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THE PRECISION OF FIELD EXPERIMENTS WITH WHEAT AS INFLUENCED BY PLOT SIZE, SHAPE AND NUMBER OF REPLICATIONS

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ABSTRACT: Two wheat uniformity trials were carried out at the Agricultural Research Station of Gemmeiza in two successive seasons of 2000/2001 and 2001/2002 using wheat cultivar Giza 168. The experimental field consisted of 8 strips with 100 rows in each. Thus, the basic unit was one row of 0.20 m wide and 3.5 m long (0.7 m^2 area). Therefore, a total of 800 basic units were used in each trial.

Yield data were used to estimate the convenient plot size and shape using Smith's method and maximum curvature approach. Also, the suitable number of replications was determined. Results obtained from statistical analysis could be summarized as follows:

1- Soil variability index was 0.6805 and 0.7271 for the two seasons reflecting an intermediate variability in the soil.

2- Variance per basic unit and coefficient of variability were decreased by increasing plot size. However, the reduction was not in proportion with the increase in plot size.

3- The exponential relationships between the coefficient of variability (C. V) and plot size (X) were:

$C.V = 20.0410\, X^{-0.30529}$ (for the 1st season)

$C.V = 28.3600\, X^{-0.3252}$ (for the 2 nd season)

4- The optimum plot size was 1/1500 fed. (2.8 m^2).

5- Plot shape had no clear effect in most cases, whereas long and narrow plots were more efficient as it decreased the variance per basic unit and coefficient of variability.

6- Number of replications increased with long and narrow plots and C.V decreased by increasing number of replications. Therefore, increasing number of replications was more effective than increasing plot size.

INTRODUCTION

The research workers in field experiments usually face problem of the variation in yield estimates. The causes for this variation are numerous but the obvious, and probably the most important one, is soil variability that has been recognized as a major factor affecting the sensivity of experimental results. Choosing a suitable design and using an optimum size of plot can minimize the effect of the soil. This emphasizes the importance of determining soil variability in experimental fields, and estimating the optimum plot size and shape as well as number of replications in these fields.

Uniformity trials have been used to determine optimum plot size and shape, number of replications, soil heterogeneity, relative efficiencies of the experimental designs and to adjust yields of subsequent experiments.

Results of the current study, together with those previously reported by other investigators, should clarify the degree of sensivity of the yield to changes in plot size and shape for varieties of crops under different patterns of soil variability, and also plot size and shape that can be adopted by researchers in their field trials under similar experimental conditions.

In Alexandria, Kassem et al (1971) found that the optimum wheat plot size ranged from 1.2 m^2 to 2.4 m^2. They reported that long and narrow plots significantly reduced the variability among plots than short wide squared plots. They also stated that as the plot size increased, the variance among plots and comparable variance were decreased, but the variance per basic unit and coefficient of variability decreased.

El-Kalla and Gomaa (1977) working on wheat reported that the optimum plot size for wheat was 3.0 m^2 (1/1400 fed) using Smith's method for Gemmeiza and Sids locations. However, it was 7.0 m^2 and 5.0 m^2 for the two locations, respectively, using the maximum curvature technique. Plot shape had no effect on plot -to- plot variability.

In Sids region, results of El-Bakry (1980) indicated that wheat needs plot of medium size. The optimum size of plot ranged from 1/933 to 1/169 fed. He also cleared that a long and narrow shaped plot was generally more efficient compared to the square or nearly square shape.

Using Kogh and Rigney approach, Abdel-Halim and Hanna (1980) found that soil variability index in wheat experiments ranged from 0.42 to 0.68. The optimum plot size was found to range from 1/620 to 1/240 with an average calculated from all experiments nearly equal to 1/350 fed.

El-Rassas (1982) found that a plot size ranging from 3.2 m^2 to 6.4 m^2 (1/1300 - 1/650 fed) was an optimum size for experimental plot in wheat trials. He stated that long and narrow plots were more effective in reducing variance per basic unit area, comparable variance and coefficient of variability.

Stewart *et al* (1994) studied the relationship between plot length and experimental error in wheat and barely. They concluded that the variance declined rapidly as plot length increases.

In wheat fertilization experiments, Nasr (1997) found that the optimum plot size ranged from 1/229 to 1/140 fed. He recommended square plots in fertilization experiments.

The present study aimed to estimate soil variability index and optimum plot size and shape as well as number of replications in wheat experiments under the conditions of Gemmeiza region in Middle Delta in Egypt.

MATERIALS AND METHODS

Experiment layout:

Two uniformity trials of wheat were carried out at the Agricultural Research Station of Gemmeiza, Gharbia Governorate, Egypt in the two successive seasons of 2000/2001 and 2001/2002 using wheat cultivar Giza 168.

The field area in each season was well prepared there after, it was divided into eight strips with 100 rows in each. Each row was 3.5 m long and 20 cm apart and that represents the basic unit. Therefore, a total of 800 basic units was used in each season. Data of grain yield of wheat (kg/plot) were collected for every basic unit.

Statistical analysis:

I-Plot size:

Data of each trial were separately analyzed to study the effect of plot size (in terms of the number of adjacent basic units grouped to form a larger plot) and plot shape (in terms of varying the basic units grouping in various patterns) on the variance per basic unit and number of replications.

Contiguous basic units were combined to form larger plots of varying sizes. Twenty-four different grouping combinations were studied in both trials. The different combinations of plot size and shape were determined as well as the number of basic units across and along for each plot shape in each combination, (Table1). Accordingly, the length and width of the plot were calculated in meters and area in square meters and relative to feddan. The number of plots was calculated by dividing the total number of basic units (800 units) by the number of basic units in each plot size.

For each plot size the weighted average of the variances of the different grouping combinations was calculated. The degrees of freedom were used as weights for their respective combination variance. Weighted means were also calculated using number of plots per combinations weights.

Optimum plot size was estimated using the two following methods:

1- Smith,s method, which was developed by Smith (1938), based on his proposed empirical relationship between plot size and plot variance. This relationship may be expressed in logarithmic form as:

$$\text{Log } V_X = \text{Log } V_i - b \text{ Log } X$$

Where:

V_X:isthe variance per basic unit calculated as, among plot variance $V_{(X)}$ divided by the square of its size in basic units (X); $V_{(X)} / X^2$.

V_i: is the variance of plots of one basic unit.

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

From the above-mentioned equation, b can be estimated as a linear regression coefficient. A simple weighting of variances by their respective degrees of freedom could be used to calculate b (Smith, 1938). But Hatheway and Williams (1958) reported that the simple weighting of the variances is not accurate by of high correlation between adjacent plots. Therefore, in the present study, b was estimated following the formula developed by Federer (1955), as follows:

$$b = \frac{\Sigma W_i \text{ Log } V_{Xi} \text{ Log } X_i - (\Sigma W_i \text{ Log } V_{Xi}) (\Sigma W_i \text{ Log } X_i) / \Sigma W_i}{\Sigma W_i (\text{Log } X_i)^2 - (\Sigma W_i \text{ Log } X_i)^2 / \Sigma W_i}$$

Where:

b : is the weighted index of soil variability.

Wi : is the degrees of freedom associated with V_{Xi}.

V_{Xi} : is the variance per basic unit among plots of size X_i.

X_i : is the number of basic units in the plot.

The value of b ranges from zero, indicating complete uniformity, to one, indicating random soil variability or a strong fertility gradient. Thus, less variability among plots would be expected in a fairly uniform experimental area. On the other hand, more variability among plots would be expected with random soil variability.

Ignoring cost factors, the optimum plot size (X opt.) was determined using the method developed by Smith (1938), from the equation:

$$X\ opt. = b/(1 - b).$$

2- *Maximum curvature technique:* which was developed by Meier and Lessman (1971) and Galal and Abou-El-Fittouh (1971). The point of maximum curvature point (X_0) for the exponential curve $C.V = AX^{-B}$, relating the coefficient of variability (C. V) and plot size (X) was determined by the following formula:

$$X0 = [A^2 B^2 (2B + 1)/(B + 2)]^{1/(2B + 2)}$$

The values of A and B in previous equation were calculated from the data using the principle of linear regression as follows:

$$B = \frac{n\Sigma Log(C.V) \, Log\,X - \Sigma Log(C.v) \, \Sigma Log\,X}{N\Sigma(Log\,X)^2 - (\Sigma Log\,X)^2}$$

$$Log\,A = \frac{\Sigma Log(C.v)}{n} - \frac{B\,\Sigma Log\,X}{n}$$

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

$$Log\,X_0 = \frac{2\,Log\,A + 2\,Log\,B + Log(2\,B + 1) - Log(B + 2)}{(2\,B + 2)}$$

The plot size directly beyond the value X_0 was considered optimum. Also, no estimates of cost were considered in this method.

II-Plot shape:

To study the effect of plot shape, differences among plot shapes consisted of the same number of basic units were tested for significance by comparing their variances (V_X) through Bartlett's test for homogeneity of variance as outlined by Steel and Torrie(1980).

III- Number of replications:

Number of replications required could be determined using several methods based on the coefficient of variation (C.V) to detect a specified percentage difference between treatment means. A commonly used method, based on Student's t statistic, was given by Federer (1955). The number of replications required was calculated using the following equation:

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

Where:

r : is the number of replications required.

t : is the value of Student's t statistic at α level of significance for the degrees of freedom associated with the C. V.

α : is the level of significance.

C.V: is the coefficient of variability.

D: is the minimum difference to be detected, expressed as percentage of the mean and it was 10 %, 15 %, and 20 % in the current study.

RESULTS AND DISCUSSION

1- Soil heterogeneity index:

Average of weighed index of soil variability (b) calculated as outlined by Federer (1955) were 0.6805 and 0.7271 for the 2000/2001 and 2001/2002 seasons, respectively, as shown in Table 4. The values of the soil variability index reflect intermediate variability in the experimental site. Values of b as reported by Smith (1938) should range from zero indicating complete uniformity to one, which implies that soil is extremely heterogeneous. These results are in agreement with those obtained by El-Rassas (1982).

2- Optimum plot size:

Table 2 represents the variance per basic unit, among plots and coefficients of variability for 24 combinations of plot sizes and shapes for the first and second seasons, respectively.

Results clear that variance among plots $V_{(X)}$ increased as plot size increased. On the other hand, increasing plot size led to reduction in the variance per basic unit $V_{(xi)}$ and coefficient of variability, (C.V.).

Results in Table 3 also indicate that coefficient of variability C.V decreased as plot size increased and that increasing the number of strips for a fixed plot size reduced the C.V more effectively than increasing the number of rows. For example, a plot size of 4 basic units, in the first season, results in a C.V of 10.8 % when the plot consisted of 1 row in 4 strips, and 12.1 % when the plot consisted of 2 rows in 2 strips, and 13.25 % when the plot consisted of 4 rows in one strip.The same trend could be observed in the second season (Table3).

Results obviously indicated that increasing plot size decreased the variance per basic unit and coefficient of variability. However, the reduction was not in proportion with the increase in the plot size. Moreover, the rate of reduction decreased as the plots became larger. This confirms the fact that the relationship between plot size and the variance per basic unit or the coefficient of variability is exponential in nature. These results are on the same line with those reported by El-Kalla and Gomaa (1977) and El-Rassas (1982).

The exponential relationships obtained for the present study were:

$C.V = 20.041X^{-0.30529}$ and $C.V = 28.36\,X^{-0.32352}$

for the first and second seasons, respectively. These relationships are graphically illustrated in Figures 1 and 2.

Soil variability and optimum plot size as estimated by each of Smith's and Maximum curvature methods are presented in Table 4. The value of soil variability index (b) was 0.6805 and 0.7271 for the first and second seasons, respectively. Using this value in calculating the optimum plot size (Smith,s method), it was found to be 3 basic units *i.e.* 2.1 m^2 being 1/2000 fed, for the two seasons of the study. Smith (1938) reported that areas half or double the optimum plot size would be 96% as efficient as the optimum plot size when b = 0.5.

By applying the maximum curvature method as modified by Meier and Lessman (1971) and Galal and Abou-El-Fittouh (1971), four basic units were found to be the optimum plot size *i. e* 2.8 m^2 being 1/1500 fed for both seasons, (Table 4).

The results of using Smith's method and maximum curvature method to estimate the optimum plot size were nearly the same. Therefore, plot size of 1/1500 fed being 2.8 m^2 could be recommend for planting wheat in Gemmeiza region.

3- Plot Shape:

Results of Bartlett test for the homogeneity of variances for the two seasons of 2000/2001 and 2001/2002 are presented in Table 5. The results obtained clear that the variances for differently shaped plots did not significantly vary for the two trials except in one case in the second season, indicating that the plot shape had no important effect. Referring to Table 1. and comparing different shapes for specified size, it could be concluded that a long and narrow shape is generally more efficient as compared with other shapes. This is clear from its low variance per basic unit area and coefficient of variation. These results are in harmony with those reported by ElñBakry (1980) and El-Rassas (1982).

4- Number of replications:

Results given in Table 6 show the effect of plot size on the number of replications required to detect a minimum difference of 10 %, 15 % and 20 % between treatment means.To detect differences of 10 %, the required number of replications in the first season varied from 26 with plot size of one basic unit to 2 with plot size of 200 basic units. Meanwhile, number of replications varied from 49 with a plot size of one basic unit to 4 with 200 basic unit plot size in the second season.

For detecting 15 % difference, the number of needed replications ranged from 12 and 22 with a plot size of one basic unit in the first and second seasons, respectively to 2 replications with a plot contains 200 basic units for both seasons. To detect 20 % difference, the needed number of replications ranged from 7 with plot size of one basic unit to one replicate with a plot size of 200 basic units in the first season. In the second season, number of replications needed to detect difference of 20 % ranged from 12 replicates with a plot size of one basic unit to one replicate with a 200 basic units plot size, (Table 6).

Results in Table 6 also indicate that the plot shape affected the number of replications. Where number of replications increased with long and narrow plots. Moreover, the number of replications also affected coefficient of variability. Comparing results of C.V. in Table 2 with the number of replications in Table 6 clearly showed that the coefficient of variability was reduced by increasing the number of replications for both seasons. These results were in agreement with those reported by ElñRassas (1982).

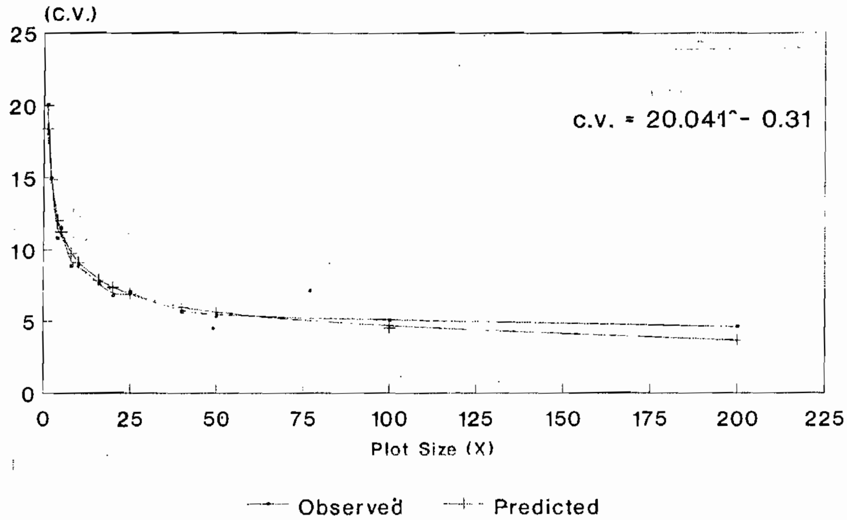

Fig. 1: Relationahip between plot size (x) and coefficient of variability (C.V) (2000/2001 season)

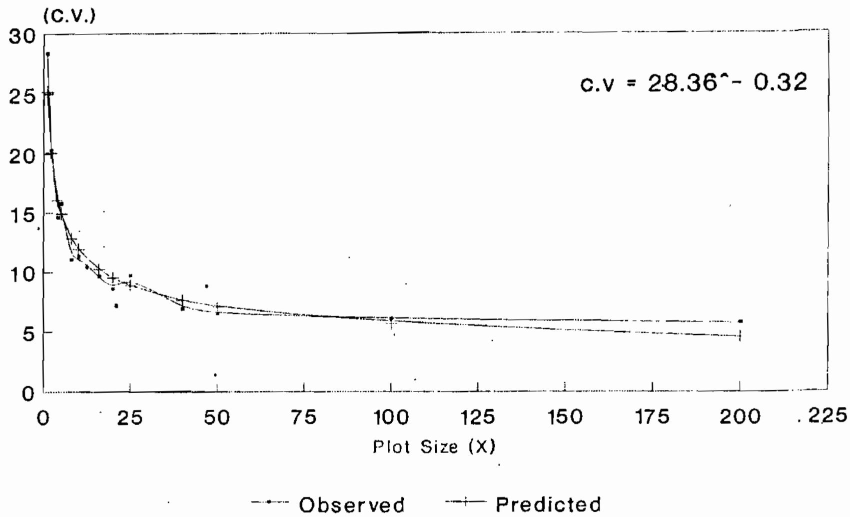

Fig. 1: Relationahip between plot size (x) and coefficient of variability (C.V) (2001/2002 season)

Table 1: Discription of the different combinations of plot size and shape for wheat at Genmeiza in the 2000/2001 and 2001/2002 seasons.

Serial No.	No. of basic Units	Plot shape	Plot dimensions (m) Width X Length	Plot area		No. of plots
				M^2	Feddan	
1	1	1 X 1	0.2 X 3.5	0.7	1/6000	800
2	2	1 X 2	0.2 X 7.0	1.4	1/3000	400
3		2 X 1	0.4 X 3.5	1.4	1/3000	400
4	4	1 X 4	0.2 X 14	2.8	1/1500	200
5		2 X 2	0.4 X 7.0	2.8	1/1500	200
6		4 X 1	0.8 X 3.5	2.8	1/1500	200
7	5	5 X 1	1.0 X 3.5	3.5	1/1200	160
8	8	2 X 4	0.4 X 14	5.6	1/750	100
9		4 X 2	0.8 X 7.0	5.6	1/750	100
10	10	5 X 2	1.0 X 7.0	7.0	1/600	80
11		10 X 1	2.0 X 3.5	7.0	1/600	80
12	16	4 X 4	0.8 X 14	11.2	1/375	50
13	20	5 X 4	1.0 X 14	14.0	1/300	40
14		10 X 2	2.0 X 7.0	14.0	1/300	40
15		20 X 1	4.0 X 3.5	14.0	1/300	40
16	25	25 X 1	5.0 X 3.5	17.5	1/240	32
17	40	10 X 4	2.0 X 14	28.0	1/150	20
18		20 X 2	4.0 X 7.0	28.0	1/150	20
19	50	25 X 2	5.0 X 7.0	35.0	1/120	16
20		50 X 1	10 X3.5	35.0	1/120	16
21	80	20 X 4	4.0 X 14	56.0	1/75	10
22	100	25 X 4	5.0 X 14	70.0	1/60	8
23		50 X 2	10 X 7.0	70.0	1/60	8
24	200	50 X 4	10 X14	140.0	1/30	4

Table 2: Variance and coefficient of variability of different plot sizes and shapes for 24 combination from 800 basic units of wheat at Gemmeiza in the two seasons of 2000/2001 and 2001/2002.

Serial Number	Plot size and shape Number of basic units			Total number of plots	(2000 / 2001) season			(2001 / 2002) season		
					Variance		Coefficient of variability C. V %	Variance		Coefficient of variability C. V %
	Size	Rows	Strips		Per basic Units (V_{X_i})	Among Units (V_X)		Per basic Units (V_{X_i})	Among Units (V_X)	
1	1	1	1	800	0.0038	0.0038	20.041	0.0076	0.0076	28.368
2	2	1	2	400	0.0021	0.0084	14.942	0.0039	0.0154	20.268
3	2	2	1	400	0.0024	0.0095	15.873	0.0043	0.0174	21.513
4	4	1	4	200	0.0011	0.0176	10.804	0.0020	0.0322	14.637
5	4	2	2	200	0.0014	0.0221	12.097	0.0023	0.0365	15.593
6	4	4	1	200	0.0017	0.0265	13.248	0.0030	0.0478	17.848
7	5	5	1	160	0.0012	0.0312	11.503	0.0023	0.0585	15.792
8	8	2	4	100	0.0007	0.0472	8.845	0.0013	0.0803	11.663
9	8	4	2	100	0.0010	0.0635	10.257	0.0016	0.1006	12.938
10	10	5	2	80	0.0007	0.0749	8.913	0.0012	0.1206	11.335
11	10	10	1	80	0.0008	0.0819	9.320	0.0014	0.1438	12.377
12	16	4	4	50	0.0006	0.1414	7.654	0.0009	0.2230	9.632
13	20	5	4	40	0.0004	0.1737	6.786	0.0007	0.2785	8.612
14	20	10	2	40	0.0005	0.1951	7.193	0.0007	0.2920	8.818
15	20	20	1	40	0.0005	0.1896	7.090	0.0009	0.3552	9.726
16	25	25	1	32	0.0005	0.2896	7.010	0.0009	0.5562	9.736
17	40	10	4	20	0.0003	0.4801	5.641	0.0004	0.7199	6.923
18	40	20	2	20	0.0003	0.4521	5.474	0.0005	0.7835	7.222
19	50	25	2	16	0.0003	0.6855	5.393	0.0004	0.9988	6.523
20	50	50	1	16	0.0003	0.7574	5.668	0.0006	1.4600	7.887
21	80	20	4	10	0.0002	1.1302	4.327	0.0003	1.9781	5.738
22	100	25	4	8	0.0002	2.4326	5.079	0.0003	3.4593	6.070
23	100	50	2	8	0.0002	1.7338	4.288	0.0003	2.7428	5.405
24	200	50	4	4	0.0002	7.9642	4.595	0.0003	12.3711	5.740

Table 3: Coefficient of variability for different plot sizes for wheat cultivar Giza 168 at Gemmeiza in 2000/2001 and 2001/2002 seasons.

Rows / plot	Strips / plot					
	2000 / 2001			2001 / 2002		
	1	2	4	1	2	4
1	20.041	14.942	10.804	28.368	20.268	14.637
2	15.873	12.097	8.845	21.513	15.593	11.663
4	13.248	10.257	7.654	17.848	12.938	9.632
5	11.503	8.913	6.786	15.792	11.335	8.612
10	9.320	7.193	5.641	12.377	8.818	6.923
20	7.090	5.474	4.327	9.726	7.222	5.738
25	7.010	5.393	5.079	9.736	6.523	6.070
50	5.668	4.288	4.595	7.887	5.405	5.740

Table 4: Optimum plot size for wheat cultivar Giza 168 at Gemmeiza as estimated by each of Smith's and maximum curvature methods in the two seasons of 2000/2001 and 2001/2002.

Season	Smith's method				Maximum curvature method				
	b	Optimum plot size			A	B	Optimum plot size		
		In basic unit	Area in M^2	Area in Fed			In basic unit	M^2	Fed
2000 / 2001	0.6805	3	2.1	1/2000	20.041	-0.3053	4	2.8	1/1500
2001 / 2002	0.7271	3	2.1	1/2000	28.360	-0.3235	4	2.8	1/1500

Table 5: Results of the Bartlett's test for the homogeneity of variances for wheat trials at Gemmeiza in 2000/2001 and 2001/2002 seasons.

Plot size	Value of Chi – square	
	2000 / 2001	2001 / 2002
2	1.5113	1.4881
4	8.2436	8.2333*
8	2.1811	1.2610
10	0.1586	0.6145
20	0.1391	0.6496
40	0.0176	0.03550
50	0.0386	0.5557
100	0.2148	0.1012

Table 6: Number of replications required to detect differences of 10 %, 15 % and 20 % between treatment means at 5 % level of significance for wheat at Gemmeiza in the 2000/2001 and 2001/2002 seasons.

Plot size		2000 / 2001			2001 /2002		
Number of basic units	Area (m^2)	Number of replications			Number of replications		
		10%	15%	20%	10%	15%	20%
1 X 1 = 1	0.7	26	12	7	49	22	12
1 X 2 = 2	1.4	17	8	4	31	14	8
2 X 1 = 2	1.4	11	5	3	20	9	5
1 X 4 = 4	2.8	17	8	4	31	14	8
2 X 2 = 4	2.8	11	5	3	20	9	5
4 X 1 = 4	2.8	7	3	2	13	6	3
5 X 1 = 5	3.5	11	5	3	20	9	5
2 X 4 = 8	5.6	7	3	2	13	6	3
4 X 2 = 8	5.6	5	2	2	8	4	2
5 X 2 = 10	7.0	10	4	2	17	8	4
10 X 1 = 10	7.0	7	3	2	11	5	3
4 X 4 = 16	11.2	4	2	1	8	3	2
5 X 4 = 20	14.0	7	3	2	11	5	3
10 X 2 = 20	14.0	4	2	1	7	3	2
20 X 1 = 20	14.0	3	2	1	5	3	1
25 X 1 = 25	17.5	4	2	1	7	3	2
10 X 4 = 40	28.0	3	2	1	5	3	1
20 X 2 = 40	28.0	3	2	1	4	2	1
25 X 2 = 50	35.0	4	2	1	7	3	2
50 X 1 = 50	35.0	3	2	1	5	3	1
20 X 4 = 80	56.0	2	2	1	4	2	1
25 X 4 = 100	70.0	3	2	1	5	3	1
50 X 2 = 100	70.0	2	2	1	4	2	1
50 X 4 = 200	140.0	3	2	1	4	2	1

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تأثير مساحة وشكل القطعة التجريبية وعدد المكررات على دقة التجارب الحقلية فى القمح

فتحى عشماوى١ ، نجدى عبد العليم محمد١ ، أسعد حمادة أسعد٢

١- المعمل المركزى لبحوث التصميم و التحليل الاحصائى _ مركز البحوث الزراعية.
٢- قسم بحوث القمح- معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية.

أقيمت تجربتى تجانس على محصول القمح صنف جيزة ١٦٨ خلال موسمى ٢٠٠٠/٢٠٠١ و ٢٠٠١/٢٠٠٢ فى محطة البحوث الزراعية بالجميزة _ محافظة الغربية وذلك لتقدير أنسب مساحة وشكل للقطعة التجريبية وأفضل عدد للمكررات وتأثير ذلك على دقة التجارب الحقلية فى محصول القمح. ويمكن تلخيص النتائج المتحصل عليها كما يلى:

١- تراوحت قيمة دليل تجانس التربة من ٠,٦٨٠٥ الى ٠,٧٢٧١ لموسمى الدراسة مما يدل على أن درجة تجانس التربة لحقول القمح فى منطقة الجميزة متوسطة.

٢- زيادة مساحة القطعة التجريبية أدت الى انخفاض التباين لوحدة المساحة ومعامل الاختلاف ولكن معدل الانخفاض لا يتناسب مع معدل زيادة مساحة القطعة التجريبية.

٣-كانت أنسب مساحة للوحدة التجريبية للقمح فى هذه المنطقة ١/١٥٠٠ من الفدان.

٤- لم يكن لشكل القطعة التجريبية تأثيرا واضحا ولكن لوحظ أن القطع المستطيلة الضيقة كانت أكثركفاءة حيث أنها تقلل التباين ومعامل الاختلاف بالقطعة التجريبية.

٥-كان لزيادة عدد المكررات تأثيرا واضحا على زيادة دقة التجربة نتيجة انخفاض معامل الاختلاف حيث كانت زيادة عدد المكررات أكثر كفاءة من زيادة مساحة القطعة التجريبية.