OPTIMUM PLOT SIZE AND SHAPE IN COTTON AND

PADDY FIELD TRIALS

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THESIS

Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Agronomy

Faculty of Agriculture

Ain Shams University

1972

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Date : / /1972.

بسم الله الرحمن الرحيم

A C K N O W L E D G E M E N T

The writer wishes to express her sincere appreciation and thanks to Dr. M.A. Moursi, Prof. of Agronomy and Chairman Agronomy Department, Faculty of Agriculture, Ain Shams University, Dr. A.R. Khalil, Director, and Dr. H.A. Abou-El-Fittouh, Statistician, Design and Statistical Analysis Section, Agricultural Research Center, Ministry of Agriculture, for suggesting the problem, supervising and guidance throughout the course of this study and during the stage of writing the manuscript.

Thanks are also extended to the staff members of the Design and Statistical Analysis Section, and the Rice Breeding Research Section, Agricultural Research Center, for their valuable help and assistance.

With deep appreciation, the writer wishes to acknowledge the use of the computing facilities of the Cairo University Scientific Computation Center.

C O N T E N T S

I. INTRODUCTION

Research workers in agriculture are mainly concerned with the improvement of their breeding strains and testing the performance of new entries under different agronomic conditions. They are also concerned, to a lesser degree, with the development of better experimental techniques to increase the sensitivity of their tests against the factors of natural variation. This may often be accomplished by improvements in the method of applying the treatments and measuring and recording the experimental results, as well as the design and statistical methods adopted.

With this regard, the statistician can play an important role by evaluating the currently used statistical concepts and procedures and suggesting ways to improve them. Essentially, his interest will be directed to the problems concerning the efficiency of experimental designs, techniques of statistical analysis, appropriate number of replications, optimum size and shape of blocks and experimental plots and their orientation in the field, ...etc.

The objective of this investigation is to study the relationship between plot size and shape on the one hand and variability in plot yield on the other so far cotton and paddy are concerned. In practice plot size and shape are sometimes determined by some non-statistical factors outside the control of the research worker. Seed supply, size and shape of the field and convenience for the different agronomic operations are among those factors. Plot size and shape also depend to a very great extent on the crop, the nature of the soil at the experimental site and the conditions of cultivation. Therefore, it is necessary and desirable to conduct detailed and careful study of this factor under varying conditions until sufficient information is gathered to reach sound conclusions. Results of this investigation, together with those previously reported by other investigators, should clarify the degree of sensitivity of the yield to changes in plot size and shape for different varieties of the two crops under different patterns of soil variability. They also provide estimates of the "optimum" plot size and shape that can be adopted by the research workers in their field trials on the two crops under similar experimental conditions.

II. REVIEW OF LITERATURE

The problem of determining the optimum plot size and shape has attracted the attention of many scientists working on different crops under different experimental conditions. They used several available procedures to investigate the effect of changing plot size and shape on the magnitude of the experimental error. They reported that increasing the size of plot generally increases the precision of the individual observations. However, as the plot size increases the block size increases and, consequently, the variability within the block is increased. By balancing these two opposite tendencies, the research workers would reach a satisfactory plot size which gives accurate results.

Among the different procedures presented to study this problem, the method devised by Smith (1938) has been most widely recognized. In his paper, Smith empirically demonstrated the existence of a linear relationship between the logarithms of plot size and plot variance. He expressed this relationship as follows :-

$$\log V_x = \log V - b \log x$$

where :

V_x = Variance, on a single unit basis, of plots of size x units,

V = Variance of single-unit plots,

b = index of soil variability, and

x = number of single units in the plot.

The index (b) in the above equation measures the degree of correlation among adjacent experimental plots, and can be estimated from uniformity trial data by using the principles of linear regression. It is used, in conjunction with cost estimates, to determine the optimum plot size.

Another method was presented by Koch and Rigney (1951) for establishing the optimum size of plot by making use of actual experimental data from split-plot and incomplete block designs. The method involves the reconstruction of the analysis of variance of the experiment so that it simulates uniformity data. Variances for the different sized plots are computed from the estimates of the variance components and reduced to a per unit basis. An unweighted least squares fit is then used to determine the optimum plot size.

Hatheway and Williams (1958) developed a method for weighting observed variances for different-sized plots to obtain an unbiased estimate of the regression coefficient with asymptotically minimum variance. The method is applicable both to uniformity trial data and to experimental data. The weights used in this case are the elements of the inverse of the variance-covariance matrix of the observed variances. The authors pointed out that estimating the weights from the data could be a source of error whose effect they did not determine.

Afonja (1967) discussed Smith's measure of soil variability and examined the different methods proposed to determine it. He indicated that these methods provide approximate values for (b). He outlined an alternative method which made use of a factorial experiment containing plots of different sizes. The primary object of this experiment was to test the effect of four set weights and four spacings on the yield of white yam. In order to obtain a constant plant population per plot, different plot sizes had to be used. The method provides independent estimates of the variances for the different sized plots and a simple unweighted regression coefficient can thus be calculated more accurately.

Federer (1955) outlined Smith's method and recapitulated some related mathematical developments. He also presented the maximum curvature method which has frequently been used to determine optimum plot size for various crops. The method involves computing the coefficient of variability for different plot sizes from uniformity trial data. The coefficients are then plotted against their respective plot sizes and a free hand curve is drawn. The point of maximum curvature is determined by inspection. The optimum plot size is considered the one just beyond the point of maximum curvature. The author indicated that this method has two weaknesses. Firstly, relative costs are ignored and, secondly, the point of maximum curvature is dependent on the smallest basic unit selected and on the scale of measurement used. As far as cost factors are concerned, Hatheway (1961) pointed out that research workers are generally more interested in designing experiments that are capable of detecting differences of a specified size among the treatments under comparison irrespective of costs. Hallauer (1964) indicated that this does not mean ignoring cost factors but, rather, using all allocated resources in a manner that provides information relative to the desired comparisons among treatments. Furthermore, a scientist will generally tend to locate a region, instead of a point, of maximum curvature on the curve. This would greatly reduce the effect of scaling and would result in an interval of acceptable plot sizes which would give the experimenter liberty to choose the most convenient plot size for his conditions.

Lessman and Atkins (1963) derived a mathematical expression which can be used to locate the critical point of maximum curvature (x critical) without need to draw the curve. The expression was reached by maximizing the derivative with respect to x, of the angle of intersection between pairs of successive tangent lines to the curve. The critical value of (x) is then used to estimate the optimum plot size when cost is considered as follows

$$\text{Optimum plot size} = (K_1/K_2)\ (x \text{ critical})$$

where :

K_1 = part of the cost proportional to number of plots per treatment, and

K_2 = part of the total cost proportional to total area per treatment.

Galal and Abou-El-Fittouh (1971) derived another equation to define the point of maximum curvature on the exponential curve relating plot size and coefficient of variability. Their derivation was based on the mathematical expression of curvature :

$$K = y'' (1 + y'^2)^{-3/2}$$

where :

K = curvature at a point (x_o, y_o) on any curve $y = f(x)$,

y' = value of the first derivative, dy/dx, at (x_o, y_o), and

y'' = value of the second derivative, d^2y/dx^2, at (x_o, y_o).

For the exponential curve C.V. = $A x^{-B}$ the curvature at plot size x_o is

$$K = AB(B + 1)\, x_o^{-(B + 2)} \left[1 + A^2B^2 x_o^{-2(B + 1)}\right]^{-3/2}$$

Setting the derivative of K with respect to x equal to zero and solving for x, they obtained the following expression for the value of x at which the curvature is maximum,

$$x \text{ critical} = \left[A^2B^2 (2B + 1)/(B + 2)\right]^{1/(2B+2)}$$

In the above expression, the values of (A) and (B) are estimated, by using the principles of linear regression, from the linear relationship between the logarithms of plot size and coefficient of variability

$$\log (C.V.) = \log (A) - B \log (x)$$

The coefficient of variability was used in many studies as an indicator of the optimum size and shape of plot. Some of these studies were conducted by Immer (1932) on sugarbeets; Justesen (1932) and Kalamkar (1932) on potatoes; Loesell (1936) on beans; Robinson et al. (1948) on peanuts; Lessman and Atkins (1963) on grain sorghum; Lord (1931); Abraham and Vachhani (1964), Gomez and Alicbusan (1969) and Hanna (1972) on paddy; and Reynolds et al. (1934), McDonald et al. (1939), Khalil et al. (1970) and Galal and Abou-El-Fittouh (1971) on cotton.

Christidis (1931) presented some mathematical considerations concerning the shape of field plots. He pointed out the importance of using homogeneous plots to secure experimental efficiency, and indicated that square plots can never be more uniform than the long and narrow ones within the limits of practical considerations.

It is generally believed that plots should be approximately square in the absence of knowledge concerning fertility trends. Otherwise, relatively long and narrow plots, with the long dimension in the direction of the greatest soil variation overcome soil heterogeneity most effectively.

Federer (1955) indicated that the shape of small plots may have little or no effect, where as for large plots the effect of shape may be considerable. Furthermore, plot shape should permit, when necessary, the operation of standard farm equipment and allow for the removal of border rows when this appears desirable.

One of the early reports on plot size and shape was that published by Lord (1931). He presented the results of a uniformity trial which he conducted at Ceylon. His objectives were to determine the optimum size of plot for field trials of irrigated broadcast paddy and the effect on yield of the position of the plot in the field. His experiment included eight 1/5 acre fields. Shortly after broadcasting each field was marked out into seventy 10 ft x 10 ft plots by ropes which remained in their position until after harvesting. A border varying from 1 ft to 3 ft in width surrounded each of the eight fields. He found that the reduction of the