American-Eurasian Journal of Scientific Research 7 (6): 264-269, 2012
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2012.7.6.1926

Estimation of Optimum Field Plot Size and Shape in Paddy Yield Trial

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Abstract: This paper is to estimate the optimum plot size with the shape for field research experiments on paddy yield trial considering the effect of plot size on variability in yield of crop as well as studying the coefficients of variation of different plot sizes and shapes of plots. The maximum curvature technique and comparable variance methods were exercised to estimate optimum plot size and shape using yield data of the 12m x 24 m (288 basic units) recorded separately from each basic unit of 1m x 1 m. Soil productivity contour map described graphically the productivity level of the experimental site. The index of soil heterogeneity (b = 0.12) indicated a degree of low similarity among the experimental plots. The results from comparable variance method were inappropriate for the estimation of the optimum plot size, where as maximum curvature technique revealed significant results. Under this method, the curve of the coefficients of variation decreased rapidly up to 18 basic units with each unit increase in the plot size. Based on the maximum curvature method the optimum plot size for paddy yield trial was estimated to be 6m x 3 m with rectangle shape for Rice Research Institute, Kala Shah Kaku, Lahore. This estimated plot size is larger than the plot size of 3mx5m generally used for paddy yield in the study area. The study results indicated that the coefficients of variation (35.24, 23.80, 21.50, 19.49 and 17.86 percent) declines with an increase in the plot size($1m^2$, $2m^2$, $3m^2$, $4m^2$, $6m^2$) respectively and this decrease is maximum with the square shape plot of size (6mx6m) basic units. As a result, square shape seems better for large plot sizes in the study area.

Key words: Optimum plot size and shape · Comparable variance · Maximum curvature · Coefficient of variation

INTRODUCTION

It is of considerable importance for the research workers of crop science to have knowledge on field plot technique, the study of size and shape of plot, best suited for a particular type of experiment. It is of utmost importance to use the most efficient shape, size and arrangements of plots in a particular experiment for obtaining the reliable results. The precision of significance tests in field trial is largely controlled by size and shape of plots, which are further controlled by the size and shape of area available for the particular trial, the nature of fertility or other variation.

The problem has therefore been selected so as to see a scientific basis for using plot size and shape within "optimum limits". To cope with the problem of the research workers, it has become necessary to standardize a suitable plot size and shape for the experimental plot of major crops grown under different conditions, which will reduce the standard error of the experiments.

Field-plot techniques deal with the various elements to a properly plan agricultural field experiment. The use of improper field-plot techniques may inflate experimental error and lead to erroneous inferences. Hence, to improve the quality as well as credibility of research results, there is a need to carry out research on field-plot techniques.

Gomez and Gomez [1] described that Uniformity trial involves planting an experimental site with a single crop variety, applying cultural and management practices as uniformly as possible. All sources of variability, except that due to native soil differences, are kept constant. The planted area is sub divided into small units of the same size (generally referred to as basic units) from which separate measurements of productivity, such as grain yield, are made. The size of the basic unit is governed mostly by available resources. The smaller the basic unit, the more detailed is the measurement of soil heterogeneity

In field experiments, soil variability is one of the important external sources of variation. This variability may be random or systematic. Usually researchers assume that the errors are independently, randomly distributed and use block experiments to minimize this source of variation. It depends upon the block or plot size and their orientation. Leilah and Al-Khateeb [2] carried out a study to estimate the optimum plot size, shape and number in the desert rangeland of Saudi Arabia. The weighted index

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of soil heterogeneity was estimated to be 0.69 which showed that plots were homogeneous. Two methods were used to appraise the optimum plot size: one was the comparable variance technique and the other was maximum curvature. Bhatti and Muhammad [3] studied the effect of shape and size of plots on spatial variability in cotton yields using statistical procedures such as frequency plot analysis and semivariogram analysis to study the nature and magnitude of variability in the yield data obtained from different plot shape and size. Results proved that there was a substantial variation in yield data from different plot sizes and shapes. As the plot size increases variability decreases. Plot sizes of 2x4 and 8x2 units were considered optimum for field experiments on cotton. Faqir *et al.* [4] studied size and shape of plots for wheat yield trials in field experiments on twenty-nine datasets of wheat with the characteristics measured, plant height, grain yield and straw yield using the index of heterogeneity and estimated ultimately the plot size under different situations. The first method was based on Lin and Binns that described the calculation of plot size, while the second method used the Smith's empirical relation.

Nasr [5] calculated estimation of optimum plot size, shape and number of replications for wheat yield trials under different fertilizer conditions. The influence of plot shape and plot orientation on the precision of field experiments was investigated using uniformity trial data for rice at Wufeng [6]. Variations were found in field size and shape on the heterogeneity index (b) and its standard error in rice uniformity trials from 1991 to 1993 [7]. Patil and Yaduraju [8] stated the effect of size and shape of plots in field experiments with wheat.

Many other research workers conducted research to find optimum plot size, shape and orientation for field experiments [9-17].

Study Objectives:

- To estimate the optimum plot size and shape for field research experiments on paddy yield trial;
- To determine the effect of plot size on variability in yield; and
- To study the coefficients of variation of different plot sizes and shapes.

MATERIALS AND METHODS

The data were collected from Rice Research Institute, Kala Shah Kaku, Lahore, Punjab on paddy yield trial in close collaboration with Rice Program, PARC. A single rice line T5 crop area of 12m x 24m was selected randomly to consider all management practices as uniform as possible. Yield data were recorded separately from each basic unit of 1m x 1 m. Grains from each of the 288 basic units were harvested, bagged, threshed, cleaned, dried and weighed separately. Yield differences between these basic units were taken as a measure of the area's soil heterogeneity.

Soil productivity contour map was drawn to describe graphically the productivity level of the experimental site based on moving averages of adjacent units. Mean, median, coefficients of variation were computed from different combinations of basic units to estimate the yield using three statistical measures. Variance among plots, V(x), variance per unit area, Vx, and coefficients of variation for plots of various sizes and shapes were calculated to determine plot size and shape of plot. Mean squares among strips were computed to indicate the direction of the fertility gradient. Maximum curvature technique was also used to describe the relationship between coefficient of variation and plot size.

Smith's index of soil heterogeneity was used to derive optimum plot size. The index gives a single value as a quantitative measure of soil heterogeneity in an area. The value of the index indicates the degree of correlation between adjacent experimental plots. Its value varies between unity and zero. The larger the value of the index, the lower is the correlation between adjacent plots, indicating that fertile spots are distributed randomly or in patches.

The soil heterogeneity index (b) was calculated by this equation: {2}

$$b = \sum w_i \log V_x \times \log X_i - \sum(w_i \log V_x)(\sum w_i \log_{X_{ij}} / \sum w_i) / \sum w_i (\log X_i)^2 - \sum(w_i \log X_{ij})^2 / \sum w_i$$

RESULTS AND DISCUSSION

The soil productivity contour map depicted graphically the productivity level of the experimental site based on moving averages of contiguous units. Mean square for horizontal strips (0.013) is relatively higher than mean square for vertical strips (0.006), which concurs with the contour map and indicates that trend of soil fertility, was more pronounced from north to south rather than east to west (Fig. 1).

Variability in yields of rice line T5 of different plot sizes and shapes showed that mean yields varied significantly with an increase in plot size (Table 1). Median values of yields are similar to mean yields apart from larger plot sizes (Table 2). Coefficients of variation for plots of various sizes and shapes are presented in

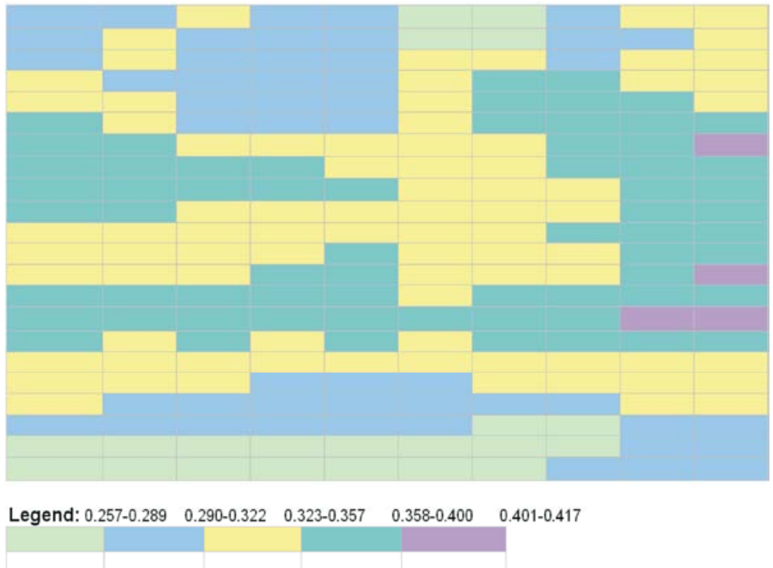

Fig. 1: Fertility Contour map based on moving averages (table 2) of uniformity yield data of Table 1

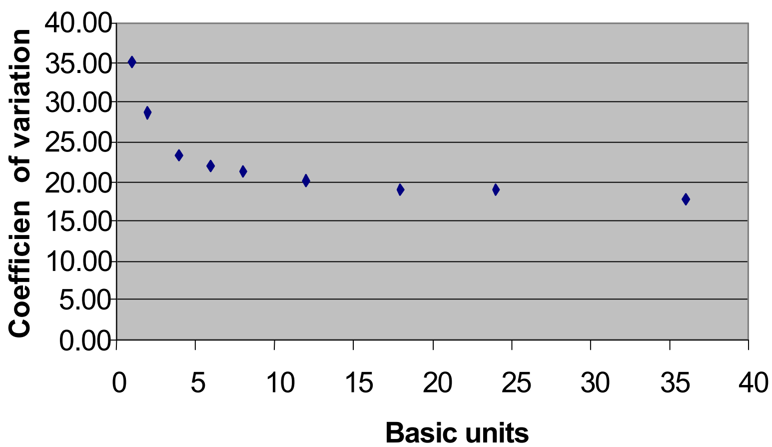

Fig. 2: Coefficient of variation in response to basic units

(Table 3). The results indicate that as plot size increases, coefficients of variation decreases. Square shape plots gave small values of coefficients of variation as compared to rectangle and strip shape plots (Table 3).

The value of soil heterogeneity index was found to be (0.12) which showed a degree of low relationship among the experimental units. The low value of soil heterogeneity index (b=0.120) indicated a little bit heterogeneity among 288 basic units.

The maximum curvature technique described the relationship between coefficients of variation and plot sizes. Under this technique, the relationship between different plot sizes and coefficients of variation was examined taking plot sizes (in terms of basic units) on the X-axis and the values of coefficients of variation on Y-axis. The point at which the curve turned sharply, the point was considered optimum plot size. Study results revealed that the coefficients of variation decreased rapidly up to 18 basic units with each unit increase in the plot size (Fig 1). This implies that the plot of rectangular shape that is (6mx3m) basic unit was the most effective in reducing soil variation and is therefore considered the optimum plot size.

The comparable variance (V) and relative information (RI %) revealed that comparable variance and relative information increases with each unit increase in the plot size. Therefore comparable variance technique does not give meaningful result regarding the optimum size of the plot and is not effective in reducing soil variation (Table 4). Leilah and Al-Khateeb [2] carried out a study to estimate the optimum plot size, shape and number in the desert rangeland of Saudi Arabia. The weighted index of

Table 1: The data on Grain yield (kg/ m^2) of rice (line T5) from a uniformity test covering an area of 12 x 24 m^2, Rice Research Institute, Kala Shah Kaku, 2009

	Column											
Row	1	2	3	4	5	6	7	8	9	10	11	12
1	0.36	0.28	0.40	0.27	0.29	0.35	0.24	0.27	0.31	0.48	0.27	0.36
2	0.29	0.28	0.35	0.34	0.36	0.29	0.21	0.28	0.26	0.34	0.33	0.35
3	0.26	0.41	0.24	0.35	0.36	0.28	0.36	0.28	0.28	0.32	0.36	0.30
4	0.29	0.42	0.29	0.25	0.33	0.27	0.26	0.25	0.39	0.32	0.30	0.43
5	0.35	0.31	0.33	0.37	0.29	0.31	0.38	0.39	0.35	0.32	0.36	0.33
6	0.32	0.35	0.30	0.28	0.29	0.30	0.33	0.49	0.48	0.28	0.29	0.32
7	0.39	0.47	0.32	0.21	0.35	0.31	0.33	0.27	0.44	0.40	0.43	0.37
8	0.43	0.39	0.33	0.44	0.35	0.30	0.30	0.34	0.35	0.51	0.31	0.41
9	0.40	0.43	0.38	0.37	0.35	0.47	0.30	0.32	0.32	0.43	0.40	0.45
10	0.35	0.33	0.44	0.39	0.29	0.40	0.43	0.27	0.38	0.33	0.35	0.43
11	0.43	0.46	0.36	0.35	0.35	0.33	0.37	0.31	0.35	0.41	0.36	0.39
12	0.34	0.33	0.33	0.35	0.34	0.28	0.36	0.30	0.40	0.39	0.32	0.40
13	0.27	0.29	0.34	0.39	0.39	0.38	0.43	0.30	0.32	0.48	0.42	0.31
14	0.41	0.42	0.35	0.36	0.33	0.41	0.36	0.30	0.30	0.35	0.38	0.36
15	0.34	0.35	0.36	0.37	0.29	0.35	0.35	0.32	0.40	0.38	0.50	0.44
16	0.40	0.34	0.37	0.42	0.50	0.32	0.39	0.43	0.44	0.35	0.40	0.46
17	0.38	0.40	0.32	0.32	0.33	0.36	0.37	0.40	0.37	0.40	0.46	0.38
18	0.37	0.40	0.32	0.31	0.35	0.30	0.33	0.30	0.33	0.35	0.34	0.32
19	0.32	0.29	0.39	0.33	0.31	0.31	0.35	0.36	0.33	0.35	0.30	0.28
20	0.34	0.34	0.37	0.29	0.27	0.31	0.33	0.29	0.31	0.38	0.41	0.34
21	0.29	0.30	0.29	0.30	0.29	0.31	0.32	0.29	0.23	0.28	0.36	0.26
22	0.20	0.24	0.25	0.34	0.27	0.26	0.30	0.25	0.23	0.31	0.31	0.27
23	0.26	0.28	0.26	0.24	0.25	0.20	0.34	0.35	0.31	0.38	0.27	0.28
24	0.28	0.25	0.30	0.33	0.32	0.32	0.26	0.32	0.30	0.34	0.31	0.35

Table 2: Moving Averages based on 3x3 basic units computed from the uniformity data of table 1

	Column									
Row	1	2	3	4	5	6	7	8	9	10
1	0.317	0.322	0.327	0.320	0.303	0.282	0.273	0.311	0.325	0.343
2	0.313	0.323	0.316	0.312	0.301	0.273	0.283	0.300	0.319	0.337
3	0.321	0.328	0.309	0.310	0.314	0.307	0.324	0.320	0.331	0.336
4	0.328	0.321	0.301	0.296	0.304	0.330	0.368	0.363	0.342	0.327
5	0.348	0.325	0.302	0.299	0.318	0.343	0.382	0.379	0.372	0.344
6	0.365	0.341	0.316	0.313	0.316	0.328	0.368	0.394	0.387	0.368
7	0.391	0.369	0.343	0.348	0.338	0.324	0.328	0.373	0.397	0.410
8	0.384	0.386	0.369	0.372	0.353	0.345	0.332	0.359	0.374	0.400
9	0.396	0.388	0.363	0.364	0.363	0.352	0.337	0.344	0.368	0.392
10	0.372	0.369	0.353	0.340	0.348	0.337	0.350	0.346	0.364	0.373
11	0.347	0.352	0.352	0.347	0.356	0.338	0.347	0.360	0.381	0.384
12	0.339	0.348	0.351	0.356	0.362	0.345	0.339	0.346	0.371	0.377
13	0.346	0.357	0.352	0.361	0.363	0.353	0.339	0.348	0.390	0.401
14	0.369	0.369	0.371	0.372	0.366	0.356	0.362	0.360	0.387	0.400
15	0.361	0.360	0.363	0.362	0.361	0.363	0.382	0.385	0.409	0.417
16	0.364	0.354	0.358	0.356	0.359	0.353	0.370	0.372	0.380	0.382
17	0.352	0.341	0.329	0.323	0.332	0.340	0.346	0.352	0.356	0.351
18	0.346	0.335	0.324	0.307	0.315	0.318	0.323	0.331	0.341	0.338
19	0.323	0.320	0.314	0.301	0.309	0.317	0.309	0.310	0.324	0.326
20	0.290	0.301	0.295	0.292	0.294	0.294	0.281	0.282	0.310	0.322
21	0.263	0.277	0.276	0.272	0.281	0.289	0.289	0.289	0.296	0.301
22	0.257	0.274	0.282	0.279	0.280	0.288	0.294	0.308	0.305	0.312

Table 3: Mean yields from different plot sizes (kg/unit)

	No. of units along columns				
No. of units along rows	1	2	3	4	6
1	0.12	0.47	0.90	1.85	4.15
2	0.47	1.86	4.16	7.38	16.58
3	1.04	4.15	9.34	16.58	37.26
4	1.85	7.19	16.60	29.47	66.22
6	4.15	16.58	37.28	66.26	148.86

Table 4: Median yields from different plot sizes (kg/units)

	No. of units along columns				
No. of units along rows	1	2	3	4	6
1	0.111	0.45	0.93	1.81	4.13
2	0.45	1.83	4.04	7.30	17.46
3	1.02	4.13	17.41	15.84	40.78
4	1.90	7.29	1.81	29.62	66.91
6	4.19	16.30	7.30	64.40	152.18

Table 5: Coefficient of variation for plots of various sizes and shapes

	No. of units along columns				
No. of units along rows	1	2	3	4	6
1	35.24	28.21	40.86	23.53	21.22
2	28.90	23.80	23.14	21.27	19.53
3	25.04	21.69	21.50	19.95	18.25
4	22.73	24.20	20.53	19.49	18.32
6	21.36	19.99	19.59	19.53	17.86

Table 6: Comparable variances (V) and relative information (RI) of plots size

Plot size (x)	Comparable variances (V)	Relative information (R.I)
2	17.14	99.60
4	25.19	146.39
6	27.77	161.38
9	29.57	171.86
12	30.43	176.87
18	31.30	181.92
24	31.75	184.53
36	32.17	186.95

Table 7: Variance among plots, $V_{(x)}$, variance per unit area, V_x, and coefficient of variation, CV for plots of various sizes and shapes, calculated from rice uniformity data of Table1

Plot size	Plot Dimensions length X Width (Meters)	Plot No	Plot Shape	V(x)	V_x	CV(%)
1	1 X 1	288	Square	0.96	0.96	35.24
2	1 X 2	144	Rectangle	34.41	8.60	28.90
3	1 X 3	96	Strip	67.22	7.47	25.04
4	1 X 4	72	Strip	100.27	6.27	22.73
6	1 X 6	48	Strip	166.37	4.62	21.36
8	1 X 8	36	Strip	232.01	3.63	18.42
2	2 X 1	144	Rectangle	34.14	8.53	28.21
4	2 X 2	72	Square	101.19	6.32	23.80
6	2 X 3	48	Strip	166.51	4.63	21.69
8	2 X 4	36	Rectangle	225.85	3.53	24.20
12	2 X 6	24	Strip	365.00	2.53	19.99
3	3 X 1	96	Strip	53.88	5.99	40.86
6	3 X 2	48	Strip	166.84	4.63	23.14
9	3 X 3	32	Square	266.13	3.29	21.50
12	3 X 4	24	Strip	365.43	2.54	20.53
18	3 X 6	16	Strip	563.58	1.74	19.59
4	4 X 1	72	Strip	100.30	6.27	23.53
8	4 X 2	36	Rectangle	232.81	3.64	21.27
12	4 X 3	24	Strip	365.08	2.54	19.95
16	4 X 4	18	Square	497.54	1.94	19.49
24	4 X 6	12	Strip	762.23	1.32	19.53
6	6 X 1	48	Strip	166.44	4.62	21.22
12	6 X 2	24	Strip	365.01	2.53	19.53
18	6 X 3	16	Rectangle	563.22	1.74	18.25
24	6 X 4	12	Strip	761.80	1.32	18.32
36	6 X 6	8	Square	1158.01	0.89	17.86

soil heterogeneity was estimated to be 0.69 which showed that plots were homogeneous. Two methods were used to appraise the optimum plot size: one was the comparable variance technique and the other was maximum curvature.

The results revealed that variance among plots $V_{(x)}$ increases with each unit increase in the plot size, whereas variance per basic unit area decreases. In addition the coefficient of variation declines with an increase in the plot size and this decrease is maximum with the square shape plot of size (6mx6m) basic units (Table 4). Square shape of plots was found better for large plot sizes such that plot sizes $1m^2$, $2m^2$, $3m^2$, $4m^2$, $6m^2$ having coefficients of variation 35.24, 23.80, 21.50, 19.49 and 17.86 percent, respectively.

CONCLUSIONS AND RECOMMENDTAION

The study results reveal that there was a considerable variation in yield data gathered from different plot sizes. Plot size of 6mx3m was found optimum for field experiment on paddy line T5 using the maximum curvature technique. Among the three shapes of the plots like rectangle, square and strip, square shape was found suitable for large plot sizes due to the decrease in the values of the coefficient of variation with each unit increase in the plot size. The estimated plot size of 6mx3m with rectangle shape for Rice research Institute, Kala Shah Kaku, Lahore, Punjab is recommended for future field experiments on paddy yield trials. Researchers of the relevant Research Station may use the estimated plot size in the study to have better control over the variability of the field experiment. Keeping in view the results of coefficients of variation, square shape plots are also suggested when the researchers do not familiar with the fertility pattern of the experimental area. Suitable plot size with shape shall improve the quality of research results in this ways contributing to the generation of more sound and viable technologies which will ultimately help to reduce the productivity deficit.

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