Journal of Root Crops, 2020, Vol. 46 No. 1, pp. 58-62
Indian Society for Root Crops
ISSN 0378-2409, ISSN 2454-9053 (online)

Estimation of Optimum Plot Size and Shape for Branching Variety of Cassava (*Manihot esculenta* Crantz) Using Statistical Methods

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Abstract

Knowledge of optimum size and shape of plots is an important factor in improving precision while conducting agricultural field experiments. An experiment for determination of optimum plot size in a branching variety of cassava (Vellayani Hraswa) was carried out using the Maximum curvature, Smith's variance law and Modified curvature methods in an area of 200 m^2 at Instructional Farm, Department of Agricultural Statistics, College of Agriculture, Vellayani, Thiruvananthapuram, India during 2015-2017. The experimental area selected was having 15 rows and 16 columns (240 plants). The maximum curvature method and Fairfield Smith's variance method gave most appropriate results. For branching type of varieties, the optimum plot size obtained was 24 units (plants) by these methods under a spacing of 90 cm x 90 cm. Regarding plot shape, 8 x 3 (length as 8 units and breadth as 3 units) is recommended as it gave less coefficient of variation than 6 x 3 units in the maximum curvature method.

Key words: Cassava, branching type, optimum plot size, maximum curvature method, Fairfield Smith's law, modified maximum curvature method

Introduction

The agricultural field experiments have become important in research field for new innovations in varietal improvement and technology development. For the conduct of field experiments, it is important for the research workers to have knowledge on field plot technique, mainly the plot size and shape best suited for the different situations. It is relevant to use the most efficient shape, size and arrangements of plots in every experiment for obtaining the most precise results with least variability. Size of plot is one of the important factors affecting the experimental accuracy and efficient comparison of treatment effects. The precision of significance tests in field trials are largely controlled by size and shape of plots, area available for the experiment and the nature of fertility or inherent soil conditions of the experimental area. To cope with this problem of research workers, it has become necessary to standardize a suitable plot size and shape, for the experiments on major crops grown under different field conditions, which will reduce the standard error of the experiments. The present study is aimed to identify the optimum plot size for conducting field experiments for a popular branching variety of cassava, which seems to be not carried out recently.

Smith (1938) introduced an empirical relationship between plot size and its variance as a measure of determining soil heterogeneity. The law states that

$$V_x = \frac{V_1}{x^b}$$

where V_x is variance of yield (per unit area) among experimental plots of size x elements; V_1 is the variance among plot of size unity and b is the regression coefficient which indicates relationship between adjacent individuals.

By conducting uniformity trials, fertility or productivity contour maps of an area can be prepared using the fertility gradient existing in a that piece of land, which can be used for estimating optimum plot sizes for the conduct of field experiments. Buckman and Brady (1960), stated that soil productivity means the ability of the soil to yield crops.

Prabhakaran and Thomas (1974) reported that the shape of plot does not have any consistent effect on the coefficient of variation (CV). However for a given plot size, long and narrow plots generally yielded lower CV than square plots of the same dimension. The optimum plot size for cassava was computed to be about 20 m^2. When fertility patterns of experimental area is unknown or when border effects are larger, it is advisable to go for square plots (Gomez and Gomez, 1976). One of the first methods used to determine the optimum plot size in field experiments for several crops is the maximum curvature method using CV. The Smith's variance law and its modifications are also used. In these methods, a uniformity trial conducted in a pre-determined area is harvested in basic units, which are combined to form experimental plots of various sizes. The CV has been obtained, for each plot size and they are represented graphically against the size of each plot assessed. The optimum plot size is determined visually corresponding to the point of maximum curvature (Prabhakaran et al., 1978).

Some important aspects that determine the optimal size of the plot includes the presence or absence of border, crop type, number of treatments, the level of technology employed in the area of cultivation and availability of financial sources (Bueno and Gomes,1983).

To determine the optimal size of plots, the comparison of variances is used. Viana et al., (2003) used modified maximum curvature method and Hatheway's method to determine the optimum plot size for experiments on cassava. More reliable results were obtained using the modified maximum curvature method. Using this method, the optimum experimental plot size for cassava was estimated to be 15.02 m^2 (26 plants).

Materials and Methods

Source of data

The experiment was carried out in an area of 200 m^2 at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram. The Farm experiences a warm humid tropical climate. During the cropping season all the weather conditions were favorable for the crop, except that there was high rainfall during later stages of crop growth, but got a favorable climate during harvest.

As the part of research work,Vellayani Hraswa, a branching variety of cassava having duration of six months was planted in an area of about five cents (200 m^2). Two nodded setts were planted in protray separately during March 2016. After one month these were planted in the main field with spacing of 90 cm x 90 cm. Experimental area selected were having 15 rows and 16 columns to accommodate 240 plants excluding the border plants on all sides. The cultural operations confirmed to the package of practices recommended by the Kerala Agricultural University. Fertilizers were applied at the rate of 75: 50: 100, N: P: K kg per hectare. The intercultural operations like weeding, removal of excess shoot about 30 days after planting, earthing up and pesticide spray were done. Gap filling was done after 20-25 days after planting in the main field. Bimonthly biometric observations were taken. Date of completion of harvest was 8^{th} October 2016. Crop was harvested individually by taking both biometric as well as yield observations.

Methods of estimation of optimum plot size

Several methods for the determination of optimum plot size and shape are being suggested and attempted by various researchers from time to time. Three most common conventional methods are as detailed below:

1. Maximum curvature method (Prabhakaran et al., 1978)
2. Smith's variance law method (Sardana et al., 1967)
3. Modified curvature method (Michel et al., 2015)

Maximum curvature method

In the maximum curvature method the basic units of uniformity trials are combined to form new units. Data on border rows were not included in analysis. The new units are formed either by combining columns or rows or both. For example, a 2-unit plot can be formed either by combining 1 row and 2 column (1 × 2) or 2 rows and 1 column (2 × 1). Combination of columns and rows should be done in such a way that no column or row is left out or overlapped. For each set of units, the CV is computed; The CV was calculated by the formula:

$CV = \frac{\sigma}{\bar{x}} \times 100$, where σ is the standard deviation, and $\bar{x}$ is the arithmetic mean of the corresponding plot size.

For a specific plot size, the average of CV for different combinations is taken. A curve is plotted by taking the plot size (in terms of basic units) on the *X*-axis and the CV values on the *Y*-axis. The point at which the curve takes a turn, *ie*, the point of maximum curvature is located (Fig. 1). The value corresponding to the point of maximum curvature will be the optimum plot size. (Sundararaj, 1977).

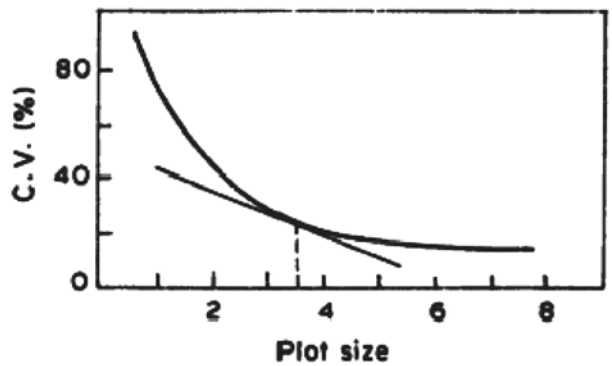

Fig.1. Graph to obtain point of maximum curvature

Smith's variance law method

According to Smith's law

$V_x = V_1 x^{-b}$

where V_x is the variance of plot size of *x* units, V_1 is the variance of plot size having unit size, *x* is the plot size and *b* is the soil heterogeneity index.

The optimum value of plot size (x_{opt}) are obtained by the following:

$$x_{opt}^{2(b+1)} = V_1^2 b^2 [\frac{3(1+b)}{2+b} - 1] \quad \ldots\ldots \text{eqn. (1)}$$

This formula was given by Agarwal and Deshpande (1967).

Modified maximum curvature method

In case of Modified Maximum curvature method:

The relationship between plot size, *x* and CV, *y* is given by the equation,

$$y = \frac{a}{x^b}$$

Where *a* and *b* are constants, *x* is the plot size and *y* is the CV

when more than one CV is there, for the same plot size, the minimum CV is taken for fitting the curve.

In case of Modified curvature method, optimum plot size is obtained by the formula

$$x_{opt} = \left[\frac{(ab)^2(2b+1)}{(b+2)}\right]^{\frac{1}{2(b+1)}} \quad \ldots\ldots \text{eqn. (2)}$$

Results and Discussion

Maximum curvature method

Results of maximum curvature method based on the plot size, arithmetic mean, standard deviation and coefficient of variation of variety 'Vellayani Hraswa' are given in Table 1. Maximum curvature graph was also plotted and is given in the Fig. 2.

From Table 1, it can be concluded that optimum plot size of branching variety was 24 units with a minimum CV of 15.90. For a 24 unit plot size, a combination of 8 x 3 with a minimum CV of 14.87 was found to be the best shape. Number of plants to be accommodated per plot is 24. The shape of optimum plot size obtained is 8

Table 1. Summary table of plot size and shape along with Coefficient of variation

Size	Shape	Mean	SD	CV (%)	Min CV	Average
20	10x2	1.99	0.329	16.50	16.11	17.33
	2x10	2.16	0.427	19.75		
	4x5	2.09	0.354	16.95		
	5x4	2.05	0.331	16.11		
24	8x3	2.01	0.299	14.87	14.87	15.90
	3x8	2.11	0.368	17.42		
	6x4	2.04	0.307	15.05		
	4x6	2.09	0.330	15.74		
	2x12	2.14	0.360	16.81		
	12x2	2.02	0.314	15.49		
26	2x13	2.12	0.339	15.98	14.27	15.13
	13x2	2.04	0.291	14.27		

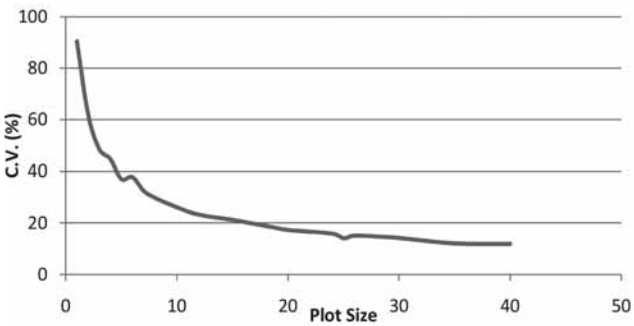

Fig. 2. Plot size vs CV for Vellayani Hraswa for estimating optimum plot size (Sundararaj, 1977).

unit length and 3 unit breadth. From the graph, maximum curvature is obtained by the range 24 units. Number of plants to be accommodated is 24 units and the area required is 19.44 m^2 (24 x 0.90 x 0.90). Here standard deviation is not continuously reducing, it lies in the range from 0.2 to 0.3 and therefore it cannot be taken as such for determination of optimum plot size. Prabhakaran and Thomas (1974) reported almost the same result. The optimum plot size for cassava was computed to be about 20 m^2. They reported that shape of plot do not have any consistent effect on the CV. However, for a given plot size long and narrow plots generally yielded lower CV than square plots of the same dimension.

Fairfield Smith's variance law

Applying the Smith's equation to various plot sizes and shapes the summary statistics and graph are given in Tables 2 and 3. The optimum plot size is also given below.

Table 2. Summary of output of Regression analysis

Regression Statistics	
Multiple R	0.997
R Square	0.995
Adjusted R Square	0.995
Standard Error	0.040
Observations	20

The logarithmic form of the equation is $y = 4.541 - 0.56 \times x$

ie., $Vx = 93.7845 \times x^{1/2(b+1)}$

The multiple correlation $\boldsymbol{R}^2$ obtained is very high and b value is 0.5603. It indicates a positive relation between adjacent plots.

The graph on logarithmic scale obtained is given below:

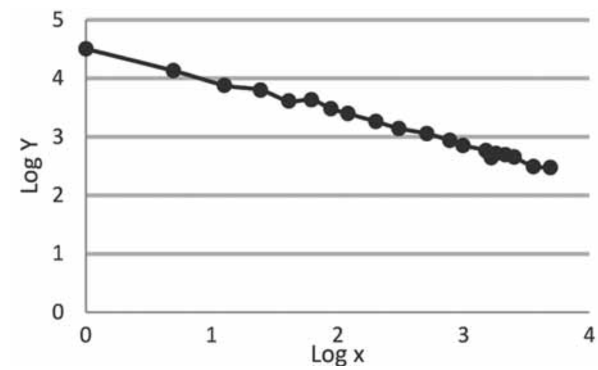

Fig. 3. Graph on Log (plot size) *vs* log CV for Vellayani Hraswa

Optimum plot size obtained by the formula (eqn. 1) was 24.39 ; which is same as the value obtained by the maximum curvature method (24)

3. Modified curvature method

Optimum plot size obtained by the formula given in eqn. (2) under this method was

$a = 93.784$, $b = 0.561$ and $x_{opt} = 11.92$

The plot size obtained under this method is too small (only 12 units) compared to the other two methods and hence not recommended.

Conclusion

By studying three different methods for the determination of optimum plot size for cassava, Maximum Curvature Method and Fairfield Smith Variance method are found to be the most appropriates.

Table 3. ANOVA table

	Degrees of freedom	Sum of squares	Mean squares	F value
Regression	1	6.36	6.3	3814
Residual	18	0.030	0.01	
Total	19	6.39		
	Coefficients in equation	Standard Error	t Stat	P value
Intercept	4.541	0.023	193	<0.01
x	-0.5603	0.009	61	<0.01

For branching type, the optimum plot size obtained was 24 units by using both methods. Regarding the shape of plots 8x3 sized plots gave a CV of 14.87 while 6x4 plots showed a CV of 15.05 units. In case of Modified curvature method optimum plot size obtained was only 12 units and as such this small value reached is discarded as it inadmissible. Minimum variance was obtained when length was taken as 8 units and breadth as 3 units in maximum curvature method. High R^2 values also indicated that maximum curvature method is better giving a plot size of 8x3 units in field experiments for branching varieties of cassava.

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