# UTLIZATION OF UNIFORMITY TRIALS TO ESTIMATE THE OPTIMUM PLOT SIZE AND SHAPE AND THE NUMBER OF REPLICATIONS IN WHEAT YIELD TRIALS

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## ABSTRACT

In the present work, two uniformity trials were carried out during the first and the second winter seasons of 2011/2012 and 2012/2013 in the Experimental farm Demo, Faculty of Agriculture, Fayoum University. The main objectives were to estimate the optimum plot size, plot shape and number of replicates for wheat yield traits using the variety Sakha 93 as plant material. The cultivated area of each field trial was divided into 12 strips; each of which consisted of 100 rows, 0.2 m width and 3.0 m long. Two statistical methods including soil variability index and maximum curvature were used to estimate the optimum plot size and shape using the yield data of 1200 basic units (each of 0.6 $m^2$). The data were subjected to two procedures of statistical analysis to estimate the optimum plot size, when the cost of conducting the experiment is not taken into consideration and to evaluate the effect of changing the plot shape on the variability. The first statistical method was that of maximum curvature which is based on the exponential relationship between plot size and the coefficient of variability. The second method was that developed by **smith's method (1938)**. Bartlett's test for homogeneity of variances, as outlined by **Steel and Torrie (1980)**, was used to study the effect of changing plot shape. The obtained results could be summarized as follows: Increasing the plot size decreased the variance per basic unit and the coefficient of variability. However, the reduction was not in proportion with the increase in plot size. The index of soil variability ranged from 0.6433 to 0.6018 as an average for the 1st and the 2nd seasons, respectively. The relationship between the coefficient of variability (C.V.) and plot size (X) were mathematically expressed by the following equation C.V. = $19.21\ X^{-0.2595}$ for the 1st season and C.V. = $19.60\ X^{-0.2725}$ for the 2nd one. Accordingly, using the soil variability index, the optimum plot size was 2 basic units (1/3500 fed.) for the two seasons, while it was 4 basic units (1/1750 fed.) in both seasons when the maximum curvature method was applied. The required number of replications for the optimum plot size using Smith method detecting a 15% difference among treatment means varied 13 and 14 in the 1st and the 2nd seasons, respectively. But, for detecting a 20% difference among treatment means, 7 replications in the 1st season and 8 replications in the 2nd one were found necessary. Optimum plot size estimated using the maximum curvature method detecting a 15% difference among treatment means varied 7 and 8 in the 1st and the 2nd seasons, respectively.

But, for detecting a 20% difference among treatment means, 4 replications in the 1st and 2nd season's one were found necessary. Generally, the plot shape did not affect on the precision of wheat yield trial in most cases in the two growing seasons.

**Key words**: *Wheat, number of replicates, plot size and shape, uniformity trials.*

## INTRODUCTION

Wheat is the most important cereal crop in Egypt as well as all of the world population. In Egypt the local production of wheat does not cover the total consumption. Consequently, increasing wheat production is a national target to fulfill the food security for the people. This target can be achieved by means of raising the productivity through growing high yielding varieties and the application of improved agro-techniques.

In field trials, the precision of significance tests are largely controlled by the size and shape of plots in addition to the area available for the particular trial, the nature of fertility and other soil variations. To cope with proper research practice, it has become necessary to standardize a suitable plot size and shape, and determine an optimum number of replicates for the major crops grown under different conditions. This will reduce the standard error of the experiments. The use of improper field-plot techniques may inflate the experimental error and lead to erroneous inferences. Hence, to improve the quality and credibility of research results, there is a need to proper on field plot techniques **(Masood and Raza, 2012).**

Determining optimum plot size, shape and number of replications provides useful information to minimize the error variance and the cost of handing the plot. Finally, such information should help agronomists, plant breeders and experimental statisticians in planning more efficient experiments to attain desirable high precision. Results of replicated field trails generally are the major criteria upon which the retention or rejection of strain is based.

Uniformity trails on wheat (*Triticum aestivium* L.) have been used in this study to determine the soil heterogeneity, the optimum plot size, shape and number of replications in wheat trails.

## MATERIALS AND METHODS

### 1-Field layout:

Two uniformity trials were carried out at the Experimental farm of Demo, Faculty of Agriculture, Fayoum University, during the two successive growing seasons of 2011/2012 and 2012/2013 using the wheat Sakha 93 variety. The study was designed to find out the optimum plot size, plot shape and the proper number of replications for wheat experiments. Cultivated area of each field trial was divided into 12 strips; each consisted of 100 rows, 3.0 m long and 0.2 m width. Each row was considered as a basic unit *i.e.* 0.6 $m^2$, consequently, a total of 1200 basic units. Every row was of 3.0 m long and 0.2 m apart, and contained 15 seeds, 20 cm apart. At harvest, data were recorded on a random sample of 10 guarded plants from each row.

### 2-Statistical Analysis:

Two methods are applied on the data sets to calculate the index of heterogeneity 'b' and ultimately the plot size under different situations. The effect of plot size and shape on the variance per basic unit area ($v_x$ ), comparable variance (v), coefficient of variability (C.V.) and number of replications (r). Before running the statistical analysis, data were arranged in sequence. To apply these methods, it is necessary to conduct the uniformity trials, which are expensive and time consuming.

There were 40 plot combinations ranging from 1 to 120 basic units covering variety of plot sizes and shapes (Tables 1 and 2). Number of plots was calculated by dividing the total number of basic units (1200 units) by the number of basic units for each plot size.

## 2.1 Optimum plot size

Optimum plot size was determined using two statistical procedures as follows:

### 2.1.1. Smith's method

The index of soil variability (b), proposed by **Smith (1938),** was estimated from the empirical relationship between plot size and variance per basic unit. This relationship may be expressed in logarithmic form as:

$$\text{Log } Vx = \text{Log } v_i - b \log x$$

**Where:**

$V_x$: is the variance per basic unit calculated as among plot variance V(x) divided by the square of plot size in(x) basic units.

$V_i$ = is the variance among plots of one basic unit.

b: is the regression coefficient which is a measure of the association between adjacent basic units.

**Smith (1938)** suggested the use of simple weighting of variances by their respective degrees of freedom to calculate (b).

**Federer (1955)** recommended the following equation to calculate (b):

$$b = \frac{(\sum w_i \log v x_i \, log x_i) - \frac{(\sum w_i \log v x_i)(\sum w_i \log x i)}{(\sum w_i)}}{\sum w_i (\log x_i)^2 - \frac{(\sum w_i \log x i)^2}{(\sum w_i)}}$$

**Where:**

**b =** Weighted index of soil variability

$\mathbf{w_i}$ = Degrees of freedom associated with $V_{Xi}$

$\mathbf{V_{Xi}}$ = Weighted variance per basic unit of the *ith* plot size.

$\mathbf{X_i}$ **=**Number of basic units in the *ith* plot size

Smith used this index in conjunction with the estimates of cost factors to determine the optimum plot size. However, **Hatheway (1961)** pointed out that in field research, scientists are generally more interested in designing experiments that are able to detect difference of specified size ignoring cost factors. Therefore, the optimum plot size was ($X_{Opt}$) calculated from the formula : $X_{Opt.} = b/ (1-b)$

### 2.1.2 . Maximum curvature procedure

The second method used was the maximum curvature approach which was modified by **Meier and Lessman (1971),** and **Galal and Abou El-Fittouh (1971)**.

The point of maximum curvature ($X_0$), for the exponential curve (C.V. = $Ax^{-B}$) relating the coefficient of variability (C.V.) and plot size (x), was determined using the following equation:

$X_0 = (A^2B^2 (2B+1) / (B+2))^{1 / (2B+2)}$

Using the principles of linear regression, values of A and B were estimated as follows:

$$B = \frac{n\sum \log(c.v)\log x - \sum \log(c.v) \sum \log x}{n\sum (\log x)^2 - (\sum \log x)^2 -}$$

$$\text{Log } A = \frac{\sum \log(c.v)}{n} - B\,\frac{\sum \log x}{n}$$

The equation used to determine $X_0$ was then converted to logarithmic form as follows:

$$\text{Log } x_0 = \frac{2\log n + 2\log B + \log(2B+1) - \log(B+2)}{(2B+2)}$$

Plot size directly beyond the $X_0$ value on the curve is considered optimum.

## 2.2. Optimum plot shape

To study the effect of plot shape, differences among shapes of plots composed of the same number of basic units, were tested for significance by comparing their variances using Bartlett Chi square test for homogeneity of variances as outlined by **Steel and Torrie (1980)**.

## 2.3. Optimum number of replications

Several methods can be used to determine the required number of replications, based on the coefficient of variation to detect a specified percentage difference between treatment means. A commonly used method, based on Student " t " statistic, was given by **Federer (1955)**. The number of replications of different plot sizes for the two trials was calculated according to the following formula:

$$r = \frac{2\, t^2 \propto (C.V.)^2}{D^2}$$

**Where:**

**t :** is the value of Students " t " the level of significance for degrees of freedom associated with the C.V.

$\propto$ **:** is the significance level

**C.V.:** is the coefficient of variability

**D:** is the minimum difference to be detected, expressed in percentage of the mean.

**r =** is the appropriate number of replications.

## RESULTS AND DISCUSSION

The Data in Tables (1 and 2) presented the variances per basic unit area, among plots and C.V. for 40 combinations of plot size and shape in the first and second seasons, respectively. Two procedures; namely Smith's method and maximum curvature method were used to estimate the optimum plot size for wheat trials grown at farm Demo in the 2011/2012 and 2012/2013 seasons.

## 1. Smith's method

The following estimates were calculated using the Smith`s method to determine the optimum plot size for each experiment:

### 1.1 Variance per basic unit area:

The results in Tables (1 and 2) show that the variance per basic unit area was generally decreased with the increase in plot size. The variance per basic unit area in the 2011/2012 season was decreased from 0.0042 for the smallest plot size (one basic unit) to 0.0003 for the plot size of 120 basic units. However, in 2012/2013 season variance per basic unit decreased from 0.0047 for one basic unit per plot to 0.00009 for 120 basic units per plot.

**Table (1): Variance and coefficients of variability for 40 combinations of plot sizes and shapes for wheat resulting from 1200 basic units in season (2011/2012).**

| Serial No | Plot size & shape | | | Plot Dimension (m) width x length s | Plot area | | No. of plots | Variance | | CV % |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of basic units | | | | $m^2$ | Per Faddan | | Per basic Unit (Vx) | Among Plots V(x) | |
| | Size | Rows | Strips | | | | | | | |
| 1 | 1 | 1 | 1 | 0.2 x 3.0 | 0.60 | 1/7000 | 1200 | 0.0042 | .0042 | 20.78 |
| 2 | 2 | 1 | 2 | 0.2 x 6.0 | 1.20 | 1/3500 | 600 | 0.0033 | .0133 | 18.51 |
| 3 | 2 | 2 | 1 | 0.4 x 3.0 | 1.20 | 1/3500 | 600 | 0.0039 | .0349 | 19.92 |
| 4 | 3 | 1 | 3 | 0.2 x 9.0 | 1.80 | 1/2333 | 400 | 0.0024 | .0388 | 15.76 |
| 5 | 4 | 1 | 4 | 0.2 x 12.0 | 2.40 | 1/1750 | 300 | 0.0019 | .0681 | 13.91 |
| 6 | 4 | 2 | 2 | 0.4 x 6.0 | 2.4 | 1/1750 | 300 | 0.0021 | .0082 | 14.51 |
| 7 | 4 | 4 | 1 | 0.8 x 3.0 | 2.4 | 1/1750 | 300 | 0.0016 | .0026 | 12.94 |
| 8 | 5 | 5 | 1 | 1.0 x 3.0 | 3.00 | 1/1400 | 240 | 0.0019 | .0681 | 13.92 |
| 9 | 6 | 1 | 6 | 0.2 x 18.0 | 3.60 | 1/1167 | 200 | 0.0019 | .0766 | 11.07 |
| 10 | 6 | 2 | 3 | 0.4x 9.0 | 3.6 | 1/1167 | 200 | 0.0009 | .1323 | 9.70 |
| 11 | 8 | 2 | 4 | 0.4 x 12.0 | 4.80 | 1/875 | 150 | 0.0013 | .0220 | 11.52 |
| 12 | 8 | 4 | 2 | 0.8 x 6.0 | 4.80 | 1/875 | 150 | 0.0011 | .0677 | 10.40 |
| 13 | 10 | 5 | 2 | 1.0 x 6.0 | 6.0 | 1/700 | 120 | 0.0012 | .1768 | 11.21 |
| 14 | 10 | 10 | 1 | 2.0 x 3.0 | 6.0 | 1/700 | 120 | 0.0008 | .1987 | 8.91 |
| 15 | 12 | 1 | 12 | 0.2 x 36.0 | 7.2 | 1/583 | 100 | 0.0006 | .3337 | 7.7 |
| 16 | 12 | 2 | 6 | 0.4 x 18.0 | 7.2 | 1/583 | 100 | 0.0012 | .0289 | 10.88 |
| 17 | 12 | 4 | 3 | 0.8 x 9.0 | 7.2 | 1/583 | 100 | 0.0010 | .0956 | 9.89 |
| 18 | 15 | 5 | 3 | 1.0 x 9.0 | 9.0 | 1/467 | 80 | 0.0011 | .2502 | 10.67 |
| 19 | 16 | 4 | 4 | 0.8 x 12.0 | 9.6 | 1/438 | 75 | 0.0008 | .3073 | 8.87 |
| 20 | 20 | 5 | 4 | 1.0 x 12.0 | 12.0 | 1/350 | 60 | 0.0006 | .5081 | 7.6 |
| 21 | 20 | 10 | 2 | 2.0 x 6.0 | 12.0 | 1/350 | 60 | 0.0007 | .0716 | 8.56 |
| 22 | 20 | 20 | 1 | 4.0 x 3.0 | 12.0 | 1/350 | 60 | 0.0006 | .2387 | 7.81 |
| 23 | 24 | 2 | 12 | 0.4 x 36.0 | 14.4 | 1/292 | 50 | 0.0007 | .6285 | 8.45 |
| 24 | 24 | 4 | 6 | 0.8 x 18.0 | 14.4 | 1/292 | 50 | 0.0005 | .8149 | 7.21 |
| 25 | 25 | 25 | 1 | 5.0 x 3.0 | 15.0 | 1/280 | 48 | 0.0003 | 1.249 | 5.9 |
| 26 | 30 | 5 | 6 | 1.0 x 18.0 | 18.0 | 1/233 | 40 | 0.0005 | .1976 | 7.11 |
| 27 | 30 | 10 | 3 | 2.0 x 9.0 | 18.0 | 1/233 | 40 | 0.0004 | .6698 | 6.54 |
| 28 | 40 | 10 | 4 | 2.0 x 12.0 | 24.0 | 1/175 | 30 | 0.0005 | 1.788 | 7.10 |
| 29 | 40 | 20 | 2 | 4.0 x 6.0 | 24.0 | 1/175 | 30 | 0.0004 | 2.331 | 6.10 |
| 30 | 48 | 4 | 12 | 0.8 x 36.0 | 28.8 | 1/146 | 25 | 0.0003 | 3.768 | 5.10 |
| 31 | 50 | 25 | 2 | 5.0 x 6.0 | 30.0 | 1/140 | 24 | 0.0005 | .3167 | 7.20 |
| 32 | 50 | 50 | 1 | 10.0 x 3.0 | 30.0 | 1/140 | 24 | 0.0004 | 1.075 | 6.60 |
| 33 | 60 | 5 | 12 | 1.0 x 36.0 | 36.0 | 1/117 | 20 | 0.0005 | 2.907 | 7.20 |
| 34 | 60 | 10 | 6 | 2.0 x 18.0 | 36.0 | 1/117 | 20 | 0.0004 | 3.838 | 6.6 |
| 35 | 60 | 20 | 3 | 4.0 x 9.0 | 36.0 | 1/117 | 20 | 0.0003 | 6.755 | 5.5 |
| 36 | 75 | 25 | 3 | 5.0 x 9.0 | 45.0 | 1/93 | 16 | 0.0004 | 1.003 | 6.40 |
| 37 | 80 | 20 | 4 | 4.0 x 12.0 | 48.0 | 1/88 | 15 | 0.0003 | 3.491 | 5.90 |
| 38 | 100 | 25 | 4 | 5.0 x 12.0 | 60.0 | 1/70 | 12 | 0.0004 | 9.783 | 6.60 |
| 39 | 100 | 50 | 2 | 10.0 x 6.0 | 60.0 | 1/70 | 12 | 0.0003 | 13.22 | 5.00 |
| 40 | 120 | 10 | 12 | 2.0 x 36.0 | 72.0 | 1/58 | 10 | 0.0003 | 24.80 | 5.00 |

**Table (2): Variance and coefficients of variability for 40 combinations of plot size and shapes for wheat resulting from 1200 basic units in season (2012/2013).**

| Serial No. | Plot size & shape | | | Plot dimension (m) width x length s | Plot area | | No. of plots | Variance | | CV % |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of basic units | | | | $m^2$ | Per Faddan | | Per basic Unit (Vx) | Among Plots V(x) | |
| | Size | Rows | Strips | | | | | | | |
| 1 | 1 | 1 | 1 | 0.2 x 3.0 | 0.6 | 1/7000 | 1200 | 0.0047 | .0047 | 21.68 |
| 2 | 2 | 1 | 2 | 0.2 x 6.0 | 1.2 | 1/3500 | 600 | .00374 | .0149 | 19.17 |
| 3 | 2 | 2 | 1 | 0.4 x 3.0 | 1.2 | 1/3500 | 600 | .00474 | .0402 | 20.96 |
| 4 | 3 | 1 | 3 | 0.2 x 9.0 | 1.8 | 1/2333 | 400 | .00264 | .0423 | 16.31 |
| 5 | 4 | 1 | 4 | 0.2 x 12.0 | 2.4 | 1/1750 | 300 | .00214 | .0773 | 14.53 |
| 6 | 4 | 2 | 2 | 0.4 x 6.0 | 2.4 | 1/1750 | 300 | .00262 | .0104 | 16.05 |
| 7 | 4 | 4 | 1 | 0.8 x 3.0 | 2.4 | 1/1750 | 300 | .00208 | .0333 | 14.30 |
| 8 | 5 | 5 | 1 | 1.0 x 3.0 | 3.0 | 1/1400 | 240 | .00247 | .0891 | 15.60 |
| 9 | 6 | 1 | 6 | 0.2 x 18.0 | 3.6 | 1/1167 | 200 | .00143 | .0919 | 11.80 |
| 10 | 6 | 2 | 3 | 0.4x 9.0 | 3.6 | 1/1167 | 200 | .00119 | .1719 | 10.83 |
| 11 | 8 | 2 | 4 | 0.4 x 12.0 | 4.8 | 1/875 | 150 | .00132 | .0211 | 11.40 |
| 12 | 8 | 4 | 2 | 0.8 x 6.0 | 4.8 | 1/875 | 150 | .00107 | .0686 | 10.26 |
| 13 | 10 | 5 | 2 | 1.0 x 6.0 | 6.0 | 1/700 | 120 | .00124 | .1794 | 10.06 |
| 14 | 10 | 10 | 1 | 2.0 x 3.0 | 6.0 | 1/700 | 120 | .00074 | .1895 | 8.53 |
| 15 | 12 | 1 | 12 | 0.2 x 36.0 | 7.2 | 1/583 | 100 | .00064 | .3715 | 7.96 |
| 16 | 12 | 2 | 6 | 0.4 x 18.0 | 7.2 | 1/583 | 100 | .00125 | .0312 | 11.09 |
| 17 | 12 | 4 | 3 | 0.8 x 9.0 | 7.2 | 1/583 | 100 | .00102 | .1029 | 10.06 |
| 18 | 15 | 5 | 3 | 1.0 x 9.0 | 9.0 | 1/467 | 80 | .00119 | .2683 | 10.82 |
| 19 | 16 | 4 | 4 | 0.8 x 12.0 | 9.6 | 1/438 | 75 | .00078 | .3134 | 8.77 |
| 20 | 20 | 5 | 4 | 1.0 x 12.0 | 12.0 | 1/350 | 60 | .00069 | .6220 | 8.24 |
| 21 | 20 | 10 | 2 | 2.0 x 6.0 | 12.0 | 1/350 | 60 | .00068 | .0680 | 8.18 |
| 22 | 20 | 20 | 1 | 4.0 x 3.0 | 12.0 | 1/350 | 60 | .00056 | .2262 | 7.45 |
| 23 | 24 | 2 | 12 | 0.4 x 36.0 | 14.4 | 1/292 | 50 | .00065 | .5876 | 8.01 |
| 24 | 24 | 4 | 6 | 0.8 x 18.0 | 14.4 | 1/292 | 50 | .00045 | .7259 | 6.67 |
| 25 | 25 | 25 | 1 | 5.0 x 3.0 | 15.0 | 1/280 | 48 | .00037 | 1.354 | 6.00 |
| 26 | 30 | 5 | 6 | 1.0 x 18.0 | 18.0 | 1/233 | 40 | .00045 | .1811 | 6.70 |
| 27 | 30 | 10 | 3 | 2.0 x 9.0 | 18.0 | 1/233 | 40 | .00040 | .6536 | 6.33 |
| 28 | 40 | 10 | 4 | 2.0 x 12.0 | 24.0 | 1/175 | 30 | .00044 | 1.608 | 6.60 |
| 29 | 40 | 20 | 2 | 4.0 x 6.0 | 24.0 | 1/175 | 30 | .00034 | 2.208 | 5.80 |
| 30 | 48 | 4 | 12 | 0.8 x 36.0 | 28.8 | 1/146 | 25 | .00031 | 4.541 | 5.50 |
| 31 | 50 | 25 | 2 | 5.0 x 6.0 | 30.0 | 1/140 | 24 | .00040 | .2520 | 6.30 |
| 32 | 50 | 50 | 1 | 10.0 x 3.0 | 30.0 | 1/140 | 24 | .00031 | .7971 | 5.59 |
| 33 | 60 | 5 | 12 | 1.0 x 36.0 | 36.0 | 1/117 | 20 | .00040 | 2.259 | 6.20 |
| 34 | 60 | 10 | 6 | 2.0 x 18.0 | 36.0 | 1/117 | 20 | .00024 | 2.493 | 4.90 |
| 35 | 60 | 20 | 3 | 4.0 x 9.0 | 36.0 | 1/117 | 20 | .00018 | 4.095 | 4.20 |
| 36 | 75 | 25 | 3 | 5.0 x 9.0 | 45.0 | 1/93 | 16 | .00016 | .4109 | 4.01 |
| 37 | 80 | 20 | 4 | 4.0 x 12.0 | 48.0 | 1/88 | 15 | .00013 | 1.364 | 3.60 |
| 38 | 100 | 25 | 4 | 5.0 x 12.0 | 60.0 | 1/70 | 12 | .00017 | 3.827 | 4.00 |
| 39 | 100 | 50 | 2 | 10.0 x 6.0 | 60.0 | 1/70 | 12 | .00086 | 3.463 | 2.90 |
| 40 | 120 | 10 | 12 | 2.0 x 36.0 | 72.0 | 1/58 | 10 | .000095 | 8.563 | 3.00 |

**1.2 Index of soil variability**

The weighted index of soil variability (b) proposed by **Federer (1955)** was found to be 0.6433 in the first season and 0.6018 in the second one as shown in Table (3). The coefficient of soil heterogeneity (B) is a reflection of the association between adjacent plots and it is expected to vary between zero to one. The value near zero denotes complete uniformity and the value near one denotes random soil variability. Thus, the obtained values of soil variability index in both seasons reflect moderate variability in the soil of the experiment at Farm Demo.

**Table (3): Optimum plot size estimated using Smith`s method in 2011/ 2012 and 2012/ 2013 seasons.**

| Seasons | B | Optimum plot size | | |
|---|---|---|---|---|
| | | Basic unit | Plot area | |
| | | | $m^2$ | Feddan |
| 2011/ 2012 | 0.6433 | 2 | **1.2** | 1/3500 |
| 2012 / 2013 | 0.6018 | 2 | 1.2 | 1/3500 |

**1.3 Optimum plot size**

Values of soil variability index (B) were used to calculate the optimum plot size which was found to be 2 basic units in both seasons. Consequently it may be concluded that the optimum plot size was 2 basic units or 1.2 $m^2$ (1/3500 feddan) in the first and second seasons.

**2. Maximum curvature method**

Average variance per basic unit, average yield and average of observed and estimated coefficient of variability for each plot size are presented in Table (4). The results showed that the value of the coefficient of variation was generally decreased as plot size increased. Coefficient of variation was decreased from 19.21 for one basic unit per plot to 4.37 for a plot size of 120 basic units in the first season and correspondingly from 19.60 for one basic unit per plot to 4.14 for 120 basic units per plot in the second season. On the other hand, the reduction in C.V was not in proportion with the increase in the plot size. Moreover, the rate of reduction decreased as plot size became larger. This confirms the fact that the relationship between plot size and the variance per basic unit or the coefficient of variability is of exponential nature.

The exponential relationships obtained for the current study were found to be C.V = 19.21 $X^{-0.2595}$ and C.V. = 19.60 $X^{-0.2725}$ and graphically in figs. (1 and 2) for the first and the second seasons, respectively, where (X) is the plot size.

According to the maximum curvature method, the coefficient of variation is used as an indicator of optimum plot size and it is graphed on the (Y) axis in relation to various plot sizes on (x) axis (Figs. 1 and 2). On the other hand, the optimum plot size is considered to be the point on the curve where the rate of change in the estimate of (Y) per increase of (x) is greatest, thus called the maximum curvature. The point of maximum curvature was 3.06 and 3.21 in the first and the second seasons, respectively. The optimum plot size was 4 basic units for both seasons, being 2.4 $m^2$ or 1/1750 feddan (Table 5).

**Table (4): Average variance per basic unit ($v_x$), average yield (Y) and average coefficient of variability (C.V.) for each plot size in 2011/2012 and 2012/2013 seasons.**

| Plot size | No. of plots | 2011/ 2012 season | | | | 2012 / 2013season | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $v_x$ | Y (kg) | C.V. | | $v_x$ | Y (kg) | C.V. | |
| | | | | Observed | Estimated | | | Observed | Estimated |
| 1 | 1200 | 0.0042 | 0.313 | 20.78 | 19.21 | 0.0047 | 0.319 | 21.68 | 19.60 |
| 2 | 600 | 0.0036 | 0.798 | 19.22 | 15.25 | 0.0042 | 0.782 | 20.07 | 15.38 |
| 3 | 400 | 0.0024 | 1.251 | 15.76 | 13.41 | 0.0026 | 1.276 | 16.31 | 13.43 |
| 4 | 300 | 0.0019 | 1.251 | 13.91 | 13.84 | 0.0023 | 1.276 | 14.96 | 13.90 |
| 5 | 240 | 0.0019 | 1.876 | 13.92 | 12.07 | 0.0025 | 1.915 | 15.60 | 12.03 |
| 6 | 200 | 0.0014 | 3.127 | 10.39 | 10.64 | 0.0013 | 3.191 | 11.32 | 10.54 |
| 8 | 150 | 0.0012 | 1.876 | 10.96 | 12.31 | 0.0012 | 1.915 | 10.83 | 12.28 |
| 10 | 120 | 0.0010 | 4.377 | 10.06 | 9.72 | 0.0010 | 4.467 | 9.30 | 9.59 |
| 12 | 100 | 0.0009 | 4.065 | 9.49 | 10.55 | 0.0010 | 4.148 | 9.70 | 10.45 |
| 15 | 80 | 0.0011 | 4.690 | 10.67 | 9.51 | 0.0012 | 4.787 | 10.82 | 9.37 |
| 16 | 75 | 0.0008 | 6.253 | 8.87 | 8.83 | 0.0008 | 6.382 | 8.77 | 8.66 |
| 20 | 60 | 0.0006 | 6.253 | 7.99 | 9.12 | 0.0006 | 6.382 | 7.96 | 8.96 |
| 24 | 50 | 0.0006 | 10.943 | 7.83 | 7.67 | 0.0006 | 11.169 | 7.34 | 7.47 |
| 25 | 48 | 0.0003 | 18.760 | 5.90 | 6.64 | 0.0004 | 19.146 | 6.00 | 6.42 |
| 30 | 40 | 0.0005 | 9.380 | 6.83 | 8.33 | 0.0004 | 6.701 | 6.52 | 7.92 |
| 40 | 30 | 0.0004 | 21.887 | 6.60 | 6.40 | 0.0004 | 22.337 | 6.20 | 6.18 |
| 48 | 25 | 0.0003 | 37.521 | 5.10 | 5.55 | 0.0003 | 38.292 | 5.50 | 5.32 |
| 50 | 24 | 0.0005 | 11.725 | 6.90 | 7.65 | 0.0004 | 11.966 | 5.95 | 7.45 |
| 60 | 20 | 0.0004 | 33.873 | 6.43 | 6.44 | 0.0003 | 34.569 | 5.10 | 5.54 |
| 75 | 16 | 0.0004 | 15.634 | 6.40 | 6.96 | 0.0002 | 15.955 | 4.01 | 6.75 |
| 80 | 15 | 0.0003 | 31.267 | 5.90 | 5.82 | 0.0001 | 31.910 | 3.60 | 5.59 |
| 100 | 12 | 0.0004 | 54.717 | 5.80 | 5.05 | 0.0005 | 55.843 | 3.45 | 4.82 |
| 120 | 10 | 0.0003 | 93.801 | 5.00 | 4.37 | 0.0001 | 95.730 | 30.00 | 4.14 |

Fig. (2): Relationship between plot size and coefficient of variation (CV) in 2012/2013 season.

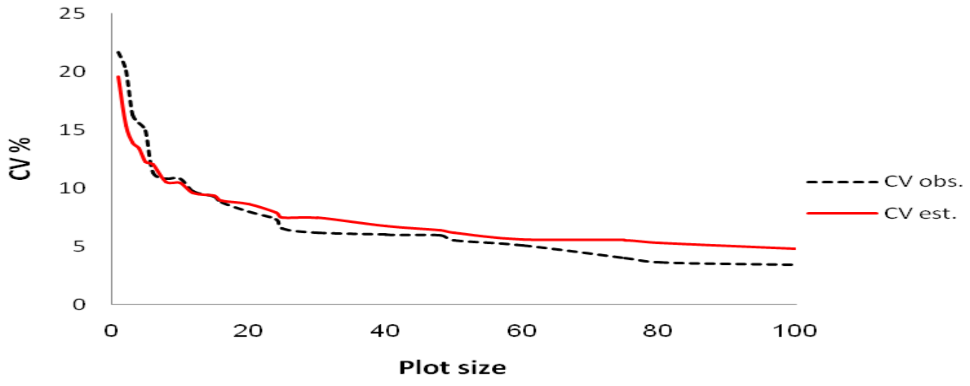


Fig. (1): Relationship between plot size and coefficient of variation (CV) in 2011/2012 season

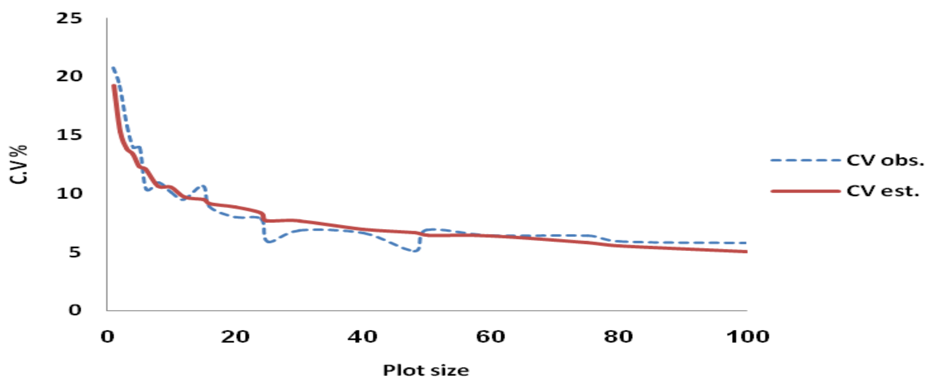


**Table (5): Optimum plot size estimated using the maximum curvature method in 2011/2012 and 2012/2013 seasons.**

| Seasons | A | B | Optimum Plot size | | |
|---|---|---|---|---|---|
| | | | Basic unit | Plot area | |
| | | | | $m^2$ | Feddan |
| 2011/2012 | 19.21 | 0.2595 | 4 | 2.40 | 1/1750 |
| 2012/2013 | 19.60 | 0.2725 | 4 | 2.40 | 1/1750 |

Generally, the estimated optimum plot size is always affected by several factors that might cause extreme fluctuations such as crop, location, agricultural practices, size of performed basic unit and statistical technique utilized for calculating such optimum size plot. Many investigators confirmd these results, among them **Kassem et al (1971), El-kalla and Gomaa (1977) ,Ashfaq *et al.* (1983)and Shaboon et al,(2013).**

**3. Plot shape**

The results of Bartlett test for the homogeneity of variances for different plot shapes of a given plot size in the first and seconed seasons are shown in Table (6). The results clearly reported that the variances of different shapes for the respective given plot size significantly affected only the variances of plot sizes of 2, 4,6,10 and 12 basic units in the first season. In the second season, changing the plot shape for a specified plot size, significantly affected only the variances of plot sizes of 2, 10, 12 and 100 basic units.

Generally, the plot shape did not affect the precision of wheat yield trial in most cases in the two growing seasons. Referring to Tables (1 and 2) and comparing the variances of different shapes for a given plot size, it may be concluded that the suited plot shape for a specified plot size were varied according to soil heterogeneity. Accordingly, the soil heterogeneity is ranked first as the limiting factors for identifying the optimum plot size and shape. These results are in accordance with the findings obtained by **El-Bakery (1980), El-Rassas *et al.* (1982), El-Rayes *et al* (1993)**, **El-Taweel (1999) and Kavitha (2010)**.

The investigator must take into account some important practical rules when determining the most desirable plot size and shape in the field experiments. The field plot should be sufficiently large to include a representative sample of the crop population, allow the elimination of border effects and to apply the experimental materials and their respective agricultural practices. On the contrary, the plot size should be sufficient by small to minimize the soil heterogeneity (intra plot variability) (**Galal and Abou El-Fittouh, 1971).**

**4. Number of replications:**

Table (7) shows the number of replications required to detect differences of 15% and 20 % between treatment means. In the first season, the number of replications required to detect a 15% difference between treatments means decreased from 15 replicates for a plot size of one basic unit, to one replicate for plots comprising 20 basic units. For detecting a 20% difference, the number of replicates varied from 8 for a plot size of one basic unit, to one replicate for a plot size of 20 basic units.

**Table (6): Results of the Bartlett`s test for the homogeneity of variances for different plot shapes of wheat trials in 2011/2012 and 2012/2013 seasons.**

| No. of basic units per plot | Chi – square value | |
|---|---|---|
| | 2011/2012 | 2012/2013 |
| 2 | 4.1782* | 8.3949* |
| 4 | 5.5671* | 4.8244 |
| 6 | 27.2220* | 1.6809 |
| 8 | 1.0417 | 1.6448 |
| 10 | 4.8784* | 7.8744* |
| 12 | 11.9403* | 11.0007* |
| 20 | 0.4693 | 0.7731 |
| 24 | 1.3946 | 1.6642 |
| 30 | 0.4908 | 0.1369 |
| 40 | 0.3665 | 0.4891 |
| 50 | 0.2920 | 0.3809 |
| 60 | 1.1854 | 3.0676 |
| 100 | 0.2375 | 6.8614* |

***: Significant and highly significant at 0.05 and 0.01 probability levels,**

In the second season, the number of replications required to detect a 15% difference decreased from 16 replicates for the plot size of one basic unit to 2 replications for the plot size of 20 basic units. To detect a 20% difference, the number of replicates decreased from 9 with for the plot size of one basic unit to one replicate for plots comprising 20 basic units.

**Table (7): Number of replications required to detect differences of 15% and 20% among treatment means at the 5% level of significance for wheat trials in 2011 / 2012 and 2012 / 2013.**

| Plot size | | Required number of replications in 2011/2012 season | | Required number of replications in 2012/2013 season | |
|---|---|---|---|---|---|
| Number of basic units | Plot area ($m^2$) | 15% differences | 20% differences | 15% differences | 20% differences |
| 1 | 0.6 | 15 | 8 | 16 | 9 |
| 2 | 1.2 | 13 | 7 | 14 | 8 |
| 3 | 1.8 | 9 | 5 | 9 | 5 |
| 4 | 2.4 | 7 | 4 | 8 | 4 |
| 5 | 3.0 | 7 | 4 | 8 | 5 |
| 6 | 3.6 | 4 | 2 | 5 | 3 |
| 8 | 4.8 | 4 | 2 | 4 | 2 |
| 10 | 6.0 | 4 | 2 | 3 | 2 |
| 12 | 7.2 | 3 | 2 | 3 | 2 |
| 15 | 9.0 | 3 | 2 | 3 | 2 |
| 16 | 9.6 | 3 | 2 | 3 | 2 |
| 20 | 12.0 | 2 | 1 | 2 | 1 |

Thus, number of replications required for detecting differences of 15% and 20% among treatment means generally decreased with the increase in plot size, but the reduction was not in proportion with the increase in plot size. The results show that the highest number of replications was required for the plot size of one basic unit.

In this investigation, the optimum size was 2 basic units. Consequently, the required number of replications for detecting a 15% difference treatment means would be 13 replications in the first season and 14 in the second season. For detecting a 20 % difference among treatment means, it was found that 7 replications in the first season and 8 replications in the second season would be necessary. The present results are in harmony with those obtained by **El-Taweel (1999)** and **Mohamed (2005)**.

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**إستخدام تجارب التجانس لتقدير أنسب مساحة وشكل للقطعة التجريبية وعدد المكررات فى تجارب محصول القمح**

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تهدف هذة الدراسة الى تقدير أنسب مساحة وشكل للقطعة التجريبية وكذلك أنسب عدد من المكررات فى تجارب محصول القمح وذلك باستخدام كلا من طريقتى دليل تجانس التربة وطريقة اقصى انحناء. وتم لتحقيق هذا الهدف اجراء تجربتي تجانس بمزرعة دمو التابعة لكلية الزراعة – جامعة الفيوم خلال الموسمين ٢٠١٢/٢٠١١ و ٢٠١٣/٢٠١٢ وذلك باستخدام الصنف-سخا ٩٣ حيث قسمت أرض التجربة الى ١٢ شرايحة تتكون كل منها من ١٠٠ خط (صف) بمساحة ٣م طول x ٠.٢ م عرض (٠.٦ م٢/خط). وبناء عليه فان كل تجربة اشتملت على ١٢٠٠ خط (صف) كل منها يمثل وحدة المساحة الاساسية فى التجربة.

أظهرت النتائج ان زيادة مساحة القطعة التجريبية أدت الى نقص كل من التباين لوحدة المساحة ومعامل الاختلاف ، ولكن لم يكن معدل الانخفاض يتناسب مع زيادة مساحة القطعة التجريبية . واظهرت نتائج استخدام طريقة Smith ان قيمة دليل تجانس التربة كانت ٠.٦٤٣٣ ، ٠.٦٠١٨ فى السنة الاولى والثانية على الترتيب مما يدل على أن درجة تجانس التربة فى مزرعة دمو متوسطة، وبناء عليه كانت أنسب مساحة للقطعة التجريبية (١.٢ م٢ ) أي ١/٣٥٠٠ من الفدان فى الموسمين . كما اوضحت النتائج ان انسب مساحة للقطعة التجريبية بطريقة اقصى انحناء كانت( ٢.٤م٢ ) أي ١/١٧٥٠ من الفدان فى كلا الموسمين . كذلك امكن تحديد العلاقة بين معامل الاختلاف ومساحة القطعة (X) فى صورة رياضية، ففى الموسم الاول كان معامل الاختلاف = ١٩.٢١ $x^{-٠.٢٥٩٥}$ وفى الموسم الثانى كان معامل الاختلاف = ١٩.٦٠ $x^{-٠.٢٧٢٥}$

كما أوضحت النتائج أن شكل القطعة التجريبية ليس له تأثير ملحوظ على النتائج المتحصل عليها فى كلا الموسمين. حيث اتضح ان زيادة مساحة القطعة التجريبية طوليا خلال الشريحة الواحدة فى الموسم الاول قد ادى الى انخفاض كل من قيمة التباين لوحدة المساحة ومعامل الاختلاف مقارنة بزيادة نفس المساحة عرضيا خلال الشرائح بينما فى الموسم الثانى زادت دقة النتائج المتحصل عليها مع زيادة مساحة القطعة التجريبية عرضيا خلال الشرائح مقارنة بالزيادة طوليا خلال الشريحة الواحدة. تشير هذه النتائج الى ان تجانس الحقل التجريبي يعتبر هو العامل الاهم فى تحديد انسب مساحة وشكل للقطعة التجريبية. كما وجد ان عدد المكررات المطلوبة لاكتشاف فروق محددة بين متوسطات المعاملات يقل مع زيادة مساحة القطعة التجريبية الا ان هذا النقص في عدد المكررات لم يكن متناسبا مع الزيادة فى مساحة القطعة.