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Determination of optimum plot size, shape and no. of replications in wheat yield trial

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Abstract

The need of determining a standard size and shape for an experimental plot of major crops in different area of the Khyber-Pakhtunkhwa, under different climatic conditions like irrigated or rainfed. The experiment on size and shape of plot with wheat variety Pirsabak-2004 was conducted in Agriculture Research Institute Tarnab, Peshawar during the year 2014-15. The land under experiment trial was under wheat rotation in previous year, and all operation like cultural manuring etc. were uniformly applied. The co-efficient of variation for the most feasible ratio of length to width (i.e. 2.50) in the experimental plot was found to be 23.95%. The long and narrow plots are more efficient as compared to shorter and wider plots of the same size. Based upon theoretical numbering of replications in order to bring down C.V to 5%, the suitable number of replication in case of plot size (3.05 m × 1.22 m) was found between 2 to 6. The fertility trend moves gradually from West to East, as compared to the North to East. The South-Western side also gave the high rate of fertility, based on the study of plot size of (3.05 m × 1.22 m) which was found most suitable for experimental purpose.

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Introduction

The efficiency of field experiments largely depends on reduced standard error and standard plot size and shape having optimum limits. To study the size and shape of plot for any particular crop in research experimentation, it is most important to use the most suitable plot size, shape and number of replications for obtaining the favorable results and to ensure the highest possible precision. Furthermore, among the many factors that contribute to the magnitude of errors in agriculture field experimentations, the following are of considerable importance;

1. Shape and Size of the individual plot
2. Shape and Size of the block division (by eliminating soil heterogeneity)
3. The position and orientation of the plots and of the blocks in the experimental field.

In any field experiment, one of the basic questions is the size of the plot along with the number of replications. Generally the plot size and number of replications are based on the previous practice of the experimenter or results of a uniformity trial conducted in that particular area used.

The need of Information on plot variability derived from uniformity trials is of value in planning future experiments. To resolve the problem of research worker and to reduce the experimental error, it is utmost necessary to standardize the suitable plot size and shape particularly for major food crops grown under different climatic conditions. To improve the quality as well as credibility of research results, there is immense need to carry out research on similar lines. Different studies have also been in this regard at different period of times.

According to Gomez and Gomez (1984) who argued that uniformity experimental trial usually involves single crop variety, uniformly cultural and management practices and also all possible sources of variability are kept under constant conditions. The planted area is further subdivided to smaller units of the same size, which is generally referred as basic experimental unit from which measurements are made.

The smaller the basic unit, more informative is the measurement. Similarly, practices of uniform plot size and shape has been made by research scientist in which Leilah and Al-Khateeb (2007) carried out study to estimate optimum plot size in the desert rangeland of Saudi Arabia. He estimated the soil heterogeneity index to be 0.69, which shows lower correlation among the adjacent plots. Mohammad *et al* (2001) analyzed 29 different data sets to determine the suitable plot size and shape in wheat under different situations of plant height, grain yield and straw yield. Also, Nasr (1997) and Masood *et al* (2006) conducted an experiment to estimate the optimum plot size, shape and number of replications for wheat yield under different fertilizer doses and estimated suitable plot sizes.

The present study is undertaken with the objective to estimate the suitable plot size, shape and number of replication on wheat variety Pirsabak-2004 in Agricultural Research Institute Tarnab, Peshawar and to suggest suitable plot size, shape as well as No. of replications.

Materials and methods

The data were collected from Agricultural Research Institute, Tarnab, and Peshawar in the year 2014-15. By considering all management practices as uniform as possible all over the area and the field dimensions were recorded to be 240 feet long by 96 feet wide.

The whole area was sown uniformly with the single variety Pirsabak-2004 in 96 rows. The row to rows distance was kept as one feet. The field was harvested in 4 rows having dimensions 5/long and 4/wide, and there were 1152 total plots. The harvesting was completed in 6 days from 6th May to 11th May, 2013. After harvesting and threshing operation, wheat bags were weighed separately for yield of each basic unit having measurement 1 m x 1 m and also the yield moving average of 3 m x 3 m were computed for each unit respectively by using Microsoft Excel package.

The standard error between plots, within the blocks was calculated for 80 different sizes and shapes of plots, after harvesting entire plots. On the basis of these combinations of plots the measurement of 48 units in length and 1, 2, 3, 4, 6, 8, 12, and 24 rows wide were made.

The plot sizes of different combination were recorded with respect to their dimensions, ratio of length to width, variance, standard deviation and coefficient of variation.

Variance of different Plot Sizes and Shapes

To calculate variance V(x) for all sets of combination from among plots of all possible sizes and shapes that fit exactly within the basic units. First the variance V(x) is calculated for the set of values as:

$$V(x) = \frac{\Sigma\,(Yi - Y\,bar)^2}{n-1} \qquad (1)$$

Coefficient of Variation

The coefficient of variation can be calculated as follows:

$$CV = \frac{\sqrt{V(x)}}{Y\,bar} \times 100 \qquad (2)$$

The plot of CV versus plot size (X) can be drawn to check the status of each plot size. The coefficient of variations (CV's) was calculated for the experiments on wheat crop with all possible plot sizes.

Percentage Efficiency

The Percentage efficiency of different plot sizes can be computed by using the expression as;

$$\text{Percentage Efficiency} = \frac{\text{Different computed Plot Sizes}}{\text{Standard basic unit Plot}} \times 100 \qquad (3)$$

Number of Replications

The theoretical number of replication in case of suitable plot size can be calculated by the relation of square of standard error to the standard error of the mean presented in equation (4).

$$r \geq \frac{t^2_{\alpha,df}\, s^2}{d^2} \qquad (4)$$

Where;

r is the number of replications, t is the critical t with r-1 degree of freedoms and d is the limit of the confidence interval.

Results and discussions

From the collected wheat yield data the analysis was made as shown in Table-1 i.e. by increasing the width and length of the plot, the ratio co-efficient of variation presents declining pattern. The different plot sizes along with their plot dimension, ratio of length to width and their corresponding variance, standard deviation, co-efficient of variation are presented in detail form in Table 1.

Table 1. Analysis of yield data of Wheat variety Pirsabak-2004 for the year 2014-15.

Length x Width	Plot Dimension	Ratio of length to width	Total No. of plots	SD	Variance	C.V
1x1	5x4	1.25	1152	5.191	26.95	20.08
1x2	5x8	0.63	96	5.141	26.43	25.83
1x3	5x12	0.42	144	5.122	26.24	25.73
1x4	5x16	0.31	192	5.151	26.53	25.88
1x6	5x24	0.21	288	5.210	27.15	26.18
1x8	5x32	0.16	389	4.960	24.60	24.92
1x12	5x48	0.10	576	5.031	25.32	25.28
2x1	10x4	2.50	24	4.768	22.73	23.95
2x2	10x8	1.25	48	5.114	26.15	25.69
2x3	10x12	0.83	72	5.103	26.04	25.64
2x4	10x16	0.63	96	5.063	25.63	25.44
2x6	10x24	0.16	144	4.924	29.25	24.74
2x8	10x32	0.31	192	4.860	23.62	24.42
2x12	10x48	0.21	288	4.732	22.39	23.77
3x1	15x4	3.75	16	5.187	26.90	26.06
3x2	15x8	1.86	32	5.124	26.26	25.74
3x3	15x12	1.25	48	5.167	26.69	26.96
3x4	15x16	0.94	64	5.086	25.87	25.55
3x6	15x24	0.63	96	4.950	25.51	24.87
3x8	15x32	0.47	128	4.956	24.56	24.90
3x12	15x48	0.31	192	4.796	23.00	24.10
4x1	20x4	5.00	12	5.179	26.83	26.02
4x2	20x8	2.50	24	5.089	25.90	25.57
4x3	20x12	1.67	36	5.018	25.20	25.21
4x4	20x16	1.25	48	5.021	25.21	25.22
4x6	20x24	0.83	72	4.895	23.97	24.60
4x8	20x32	0.63	96	4.828	32.31	24.26
4x12	20x48	0.42	144	4.711	22.98	23.67
6x1	30x4	7.50	8	5.194	26.09	26.09
6x2	30x8	3.75	16	5.050	26.51	25.37
6x3	30x12	2.50	24	5.062	25.62	25.43
6x4	30x16	1.88	32	5.073	25.79	25.49
6x6	30x24	1.25	48	4.943	24.99	24.84
6x8	30x32	0.94	64	4.948	24.49	24.86
6x12	30x48	0.63	96	4.771	22.77	23.97
8x1	40x4	10.00	6	5.175	26.79	26.00
8x2	40x8	5.00	12	5.106	26.06	25.65
8x3	40x12	3.33	18	5.085	25.86	25.55
8x4	40x16	2.50	24	5.049	25.50	25.37
8x6	40x24	1.67	36	4.896	23.97	24.60
8x8	40x32	1.25	48	4.872	23.73	24.47
8x12	40x48	0.83	72	4.834	23.37	24.29
12x1	60x4	15.00	4	5.496	27.00	26.10

Length x Width	Plot Dimension	Ratio of length to width	Total No. of plots	SD	Variance	C.V
12x2	60x8	7.50	8	5.131	26.39	25.78
12x3	60x12	5.00	12	5.050	25.50	25.37
12x4	60x16	3.75	16	5.070	25.71	25.47
12x6	60x24	2.50	24	4.911	24.13	24.68
12x8	60x32	1.88	32	4.933	24.34	24.79
12x12	60x48	1.25	48	4.794	22.99	24.09
16x1	80x4	20.00	3	5.193	26.97	26.09
16x2	80x8	10.00	6	5.140	26.42	25.82
16x3	80x12	6.67	9	5.058	25.58	25.41
16x4	80x16	5.00	12	5.087	25.88	25.56
16x6	80x24	3.33	18	4.936	24.36	24.80
16x8	80x32	2.50	24	4.947	24.48	24.86
16x12	80x48	1.67	36	4.806	23.10	24.15
24x1	120x4	30.00	2	5.193	26.97	26.09
24x2	120x8	15.00	4	5.139	26.41	25.82
24x3	120.12	10.00	6	5.051	25.51	25.38
24x4	120x16	7.50	8	5.073	25.74	25.49
24x6	120x24	5.00	12	4.934	25.34	24.79
24x8	120x32	3.75	16	4.946	24.46	24.85
24x12	120x48	2.50	24	4.821	23.24	24.22
48x1	240x4	60.00	48	5.200	27.05	26.13
48x2	240x8	30.00	2	5.135	26.37	25.77
48x3	240x12	20.00	3	5.068	25.69	25.42
48x4	240x16	15.00	4	5.095	25.96	25.57
48x6	240x24	10.00	6	4.973	24.53	24.87
48x8	240x32	7.50	8	4.981	24,81	25.02
48x12	240x48	5.00	12	4.883	23.85	24.52
1x24	5x96	0.05	24	5.219	27.24	26.22
2x24	10x96	0.10	48	4.690	22.00	23.57
3x24	15x96	0.16	72	4.649	21.61	23.36
4x24	20x96	0.21	96	4.639	21.52	23.31
6x24	30x96	0.31	144	4.580	20.98	23.01
8x24	40x96	0.42	192	4.573	20.91	22.96
12x24	60x96	0.63	288	4.570	20.88	22.96
16x24	80x96	0.83	384	4.161	17.31	20.91
24x24	120x96	1.25	576	4.412	19.96	22.16

In Table 2, the standard errors in percentage form regarding the mean yield of varying sizes of different length to width combinations are presented.

From the observed data, the standard error in percentage of the mean was found to be decreased with increased plot size. It is also indicated that by increasing the width of plots from one row to another represents significantly reduced standard. The standard error of the 3.05 m×1.22 m plot was calculated to be 23.95 percent of the mean yield. Moreover, the shape of plot has been decided not only on the basis of least value of co-efficient of variation, but also by convenience of cultivation. Based on the calculated results, the ratio of length to width of the experimental plot is found to be at least 2.50. Moreover, results showed that long and narrow plots are more efficient than shorter and wider of the same size.

Table 2. Standard error of mean yields of plot varying in Size and Shape.

Length of plot	Standard deviation of yield (percent) for plots of indicated width (rows)							
	1	2	3	4	6	8	12	24
1.	26.08	12.92	8.58	6.47	4.36	3.12	2.11	1.09
2.	11.98	6.42	4.27	3.18	2.05	1.53	0.99	0.49
3.	8.68	4.29	2.88	2.13	1.41	1.04	0.67	0.32
4.	6.51	3.20	2.10	1.58	1.03	0.75	0.50	0.24
6.	4.35	2.16	1.41	1.06	0.69	0.12	0.33	0.20
7.	3.25	1.60	1.06	0.70	0.51	0.38	0.25	0.12
12.	2.18	1.07	0.71	0.53	0.34	0.26	0.17	0.08
16.	1.63	0.81	0.53	0.40	0.26	0.19	0.13	0.05
24.	1.09	0.54	0.35	0.27	0.17	0.13	0.08	0.04
48.	0.54	0.27	0.18	0.13	0.09	0.07	0.04	-----

Moreover, by increasing the length of the plots resulting reduced standard error of the means. In all the above experiments although the CV is greater but in most cases the difference is very small. These results do not endorse the usual assertion of long and narrow plots. Wiedemann and Leininger (1963) also concluded that there is very little difference in variance due to shape. Similar results are obtained by Kempthorne (1952), Rampton and Petersen (1962) Crews *et al.* (1963) and Reddy and Chetty (1985) in practicing field plot technique to different crops.

From Table 3, the number of replications needed to reduce the standard error of the mean to 5 percent. The standard errors of mean for several replications are calculated by dividing the standard error of a single plot by the square root of N, where "N" is the number of replications.

Table 3. Theoretical number of replications needed to reduce the standard error.

Length of plot	Number of replications for plots of indicated number of rows							
	1	2	3	4	6	8	12	24
1.	27.2	6.7	3.0	1.0	0.8	0.4	0.2	0.5
2.	5.7	1.7	0.7	0.4	0.2	0.1	0.04	0.01
3.	3.0	0.7	0.3	0.2	0.1	0.04	0.02	0.004
4.	1.7	0.4	0.2	0.1	0.04	0.02	0.01	0.003
6.	0.8	0.2	0.1	0.1	0.02	0.01	0.004	0.003
8.	0.4	0.1	0.1	0.03	0.01	0.01	0.003	0.001
12.	0.2	0.1	0.02	0.01	0.01	0.003	0.001	0.0003
16.	0.1	0.03	0.01	0.01	0.003	0.001	0.001	0.0001
24.	0.1	0.01	0.01	0.003	0.001	0.001	0.0003	0.0001
48.	0.01	0.003	0.001	0.001	0.0003	0.0001	0.0001	------

The main purpose of replications is to reduce the amount of error. For each plot sizes, it has been examined to see whether the available used land is consistent with theoretical number of replications required. Theoretical number of replications which bring down the Coefficient of variation to 5% has been calculated in case of each plot size and it was found that in case of plot size 3.05 m×1.22 m the number of replications required is in between 2 to 6 as presented in Table-3. Similarly, by fixing the plot size the number of replications decreases for small differences d (15, 16, .. 25) and for large differences the decrease is not clearly detectable. Similar results have been obtained by Rampton and Petersen (1962) and Crews *et al.* (1963) in performing field plot techniques to different crops.

From Table-4, the efficiency of plots of varying size and shape has been calculated on the basis of variance per unit area. By calculating the variance of a single row as a standard, we may determine the efficiency of all other plots in relation to the efficiency of this ultimate unit of size.

Table 4. Percentage efficiency in use of land for plot varying in size and shape.

Length of plot	Percentage efficiency of plot of indicated width (rows)							
	1	2	3	4	6	8	12	24
1.	100	50.98	34.24	25.40	16.54	13.69	8.87	4.12
2.	59.28	25.77	17.25	13.14	9.26	7.13	5.02	2.55
3.	33.40	17.11	11.22	8.68	5.87	4.57	3.26	1.73
4.	25.11	13.01	8.91	6.68	4.69	3.61	2.44	1.30
6.	16.65	8.47	5.84	4.36	3.06	2.29	1.69	0.89
8.	12.58	6.46	4.34	3.30	2.34	1.78	1.20	0.67
12.	8.30	4.26	2.94	2.18	1.55	1.15	0.81	0.45
16.	6.25	3.19	2.20	1.63	1.15	0.86	0.61	0.41
24.	4.16	2.13	1.47	1.09	0.77	0.57	0.40	0.23
48.	2.08	1.07	0.73	0.59	0.38	0.28	0.20	..

The original yield data in Table 1, were combined to form moving average of (3 x 3) basic units. The field area then considered as consisting of 1012 plots. On the basis of calculated results that fertility trend of the plot moves gradually from West to East, where as the North-East side of the plot seems least fertile. The maximum fertility of the plot seems to be on the South-Western side.

Conclusions and recommendations

The results of the study revealed that for wheat variety pirsabak-2004 which was grown in Agricultural Research Institute Tarnab, Peshawar under uniform soil and climatic conditions, the optimum plot size was recorded to be 3.05 m × 1.22 m, based on the criteria of reduced standard error (calculated value 4.768) and minimum value of the ratio i.e. coefficient of variation (recorded as 23.95 percent).

The shape of plot was determined by computing the ratio of length to width of the experimental plot which was found to be 2.5. It was quite clear that long and narrow plots are more efficient than shorter and wider of the same size.

The number of replications two (2) to Six (6) was found suitable, possessing less amount of error. Therefore, it can be suggested that less number of replication should be at least two (2) and not more than six (6).

The estimated plot size 3.05 m × 1.22 m with long and narrow shape and having at least 2 to 6 number of replication at Agricultural Research Institute Tarnab, Peshawar, Khyber-Pakhtunkhwa is recommended for future field experiments on wheat yield trials particularly for wheat variety Pirsabak-2004 and in general vice versa. Moreover, by using the suitable plot size, shape and No. of replication shall be helpful and improve the quality of research results contributing to the generation of more advanced technology which ultimately reduce the deficits in the productivity.

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