in an area of lines 6 and 8 m in length, performing 46 combinations of experimental area. X_0 was determined using the modified maximum curvature and the maximum distance method. To increase the R^2, the calculations have been redone using 20 combinations of experimental area. By adopting the bigest obtained area, it was concluded that the optimum size of an experimental plot for works with reflectance in beans is 5.40 m² and the combination that presents the best distribution is 2 lines totalling 6 m long.

Key words: Reflectance, experimental error, modified maximum curvature, maximum distance.

INTRODUCTION

The spectral response of vegetation usually shows that plants absorb more solar energy in the visible region and the bands used for determining the vegetation indices (VI) are in the red and near infrared region (Monteiro et al., 2012).The GreenSeeker® is an instrument that provides the normalized difference vegetation index (NDVI) via reflectance measurements, the interpretation of which can provide information in a rapid and targeted way on nutritional conditions, physiological state, stress and potential crop yields, even in cloudy days, which prevent the acquisition from satellites (Malenovský et al., 2009; Gutiérrez-Soto et al., 2011; Martin et al., 2012; Ali et al., 2015). The reflectance, percentage of light reflected by the culture, can also detect variations in leaf area of plants attacked by diseases, serving as a parameter to estimate damage to production and determine the economic

*Corresponding author. E-mail: rogernmichels@utfpr.edu.br.

Abbreviations: MMC, Modified maximum curvature; **MMC,** maximum curvature method; **MD,** maximum distance.

damage threshold (Hikishima et al., 2010). For experiments with beans, the size of the portions differ according to the purpose of the study. To check the efficiency of the severity assessment of angular leaf spot in common bean based in healthy and diseased areas of the leaf, Parrella et al. (2013) adopted portions 8 m² (4 m long and 2 m wide). Doblinski et al. (2010) adopted a 2 m² area in the study of diffuse pollution of swine wastewater on the beans. To estimate the productivity of grains and wheat plant height using reflectance measurements Xavier et al. (2006) adopted 3.6 m² plots (3 m long by 1.2 m wide). In order to quantify the damage and the relationship between severity, reflectance and productivity in the pathosystem of Asian soybean rust, Hikishima et al. (2010) adopted as experimental unit an area of 6.75 m², or 3 lines of 5 m in length.

The economy of human and financial resources, without losing experimental precision, is considered an important factor in the design of experiments. To plan the tests and assess the magnitude of the experimental accuracy is important to determine the level of credibility of the results obtained in the research (Storck, 2011; Storck et al, 2011). The establishment of optimum plot size, in any culture, is one of the ways to increase the experimental precision and maximize the information obtained in an experiment (Silva et al., 2012), and is a recognized way to reduce experimental error, while there are several methods for its estimation based on different principles (Lorentz et al., 2012).The experimental error, which is the existing variance between experimental units that received the same treatment, is estimated by applying repetition, which is one of the principles of the trial and to avoid it is necessary to know the characteristics of the experimental area and the grown culture (Oliveira et al., 2005). Works with the right size of plots allow optimal use of resources, while also allowing the researcher greater control and management of their experiment, when performed in a smaller area (Lackey and Stein, 2014).For determining the optimum plot size through the method of maximum modified curvature and the maximum distance method a blank experiment is necessary, with the culture of interest and then the experimental area is subdivided into smaller portions, called basic units from which the data is collected independently while identifying the relative position. After the taking of the data, plots of different sizes and shapes are simulated through the sum of contiguous plots (Lorentz et al., 2012).

The objective of this study was to estimate the optimal size of plots for reflectance measurements in beans by the modified maximum curvature method and the Lorentz et al. (2012) called maximum distance.

MATERIALS AND METHODS

The experiment was conducted in a growing area of the State University of Londrina (UEL), in Londrina-PR, in the dry season of 2013. The cultivated beans were the IPR Andorinha (registration No. 30617, Ministry of Agriculture, Livestock and Supply), seeded with 0.45 m spacing between rows and 11 plants per meter.With the aid of the GreenSeeker® equipment were collected reflectance values in six rows wide by 23 m long at intervals of each meter thereby obtaining 138 readings. The basic unit for this study was set at 0.45 m², obtained through the minor form: 0.45 m × 1 m (Table 1). The optimum plot size was estimated using initially the method of the modified maximum curvature proposed ^{b}y Lessman; Atkins (1963) apud Meier and Lessman (1971). In this method, the measure of variability given by coefficient of variation (CV_x) and the portion size with X basic units is clarified by $CVx=aX^{-b}$, where aand b are the parameters to be estimated. The optimum plot size was estimated by the expression:

$$X_0 = exp\left\{\left[\frac{1}{2b+2}\right]\log\left[\frac{(ab)^2(2b+1)}{b+2}\right]\right\}$$

Where, X_0 is the value of the abscissa at the point of maximum curvature, which corresponds to the optimum plot size (Meier and Lessman, 1971).

The method of maximum distance was then calculated, where its resolution of the geometry formed by ay_c curve, described by $CV_x=aX^{-b}$, and a secant line to this curve, y_r. We look for the point of the curve y_c that is at the largest distance from the line y_r, since the line segment along this distance is perpendicular to the line y_r (Lorentz et al., 2012).The solution method presented by Lorentz et al. (2012) proposes to express the line perpendicular to the line y_r as an aid to find the point sought of the y_c curve. So, this line perpendicular to the line y_r will be called the y_p, expressed by $y_p=ex+f$. The angular coefficient c and the linear coefficient d, both from the line y_r, are fixed and can be obtained from two y_r points common to the y_r curve.The common point between y_c e $y_r$which is more to the left, given by (x_{cri}, y_{cri}), and the common point more to the right, given by (x_{crf}, y_{crf}), then c and d are expressed, respectively, by $c = \frac{y_{crf} - y_{cri}}{x_{crf} - x_{cri}}$ and $d = y_{cri} - cx_{cri}$ or $d = y_{crf} - cx_{crf}$, and these expressions for d are obtained by isolating the equation for y_R,having been replaced in this, the point (x_{cri}, y_{rri}), or the point (x_{crf}, y_{crf}). The angular coefficient e of the line y_p is also fixed and may be obtained by using the condition that the y_R and y_P lines are perpendicular to each other. In this way, $e = \frac{-1}{c}$.The determination of the linear coefficient f of the line y_P is part of the interactive method proposed by Lorentz et al. (2012) and that has as its solution: $x_{rpj} = \frac{f-d}{c-e}$.The distance between the points (x_{cj}, x_{cj}) and (x_{rpj}, x_{rpj}), this distance is on line y_{pj}, which is perpendicular to y_r, and is given by

$$d_{cr} = \sqrt{(yc_j - y_{rpj})^2 + (xc_j - x_{rpj})^2}$$

RESULTS AND DISCUSSION

By the method of the modified maximum curvature (MMC) the estimates of *a* and *b* were 2.0012 and 0.058, respectively (Figure 1), thus, the optimum plot size was the minimum measure, that is, 0.45 m² because X_0 = 0.365. The result is justified by the low coefficient of variation, with 2.423 maximum and 1.401 minimum (Table 2). In order to obtain a more representative R², we limited following

Table 1. Size (X), shape and total number of plots for the determination of the optimal size in studies using reflectance.

Simulation	Size (WxL)	Form (WxL)	Area(m²)	Number of plots
1	1	0.45 m × 1 m	0.45	138
2	2	0.45 m × 2 m	0.90	66
3	2	0.90 m × 1 m	0.90	69
4	3	0.45 m × 3 m	1.35	42
5	3	1.35 m × 1 m	1.35	46
6	4	0.45 m × 4 m	1.80	30
7	4	0.90 m × 2 m	1.80	33
8	4	1.80 m × 1 m	1.80	23
9	5	0.45 m × 5 m	2.25	24
10	5	2.25 m × 1 m	2.25	23
11	6	0.45 m × 6 m	2.70	18
12	6	0.90 m × 3 m	2.70	20
13	6	2.70 m × 1 m	2.70	22
14	6	1.35 m × 2 m	3.15	21
15	7	0.45 m × 7 m	3.25	18
16	8	0.45 m × 8 m	3.60	12
17	8	0.90 m × 4 m	3.60	15
18	8	1.80 m × 2 m	3.60	11
19	9	1.35 m × 3 m	4.05	14
20	10	0.90 m × 5 m	4.50	12
21	10	2.25 m × 2 m	4.50	11
22	12	1.35 m × 4 m	5.40	10
23	12	0.90 m × 6 m	5.40	9
24	12	1.80 m × 3 m	5.40	7
25	12	2.70 m × 2 m	5.40	11
26	15	1.35 m × 5 m	6.75	8
27	15	2.25 m × 3 m	6.75	7
28	16	1.80 m × 4 m	7.20	5
29	18	1,35 m × 6 m	8.10	6
30	18	2.70 m × 3 m	8.10	7
31	20	1.80 m × 5 m	9.00	4
32	20	2,25 m × 4 m	9.00	5
33	21	1.35 m × 7 m	9.45	6
34	24	1.35 m × 8 m	10.80	4
35	24	1.80 m × 6 m	10.80	3
36	24	2.70 m × 4 m	10.80	5
37	25	2.25 m × 5 m	11.25	4
38	28	1.80 m × 7 m	12.60	3
39	30	2.25 m × 6 m	13.50	3
40	30	2.70 m × 5 m	13.50	4
41	32	1.80 m × 8 m	14.40	2
42	35	2.25 m × 7 m	15.75	3
43	36	2.70 m × 6 m	16.20	3
44	40	2.25 m × 8 m	18.00	2
45	42	2.70 m × 7 m	18.90	3
46	48	2.70 m × 8 m	21.60	2

* L = length, W = Width.

simulations to the number 20 and calculations were redone and we obtained the same value of 0.45 m² through the modified maximum curvature method (MMC), because X_0 = 0.587. In the method of maximum distance (MD), in

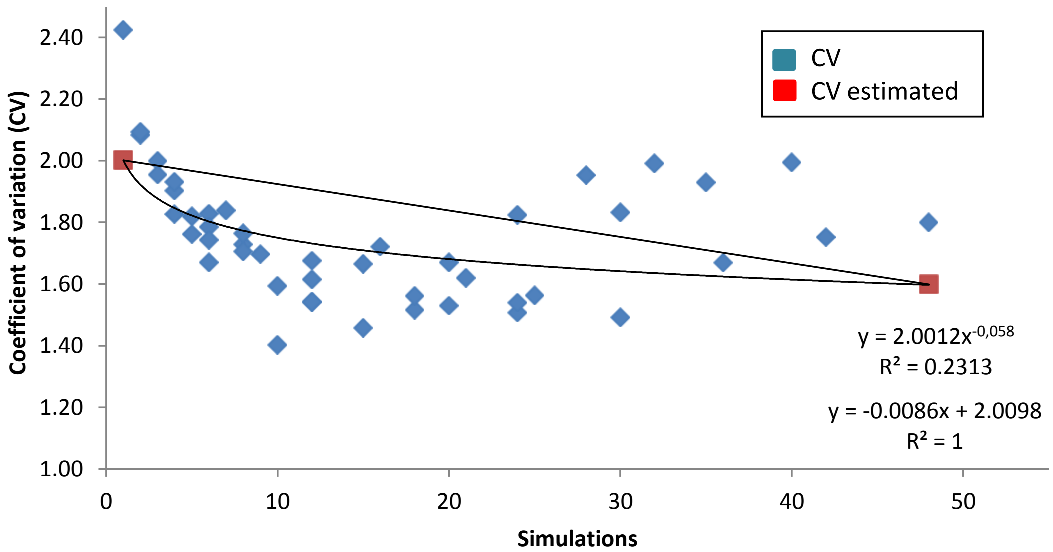

Figure 1. Regression of observed CV and estimated CV data for the variables *a*, *b*, *c* and *d* for 46 simulations.

Table 2. Standard deviation, mean and variation coefficient of reflectance data.

Simulation	Standard deviation	Average	Coefficient of variation (%)
1	20.652	852.242	2.423
2	17.750	852.242	2.082
3	17.834	852.242	2.092
4	17.032	851.992	1.999
5	16.658	852.242	1.954
6	16.189	851.000	1.902
7	15.562	852.242	1.826
8	16.440	851.431	1.930
9	14.987	851.000	1.761
10	15.482	851.200	1.818
11	15.527	849.713	1.827
12	15.206	851.992	1.784
13	14.226	852.242	1.669
14	14.850	852.242	1.742
15	15.663	851.992	1.838
16	14.656	847.770	1.728
17	15.010	851.366	1.763
18	14.519	851.431	1.705
19	14.494	854.158	1.696
20	13.558	851.138	1.593
21	11.966	853.750	1.401
22	13.735	851.000	1.613
23	13.131	852.242	1.540
24	14.264	851.261	1.675
25	13.131	852.242	1.540
26	12.403	851.000	1.457
27	14.168	850.942	1.665
28	14.633	850.225	1.721
29	12.869	849.713	1.514

Table 2. Contd.

Simulation	Standard deviation	Average	Coefficient of variation (%)
30	13.305	851.992	1.561
31	13.006	850.225	1.529
32	14.190	849.940	1.669
33	13.796	851.992	1.619
34	12.769	847.770	1.506
35	15.486	849.208	1.823
36	13.100	851.000	1.539
37	13.281	849.940	1.562
38	16.623	851.261	1.952
39	15.543	848.744	1.831
40	12.687	851.000	1.490
41	16.860	846.859	1.990
42	16.414	850.942	1.928
43	14.178	849.713	1.668
44	16.882	846.587	1.994
45	14.922	851.992	1.751
46	15.261	847.770	1.800

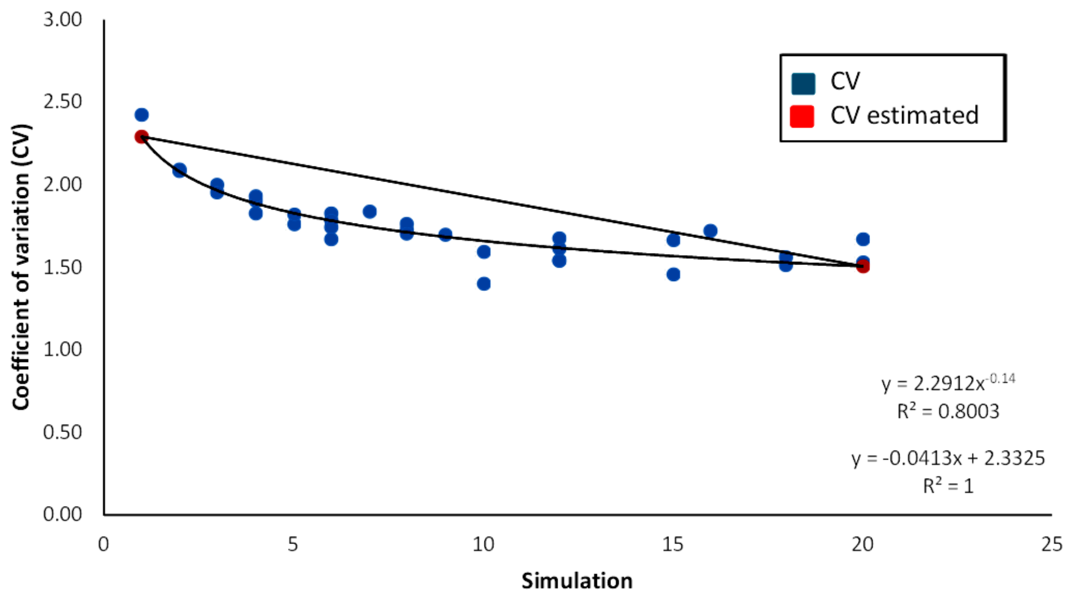

Figure 2. Regression of observed CV and estimated CV data to obtain the variables *a*, *b*, *c* and *d* for 20 simulations.

addition to the values of *a* and *b*, were obtained the values of *c* and *d* by linear regression of the estimated CV (*c* = - 0.0086 and *d* = 2.0098, Figure 1) and the value of *e* was obtained by *e* = - 1/C (*e* = 116.28). The value of the optimum plot size was 5.40 m². In order to obtain a more representative R^2, we limited following simulations to the number 20 and calculations were redone. Thus, were obtained the following values: *a* = 2.2912; *b* = - 0.14; *c* = - 0.0413; *d* = 2.3325 (Figure 2) and *e* = 24.21, resulting in an optimum plot size of 2.70 m² by the maximum distance method (MD). In order to confirm the result obtained with the coefficient of variation, calculations were redone using the variance (V), obtaining the following values: *a* = 381.53; b = 0.2810; *c* = - 11.427; *d* = 392.96 (Figure 3) and *e* = 0.0875, resulting in the same optimal plot size, 5.40 m². Monteiro et al. (2012) adopted plots that were 3.20 m long and 2.20 m wide (7.02 m²) for studies with radiometer in beans, a value higher than estimated by the method of

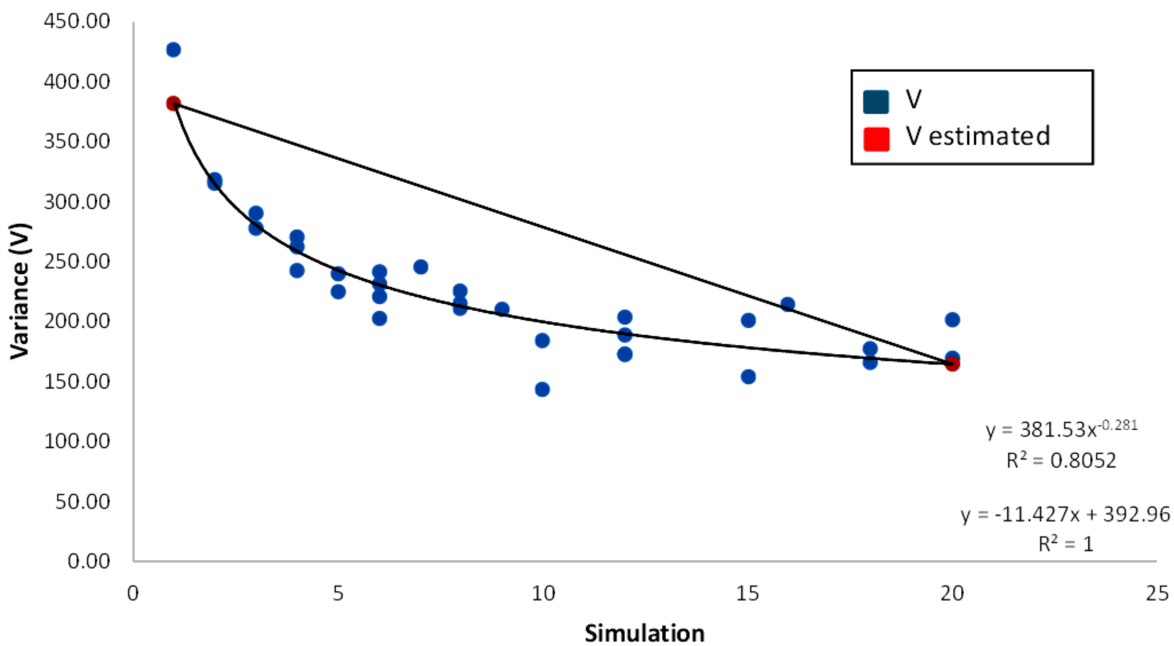

Figure 3. Regression of observed V and estimated V data to obtain the variables *a*, *b*, *c* and *d* for 20 simulations.

maximum distance (5.40 m²).

Conclusion

With optimum size values of plots obtained by the MMC for 46 and 20 combinations equal to 0.45 m² for MD with 20 simulations equal to 2.70 m² and MD for 46 simulations, and for variance equal to 5.40 m², it could be concluded that the highest value is the most suitable for works in beans with application of radiometer. Adopting as a criterion the lowest CV, the optimal size area is 5,40 m² with combination 2x6 that is two lines (0.90 m) wide and 6 m long.

Conflict of interests

The authors did not declare any conflict of interest.

ACKNOWLEDGEMENTS

The authors acknowledge the support provided by the Agronomic Institute of Paraná - IAPAR for providing the seeds used in conducting this experiment.

REFERENCES

Ali AM, Thind HS, Singh V, Singh BA (2015). A Framework for nitrogen management in dry direct-seeded rice using greenseeker[tm] optical sensor. Comput. Electron. Agric. 161:11-15.

Doblinski AF, Sampaio SC, Silva VR Da, Nóbrega IHP, Gomes SD, Dal Bosco TC (2010). Nonpoint source pollution by swine farming wastewater in bean crop. Rev. Bras. Eng. Agríc. Ambient. 14(1):87-93.

Gutierrez-soto MV, Cadet-Piedra E, Rodriguez-Montero W, Araya-Alfaro JM (2011). El greenseeker™ y el diagnóstico del estado de salud de los cultivos. Agron. Mesoam. 22(2):397-403.

Hikishima M, Canteri MG, Godoy CV, Koga IJ, Silva AJ (2010). Da. Quantificação de danos e relações entre severidade, medidas de refletância e produtividade no patossistema ferrugem asiática da soja. Trop. Plant Pathol. 35(2):96-103.

Lackey IG, Stein ED (2014). Selecting the optimum plot size for a california design-based stream and wetland mapping program. Environ. Monit. Assess. 186(4):2599-2608.

Lorentz IH, Erichsen R, Lucio AD (2012). Proposta de método para estimação de tamanho de parcela para culturas agrícolas. Rev. Ceres 59:6.

Malenovský Z, Mishra KB, Zemek F, Rascher U, Nedbal L (2009). Scientific and technical challenges in remote sensing of plant canopy reflectance and fluorescence. J. Exp. Bot. 60(11):2987-3004.

Martin DE, Lópes JD, Lan Y (2012). laboratory evaluation of the greenseeker[tm] handheld optical sensor to variations in orientation and height above canopy. Int. J. Agric. Boil. Eng. 5(1):43-47.

Meier VD, Lessman KJ (1971). Estimation of optimum field plot shape and size for testing yield in crambeabyssinicahochst. Crop Sci. 11:648-650.

Monteiro PFC, Ângulo Filho R, Xavier AC, Monteiro ROC (2012). Assessing biophysical variable parameters of bean crop with hyperspectral measurements. Sci. Agric. 69(2):87-94.

Oliveira SJR, Storck L, Lopes SJ, Lúcio AD, Feijó S, Damo HP (2005). Plot size and experimental unit relationship in exploratory experiments. Sci. Agric. 62(6):585-589.

Parrella RADC, Santos JBD, Parrella NNLD, Silva DVFE (2013). Evaluation efficiency of severity of angular leaf spot in common bean based on diseased and healthy leaf area. Crop Breed. Appl. Biotechnol. 13(3):178-185.

Silva IFDD, Campos KA, Morais ARD, Cogo FD, Zambon CR(2012). Tamanho ótimo de parcela para experimentos com rabanetes.Rev. Ceres 59(5):624-629.

Storck L (2011). Partial collection of data on potato yield for experimental planning. Field Crops Res. 121(2):268-290.

Storck L, Lopes SJ, Lucio AD, Cargnelutti Filho A (2011). Optimum plot size and number of replications related to selective precision. Ciênc. Rural 41(3): 390-396.

Xavier AC, Rudorff BFT, Moreira MA, Alvarenga BS, Freitas JGD, Salomon MV (2006). Hyperspectral field reflectance measurements to estimate wheat grain yield and plant height. Sci. Agric. 63(2):130-138.