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OPTIMUM SIZE AND SHAPE OF PLOTS BASED ON DATA FROM A UNIFORMITY TRIAL ON WHEAT (*TRITICUM AESTIVUM L.*) IN HARYANA INDIA

Manoj Kumar[1*], Todarmal Poonia[2], Nitin Bhardwaj[2] and Anurag[3]
[1] Department of Mathematics and Statistics, C.C.S. H.A.U., Hisar.India
[2] Department of Agronomy. C.C.S. H.A.U., Hisar, India
[3] Department of Agrometrelogy. C.C.S. H.A.U., Hisar, India
*Corresponding author E-mail id: m25424553@gmail.com
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ABSTRACT

The most obvious use of uniformity trial data is to provide information on the most suitable size and shape of plots, in which the field was planted to a single variety and harvested as small plots. Wheat (*Triticum aestivum L.*) was grown using uniform crop improvement practices during Rabi season at Research Farm of Agronomy, Department of Agronomy, C.C.S.H.A.U., Hisar, Haryana state, India, to estimate optimum plot size and shape. The yield data of 18 m × 36 m (648 basic units) recorded separately from each basic unit of 1 m × 1 m. The variability among plots of different sizes and shapes was determined by calculating coefficient of variation. It was also observed that the rate of decrease of C.V. was higher when the plots were elongated in E-W direction (64.84 per cent decrease) than those elongated in N-S direction (59.81 per cent decrease), thus indicating more homogeneity in E-W direction. Thus for a fixed size of plot, the plots elongated in N-S direction give less C.V. as compared to the plots in E-W direction, indicating thereby that the plots become more homogeneous when elongated along N-S direction. Further it was observed that long-narrow plots elongated in N-S direction had less coefficient of variation than compact and square plots for a given particular plot size in controlling the soil heterogeneity. Based on the maximum curvature method the optimum plot size for yield trial was estimated to be 6 m^2 with rectangular shape.

Keywords: Uniformity trial, Optimum plot size, coefficient of variation

Introduction

Uniformity trial involves planting an experimental site with a single crop variety and applying all cultural and management practices as uniform as possible. All sources of variability, except that due to native soil difference, are kept constant. The planted area is subdivided into small units of the same from which separate measurements of productivity, such as grain yield are made. Yield differences between these basic units are taken as a measure of the area's soil heterogeneity.

The variability of experimental area can be quantified by organising uniformity trial specifically designed for identifying the variability or the heterogeneity index of the character under study in the experimental area (Smith, 1938).

Khan *et al.* (2016) conducted a uniformity trial on Indian mustard (*Brassica juncea*) cultivar RH-749 during rabi season 2013-14 and observed that the coefficient of variation decreases as the plot size increase in both direction. They have also observed that long and narrow plots elongated in E-W direction were more useful than the compact and square plots in controlling the soil heterogeneity and optimum plot size for yield trial was estimated to be 5m 32 with rectangle shape. The coefficient of variation (CV) decreased from 10.66 to 3.89 with the increase in block size from 4 to 24, indicating that as the block size increased, homogeneity within the block also increases and the blocks elongated in E-W direction were more effective in reducing error variation than those elongated in N-S direction. The 24 plot blocks were found to be most efficient with 12m × 2m block shape. Most of the researcher likes Agnihotri *et al.* (1995 and 1996), Aggarwal (1973), Handa *et al.* (1995), Massod and Javed (2003), Kumar *et al.* (2002) and Strock *et al.* (2010) have been carried out the work to find out the optimum plot shape and size for both agronomic and horticultural crops.

India is the second largest producer of wheat after China and Haryana has second rank in terms of wheat yield sustainability after Punjab. It was of prime importance to conduct the uniformity trial on wheat (*Tritcum aestivum L.*) in Haryana state of India with the utilization of data for the estimation of optimum plot shape and size.

Material and Methods

Source of data

The data were collected from the Research Farm of Agronomy Department, CCSHAU, Hisar, Haryana, India, where a uniform crop of wheat (*Tritcum aestivum L.*) was grown during Rabi season of 2021-22 over an area of 18 m × 36 m (648 m^2). The field was divided into rows (East-West direction) and columns (North-South direction). The spacing between rows was 20 cm and plants within rows were about

10 cm apart. Border of 1.0 m each on both sides of the sown area was left out and harvesting of crop was done in small units each of size 1 m × 1 m (1 m^2). The units were arranged in 18 rows and 36 columns so total number of experimental units thus obtained was 648 units in all. The grains from each of these basic units were harvested, bagged, threshed, cleaned, dried and weighted (in grams) separately. Yield differences between these basic units were taken as a measure of the area's soil heterogeneity. The contiguous plots were then grouped into 2, 3, 4, 6, 9, 12 and 18 plots. Coefficient of variation (CV) for each size and shape of plot was calculated and the coefficient of variation so obtained was utilized to determine optimum shape and of plot. A number of research workers have attempted to study the soil fertility variation through various methods. Some of the methods for soil fertility variation/plot size are given below:

1 Soil Fertility Contour Map

2 Fairfield Smith's Variance Law

3 Maximum Curvature Method

The descriptions of the method are as follows:

Soil Fertility Contour Map: Soil productivity contour map is a simple but informative presentation of soil heterogeneity. The map describes graphically the productivity level of the experiment site based on moving average of contiguous units

Relationship between plot sizes and coefficient of variation: Smith wax the first one to give the functional relationship between plot size and coefficient of variation which is given by

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

Taking logarithmic on both sides and apply the properties of $logm^n = nlogm$, we have

$$logV_x = logV_1 - blogx \quad (2)$$

Where V_x is the variance of yield per unit area among plots of size *X* units,

V_1 is the variance among plots of size unity, *b* is the linear regression coefficient, indicating the relationship between adjacent individual experimental units or in other words it reflects soil heterogeneity and thus serve as an index of soil heterogeneity which can assume the values from 0 to 1, and *X* is the number of basic units per plot.

The index of soil heterogeneity '*b*' is the regression of the log of the plot variance (on a per unit basis) on the log of the number of basic units per plot. The bigger the estimated value of '*b*', the bigger the soil heterogeneity; in other words, values close to the unit indicate larger soil heterogeneity and values close to nullity indicate that the adjacent portions are more correlated. It is worth noticing that '*b*' corresponds to all sources of environmental variation, not only to the soil variability. Smith (1938) computed the values of regression coefficients for thirty different sets of uniformity trial data and found that most of the regression coefficients fell within the range of 0.2 to 0.8. Generally, coefficient of variation is used as a relative measure for computing variability index of *Vx*.

In equation (2), the values of *V*1 and *b* were computed by the principle of least squares. The coefficient of determination (R^2) was computed for fitted equation to examine the suitability of the Smith's equation.

The relative efficiencies of plot sizes was obtained by the Agarwal and Deshpande (1967). Relative efficiency in terms of coefficients of variations and plot sizes can be written as

$$R.E. = (\frac{CV_1}{CV_2})^2 \times (\frac{X_1}{X_2})^2$$

Where, CV1 and CV_2 are the coefficients of variation corresponding for plot sizes X_1 and X_2 respectively.

Taking the efficiency of smallest plot as unity, the relative efficiencies of various plot sizes has been calculated.

Maximum curvature Method: The maximum curvature method (Agarwal, 1973) has frequently been used to determine plot size for various field crops. With this method, yield data from 'basic units' of a uniformity trial were combined into plots of different sizes and shapes which were compared for degree of variability. An index of variability, *i.e.*, coefficient of variation (C.V.) and plot sizes were plotted on the Y-axis and X-axis, respectively. The optimum plot size was read by inspection as the point on the curve where the rate of change for the variability index per increment of plot size was greatest. This method has two shortcomings: (*i*) the relative costs of various plot sizes were not considered and (*ii*) the point of maximum curvature was not independent of the basic unit.

Agarwal (1973) give the formula to find out the optimum plot size

$$X_{opt}^{2(1+b)} = V_1^{\,2} b^2 \{\left[\frac{3(1+b)}{(2+b)}\right] - 1\}$$

Optimum plot size using cost consideration: The cost of field experimentation must also be reflected in optimum plot size. Smith (1938) worked out optimum plot size for different values of costs under assumption of linear cost structure. The formula is given by:

$$X_{opt} = \frac{bC_1}{(1-b)C_2}$$

Where, X_{opt} is the optimum plot size which provides the maximum information per unit of cost

C_1 is that part of total cost which is proportional to number of plots per treatments and C_2 is that part of total cost which is proportional to the total area per treatment.

Result and Discussion

Spatial variation of fertility contour map of the field is shown in Figure -1 for 18x36 basic units. The highest yield was observed in the eastern half field (except for northern parts) while a scattered pattern of yield (or a mix of lower and higher yield) was observed in the western half. Mostly, the lower yield was concentrated in northern parts that extended throughout the field in a linear direction in east-west directions, whereas higher yields were in the clusters located in south-western parts of the field.

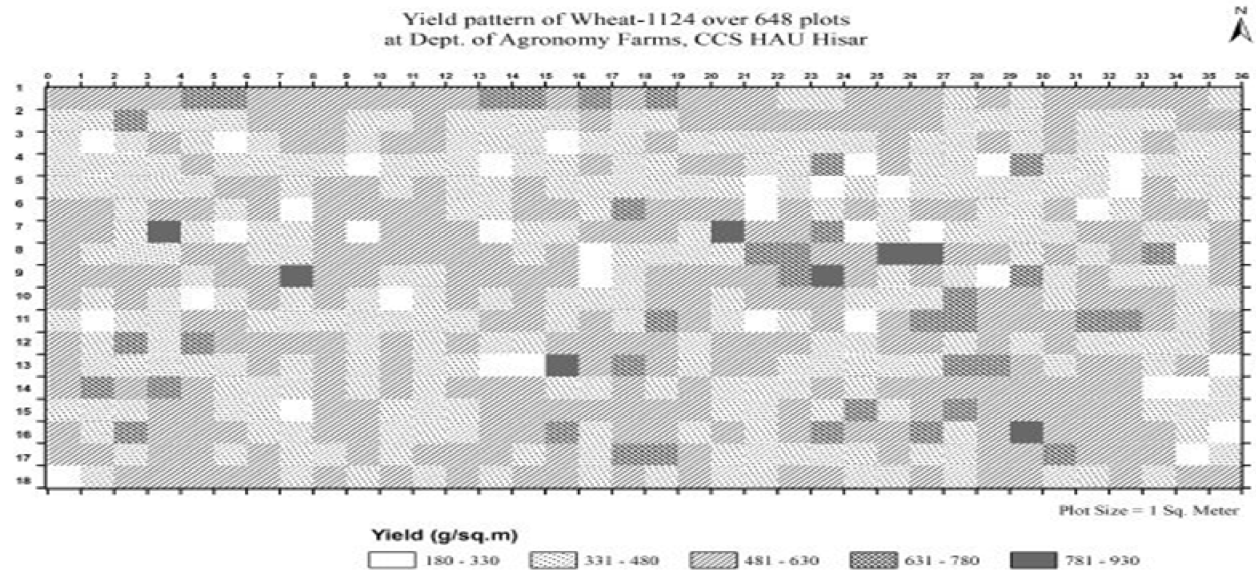

Fig. 1 : Fertility Contour map of a field 18X36 basic units, constructing from the moving averages of 3X3 basic units

Effect of plot size on error variability: To have an idea about nature and magnitude of variability due to soil heterogeneity in plot yields, the coefficient of variation of yields of harvested units for various plot sizes of 1, 2, 3, 6, 9, 12 and 18 in different shapes were calculated and are presented in Table-1.

Table 1 : Coefficient of variation of different plot sizes and shapes

No. of Units N-S	Number of units along E-W				
	1	**2**	**3**	**6**	**9**
1	21.9	15.6	12.8	9.6	7.7
2	17.1	12.6	10.4	7.9	6.3
3	15.2	11.3	9.2	7.2	6
4	13.9	10.1	8.4	6.4	4.7
6	11.4	8.4	6.6	5	3.9
9	10.1	7.5	5.7	3.8	3
12	9.4	6.8	5.2	3.7	2.6
18	8.8	6.5	4.8	3.4	1.7

It is clear from the table that the coefficient of variation decreased with the increase in plot size in either direction. This decrease was rapid for the small plot sizes but lessens for larger plot sizes. It was also observed that the rate of decrease of C.V. was higher when the plots were elongated in E-W direction i.e. from 21.9 to 7.7 (64.84 per cent decrease) than those elongated in N-S direction i.e. from 21.9 to 8.8 (59.81 per cent decrease), thus indicating more homogeneity in E-W direction. Thus the plots elongated in E-W direction give less C.V. as compared to the plots in N-S direction for a fixed size of plot which indicate that the plots become more homogeneous when elongated along E-W direction

Effect on plot shape on error variability:

Table 2 : Coefficient of variation for various plot sizes and plot shapes

Plot Size (in units)	Plot shape	C.V.(%)	Minimum C.V. (%)
1	1:1	21.86	21.86
2	1:2	15.62	15.62
	2:1	17.10	
3	1:3	12.81	12.81
	3:1	15.20	
4	2:2	12.64	12.64
	4:1	13.9	
6	1:6	9.61	9.61
	2:3	10.42	
	3:2	11.30	
	6:1	11.43	
9	1:9	7.71	7.71
	3:3	9.24	
	9:1	10.14	
12	1:12	7.62	7.62
	2:6	7.91	
	4:3	8.42	
	6:2	8.45	
	12:1	9.43	
18	1:18	6.22	6.22
	2:9	6.31	
	3:6	7.24	
	6:3	6.63	
	9:2	7.52	
	18:1	8.81	

It was obvious from the table -2 that the C.V. was minimum for the plot shape 1:6, *i.e*., of the order of 9.61 per cent. The same pattern exists for the plot of size of 9 units where the minimum C.V. was of the order of 7.71 per cent for the plot shape 1:9 and for the plot of size 12 units where the minimum C.V. was of the order of 7.91 per cent for the plot shape 1:12 and for the plot of size 18 units where the minimum C.V. was of the order of 3.28 per cent for the plot shape 1:18. Thus, longer plots were more beneficial than the plots in compact and square shape.

Relationship between coefficient of variation and plot size*:* It has been observed that there exists a relationship between the plot size and the coefficient of variation as was established by Fairfield Smith in 1938. For the present uniformity trial data, we obtain the following parameter of Smith's equation by using following R-code:

```
trial = read.csv("C:/Users/Dr. Manoj/Desktop/run.csv")
fit1<-nls(cv~a/(size^b),data=trial,start=c(a=1,b=0.35))
summary (fit1)
```

Table 3 : Parameter Coefficient of the Fairfield Smith's equation

Parameter	Coefficient	S.E.	t-value	p-value
a	22.00407	0.518	42.43	<.01
b	0.3970	0.011	33.19	<0.01

The Smith's equation is found to be $CV = 22.004\, x^{-0.397}$

The equation was in conformity with Smith's law, where the soil variability index (b) was 0.3970. It indicates the positive correlation between the adjacent basic units.

Relative efficiencies for different plot sizes:

To compare the efficiencies of plots of various sizes, efficiency of the smallest plot was taken as unity as the smallest plot was the most efficient of all the plot sizes. The relative efficiencies for the present experiment is presented in Table-4. It was observed that the smallest plot has the maximum efficiency but as the plot size increases the efficiency goes on decreases due to the presence of soil variability.

Table 4 : Relative efficiencies of various plot sizes

Plot sizes	Plot shapes	Coefficient of variation	Relative efficiency
1	1:1	21.9	1.00
2	1:2	15.6	0.847
3	1:3	12.8	0.559
6	1:6	12.6	0.144
9	1:9	7.7	0.172
12	1:12	7.6	0.099
18	1:18	6.2	0.066

Optimum plot size

Maximum Curvature Method: In this method basic units of uniformity trials are combined to form new units. The new units are formed by combining columns, rows or both. Combination of columns and rows be done in such a way that no columns or rows is left out. For each set of units, the coefficient of variation (CV) is computed. A curve is plotted by taking the plot size (in terms of basic units) on X-axis and the CV values on the Y-axis of graph sheet. The point at which the curve takes a turn, *i.e.,* the point of maximum curvature is located by inspection. The value corresponding to the point of maximum curvature will be optimum plot size.

This method of fixing optimum plot size is known as maximum curvature method. This is only an approximate method of fixing. For the figure -2 it is clear that the curve takes a turn between plot sizes 5 to 10. The optimum plot size is, therefore, 6 square meters.

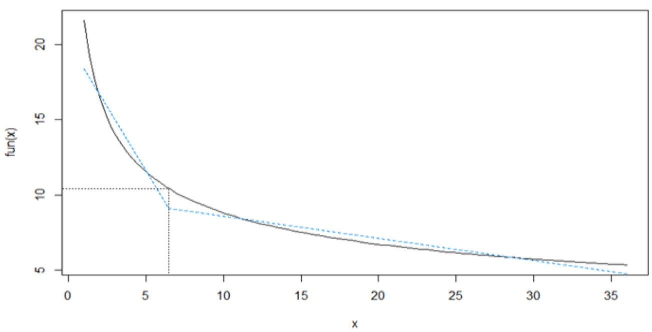

Fig. 2 : Curve plot by Maximum curvature Method

By using equation given by Agarwal (1973), the optimum plot size has been worked out by maximum curvature method and was found to be approximately 6 units (*i.e.*, 6 m^2).

The optimum plot sizes were also computed by Smith's method considering the values of C1/C2 from 0.5 to 6.5 and the results are presented in Table -5. It was observed that for a given plot arrangement, the optimum plot size increases with the increase in the cost ratio, *i.e*., when the fixed cost becomes larger than the variable cost. The results from Smith's method were inappropriate for the estimation of optimum plot size, whereas maximum curvature technique revealed significant results. Accordingly plot size of 6 m^2 was found optimum for field experiment on wheat using the maximum curvature technique.

Table 5 : Optimum plot size under cost consideration

C1/C2	Optimum size of plot (m^2)	C1/C2	Optimum size of plot (m^2)
0.5	0.33	7	4.61
1	0.66	7.5	4.94
1.5	0.99	8	5.27
2	1.32	8.5	5.60
2.5	1.65	9	5.93
3.5	2.30	9.4	6.19
4	2.63	9.5	6.25
4.5	2.96	10	6.58
5	3.29	10.5	6.91
5.5	3.62	11	7.24
6	3.95	11.5	7.57
6.5	4.28	12	7.90

Conclusion

The study results reveal that there was a not so much variation in yield data gathered from different plot sizes. It was observed that long and narrow plots elongated in E-W direction were more useful than the compact and square plots. The relative efficiency of the smallest plot has found to be highest but it decreased with the increases in plot size due to the presence of soil variability.

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