MARDI Res. Bull., (1984) 12, 2: (224–229)

DETERMINATION OF OPTIMUM PLOT SIZE AND SUITABLE PLOT SHAPE FROM A SWEET CORN UNIFORMITY TRIAL

YAHYA BIN AWANG* AND KHALID BIN MOHD. NOR**

Keywords: Plot size, Plot shape, Uniformity trial, Sweet corn.

RINGKASAN

Data daripada kajian keseragaman tanah dari jagung manis UPM Bakti I, yang dijalankan di kawasan Penyelidikan Agronomi, Universiti Pertanian Malaysia, telah digunakan untuk menentukan saiz plot optima dan bentuk plot yang sesuai bagi tanaman tersebut. Kaedah yang telah dicadangkan oleh SMITH (1938) telah digunakan bagi tujuan ini. Keputusan telah menunjukkan saiz plot optima bagi jagung adalah 9.0 m persegi dan boleh disusun dalam sebarang bentuk dan arah.

INTRODUCTION

According to KHALID (1979), the degree of precision of an experiment depends on the intrinsic variability of the experimental material and the accuracy of the design of the experiment which includes consideration of plot size and shape. These are some of the basic problems that always confront researchers in making decision in their field experimentation. The problem often arises because the variability of the experimental area is unknown. For a given crop, the size and shapes of plot that will give the maximum information per unit cost (i.e. the optimum plot size and shape) depend on two factors: the variability of the soil and the relative cost of experimentation.

Several procedures have been proposed for soil variability estimation, but the method derived by SMITH (1938) is found to be the most widely used (KELLER, 1949; BRIM and MASON, 1959; HALLAUER, 1964 ; CREW and MASON, 1963; GOMEZ and ALICBUSAN, 1968, ZUHLKE and GRITTON, 1969; WIEDIMANN and LEININGER, 1963; and KHALID, 1979).

In Smith's uniformity trials on wheat, he postulated an empirical relationship that explained the soil heterogeneity pattern by a regression coefficient as follows:–

$$V_x = \frac{V_1}{x^b} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

or when expressed in logarithmic form as;

$$\log V_x = \log V_1 - b \log x \quad \ldots\ldots\ldots\ldots \quad (2)$$

where V_x is the variance per unit area of plots of size x basic units, V_1 is the variance among the basic units, and b is the index of soil heterogeneity. The linear logarithm was shown to be true in 39 other uniformity trials, and could be generalised so that it could be applicable to any size of field with some adjustment of the regression coefficient.

The objective of this study is to utilise the information on soil heterogeneity from a uniformity trial for the determination of optimum plot size and shape for maize.

MATERIAL AND METHOD

A uniformity trial on maize was conducted in July, 1979 at the Agronomy Research Area of the Universiti Pertanian Malaysia. In the trial, the indicator variety was UPM Bakti I, planted at 75 x 30 cm in one of the blocks occupying an area of 24 x 15.6 m or 374.4 sq metres.

No fertilizer was applied. All agronomic practices were kept as uniform as possible and crop protection measures were adopted as necessary.

The trial block was divided into 416 basic unit plots of size 0.6 x 1.5 m each. At harvest, each basic unit was harvested by hand and fresh weight of unhusked cobs was recorded for statistical analysis.

*Project Development Division, MARDI Negeri Johor.
**Faculty of Agriculture, Universiti Pertanian Malaysia, Serdang, Selangor.

Different plot sizes and shapes were then obtained by adding together different combinations of adjacent basic units. Only combinations which exactly fitted into the whole area were analyzed.

The method proposed by Smith was applied to determine the degree of soil heterogeneity. The index of soil heterogeneity, b, was estimated through the least squares method from equation (2). Other methods, such as soil productivity contour map, serial correlation and mean squares among strips were used to further explain the soil variability pattern.

Optimum plot size for unguarded plot was estimated by using the following equation:–

$$x = \frac{b\,k_1}{(1-b)\,k_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where:–

k_1 = cost associated with the plot

k_2 = cost associated with the unit area

b = adjusted regression coefficient from uniformity trial.

Estimates of cost in man-hour were obtained by consultation, reference and discussion with those researchers familiar with the crop. This is as presented in *Table 1*.

Differences between plot shape of the same number of basic units were tested for significance by comparing their variances (V_x). The most suitable plot shape for a given plot size is shown by the smallest variance value.

RESULTS AND DISCUSSION

Soil Variability and Fertility Pattern

The pattern of the soil variability is shown by the fertility contour map constructed based on the moving averages of adjacent plots *(Figure 1)*. The pattern shows that there is a bidirectional fertility gradient occurring in the area. By comparing the mean square value among columns to that among rows, the relatively higher mean square value among columns indicate greater variability of soil fertility in the column-wise direction than in the row-wise direction.

Table 1. Estimates of cost in man-hours for conducting a maize experiment

Operation	Man-hour/sq m K2	Man-hours/plot K1
Land preparation	0.004167	–
Plot arrangement	0.004167	0.077422
Sowing	0.005555	–
Thinning	–	0.309665
Ridging	–	0.387083
Fertilization	0.025000	0.309665
Weeding	0.004167	–
Pest control	0.004167	–
Disease control	0.004167	–
Field inspection	–	0.041285
Harvesting	0.025000	0.464500
Weighing and data recording	–	0.619271
Data preparation and analysis	–	0.333333
Total	0.076390	2.542224

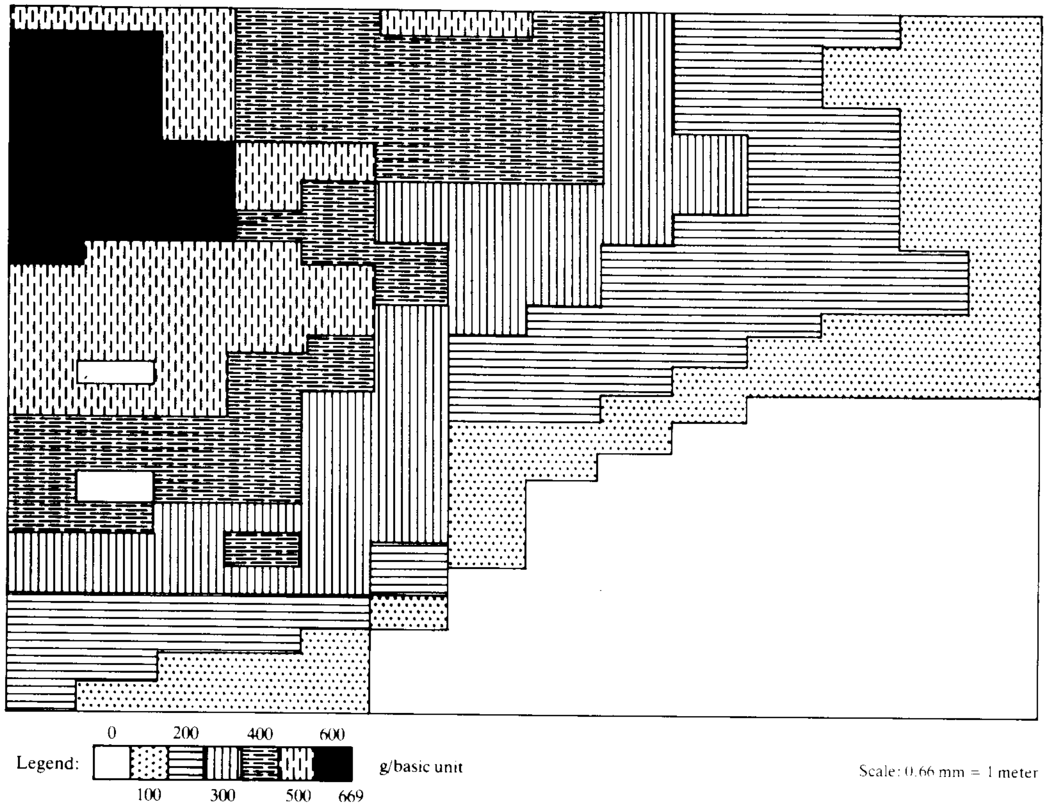

Figure 1. Fertility contour map based on moving averages of uniformity maize yield data, Agronomy Research Area, U.P.M.

By applying Smith's method, the relationship between variance per unit area against plot size *(Figure 2)* was determined to be: –

$$\log V_x = 4.7153 - 0.1107 \log x$$

The relatively high value of the coefficient of determination ($R^2 = 72.74\%$) confirmed that the data obtained from the trial supports the application of this technique *(Table 2)*.

According to SMITH (1938), the b value varies from zero to unity. When the value of b approaches unity, it indicates a low correlation between adjacent units, and conversely, a value near zero indicates a high degree of similarity or a strong correlation exists between adjacent plots. The relatively low b value ($b = 0.1107^{**}$ at $P \leq 0.01$) obtained indicated that the status of the soil fertility among the adjacent units was highly

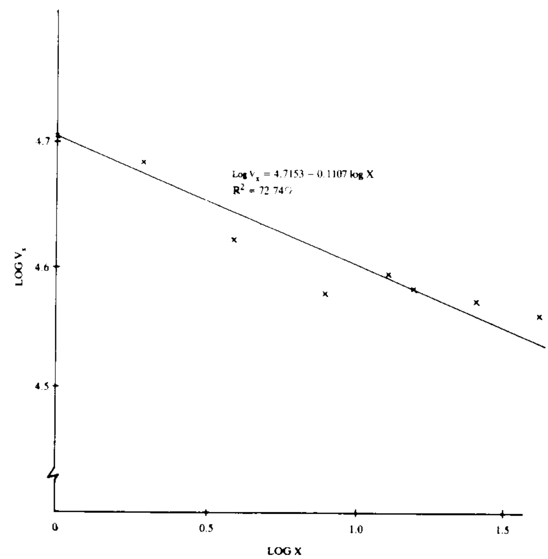

Figure 2. Relationship between variance per unit area (V_x) and plot size (x)

Table 2. ANOVA with the empirical logarithmic relationship between plot variability and plot size fitted to the uniformity data

	Degrees of Freedom	Sum of Squares	Mean Square	F−value
Regression	1	123.9524	123.9524	18.6788**
Deviation from regression	7	46.4523	6.6360	
Total	8	170.4048		

**Significant at the 0.01 probability level.

correlated. Therefore, increasing the plot size is not an effective measure of increasing the degree of precision of an experimental result.

Variability and Plot Size

The relationship between the coefficient of variation and plot size is shown in *Figure 3*. There was a progressive decrease in the coefficient of variation as plot size increased, especially in the first 10 basic units plot size. The rate of decrease was reduced tremendously when plot size came to about 14 basic units or 12.6 sq m that is, at the maximum curvature of the curve.

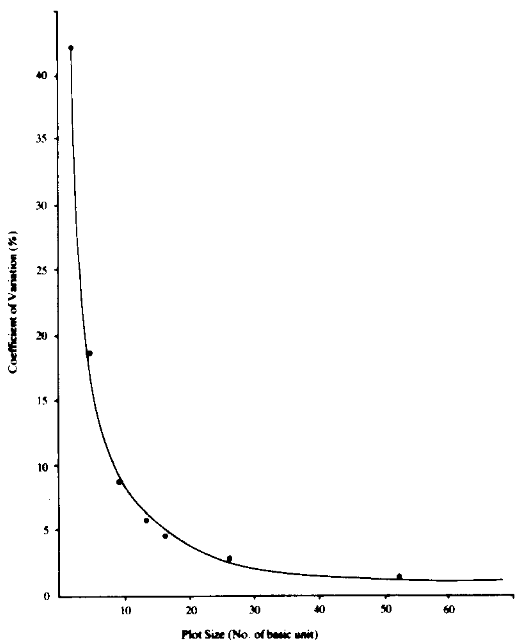

Figure 3. Relationship between coefficient of variation (CV) and plot size, x basic unit

By using equation (3), the optimum plot size was estimated to be 10 basic units or 9.0 sq metres.

As can be seen from the formula (3), the optimum plot size is influenced not only by the index of soil heterogeneity, but also by costs consideration.

Variability and Plot Shape

The among plot variances associated with the different shapes of a given plot size were compared using the F−test where the test criteria was the ratio of the larger to the smaller variance. The results are shown in *Table 3*. Non-significant results were obtained for all the comparisons. This indicated that, within the range of plot sizes considered, the shape of the plot, or the manner in which the basic unit were combined, did not have any appreciable effect upon plot variability. Therefore, for a given plot size, the plot can be arranged in any way convenient to the researcher and to the shape of the field.

The same findings were also reported for other crops by SMITH (1938), WIEDIMANN and LEININGER (1963), TORRIE, SCHMIDTH and TEMPAS (1963) and GOMEZ and ALICBUSAN (1968). This is probably due to the uniformity or bidirectional fertility gradient of the experimental site.

CONCLUSION

By using the index of soil heterogeneity and experimental cost, the optimum plot size for unguarded plot was determined to be 9.0

Table 3. Variance per unit area, Vx, coefficient of variation, CV and F–test for plots of various sizes and shape from maize uniformity trial

Plot size and shape			df	Vx	CV	F-test
Basic unit (no.)	Width no. of rows	Length no. of columns				
1	1	1	415	52 786.76	84.36	–
2	2	1	217	52 750.43	42.17	1.192 ns
	1	2	217	44 257.04	38.62	–
4	2	2	103	41 485.02	18.70	–
	1	4	103	41 941.14	18.80	1.011 ns
8	2	4	51	43 267.49	9.55	1.364 ns
	1	8	51	31 751.65	8.17	–
13	13	1	31	38 988.14	5.58	–
16	2	8	25	38 101.13	4.48	–
26	13	2	15	37 102.02	2.72	–
52	13	4	7	37 633.43	1.37	–

ns = not significant

sq metres. Within the same size, plot shape did not significantly affect plot variability and therefore the recommended plot shapes are 3 x 3 m or 7.5 x 1.2 metres.

SUMMARY

Data obtained from a sweet corn uniformity trial conducted at Agronomy Research Area, Universiti Pertanian Malaysia has been used for the determination of optimum plot size and suitable plot shape. The method proposed by SMITH (1938) was applied for these purposes. The results showed that the optimum plot size was estimated to be 9.0 sq m and can be arranged in any shape and direction.

REFERENCES

BRIM, C.A. and MASON, D.D. (1959). Optimum plot size for soya bean yield trials. *Agron. J.* **51**, 331–334.

CREW, J.W. and MASON, D.D. (1963). Field plot technique studies with flue-cured tobacco I. Optimum plot size and shape. *Agron. J.* **55**, 197–199.

GOMEZ, K.A. and ALICBUSAN, A.C. (1968). Estimation of optimum plot size from rice uniformity data. *Pfil. Agr.* **50**, 586–601.

HALLAUER, A.R. (1964). Estimation of soil variability and convenient plot size from corn trials. *Agron. J.* **56**, 493–499.

KHALID, M.N. (1979). Optimum plot size and shapes for three selected legumes. Proc. Legumes in the Tropics, pp. 443–447.

KELLER, K.R. (1949). Uniformity trial on hops, *Humulus lupulus* L., for increasing the precission of field experiments. *Agron. J.* **41**, 389–392.

SMITH, H.F. (1938). An empirical law describing heterogeneity in the yield of Agriculture Crops. *J. Agron. Sc.* **28**, 1–23.

TORRIE, J.H., SCHMIDTH, D.R. and TEMPAS, C.H. (1963). Estimates of optimum plot size and shape and replicate number of forage yield of alfalfa – bromograss mixture. *Agron. J.* **55**, 258–260.

WIEDIMANN, A.W. and LEININGER, L.N. (1963). Estimation of optimum plot size and shape for safflower yield trials. *Agron. J.* **55**, 222–225.

ZUHLKE, T.A. and GRITTON, E.T. (1969). Optimum plot size and shape for pea yield trials. *Agron. J.* **61**, 905–908.

Accepted for publication on 27th April, 1984