Size and Shape of Plots for Wheat Yield Trials in Field Experiments.

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ABSTRAC

Wheat uniformity trials was conducted at experimental farm , Faculty of Agriculture, Kafrelshiekh university, during 2011/2012 winter season. The cultivar grown was Misr1, the experimental field consisted of 8 strips with 100 ridges in each strip. Thus, the basic unit was one row 0.2m wide and 3.0m long (area $0.6m^2$). Therefore, a total 800 basic units was used. Yield data recorded for the basic units were later combined to obtain the yield of different sized plot groupings. The data were subjected to two procedures of statistical analysis to estimate the optimum plot size, The first statistical method was the maximum curvature The second method was that developed by Smith (1938). Bartlett's test for homogeneity of variances, was used to study the effect of changing plot shape. The results obtained could be summarized as follows:

1- Increasing the plot size decreased the variance per basic unit and the coefficient of variation. However, the reduction was not in proportion with the increase in plot size.
2- Long and narrow plots were more efficient.
3- The index of soil variability was 0.52 (intermediate soil heterogeneity)
4- The optimum size of plot ranged from2 to 4 basic units (i.e.1.2 m^2 to $2.4m^2$)).

INTRODUCTION

In any field experiment, one of the basic questions is the size of the plot along with the number of replications. Usually the plot size and number of replications are based on the previous experience of the experimenter or results of a uniformity trial conducted in that area used. Smith's (1938) law is used to calculate plot size from a uniformity trial, which is still unchallenged despite its lack of a theoretical basis (Pearce, 1976). Smith's law is as follows.

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

Where

V_x = the variance per basic unit of plots of size x units.

x = the number of basic units.

V_1 = the variance between basic units.

b = a measure of the degree of correlation between adjacent basic units or coefficient of heterogeneity (Smith's index).

Lin and Binns (1984) have given a method based on intra block correlation from RCBD, which calculates the plot size and its alternative to the Smith's law in the absence of uniformity trial. Some studies regarding wheat plot size have been made using uniformity trial by Ashfaq and Yab (1974) and Ashfaq *et al.* (1984).

Kassem *et al* (1971) at Alexandria, studied the optimum size and shape of plots from uniformity trials on wheat. They found that the optimum plot size ranged from 1.2 – 2.4m^2 (i.e. 1/3500 – 1/750 fad.). They stated that long narrow plots reduced significantly the variability among plots than the short wide or square plots. They also reported that, as the plot size increased, the variance among plots and comparable variance were increased, but the variance per basic unit and the coefficient of variation decreased.

El-kalla and Gomaa (1977) reported an optimum plot size for wheat which was 3.0m^2 (1/1400 fad.), using Smith's procedure for the two utilized locations Gemmeiza and Sids. However, it was 7.0 and 5.0m^2 by using modified maximum curvature technique for the previous two locations respectively. Plot shape had an effect on plot-to-plot variability.

El-Bakry (1980) recorded that wheat needs plots of medium size. He found that the optimum size of plot at Sids ranged from 1/933 to 1/169 fad. He also added that a long and narrow shape was generally more efficient as compared to the square or nearly square shape.

El-Rassas (1982) working on wheat and corn found that the optimum plot size ranged from 3.2 to 6.4m^2 (1/1300-1./650 fad.) for wheat yield trails and 14 to 26m^2 (1/300-1/160 fad.) for corn yield trails. He stated that long and narrow plots were more effective in reducing variance per basic unit area, comparable variance and coefficient of variation.

Leilah and Al-Khateeb (2007) They studied that the convenient quadrate size, shape and number in the desert rangeland of Saudi Arabia. They found that the weighed index of soil variability (b) was estimated to be 0.69 indicating that medium to large homogenous exists in the experimental site. As the quadrate size (x) increased, the variance among plots (vx) and comparable variance (v) increased, but the variance per basic unit (vx) , and coefficient of variation (cv) tended to decrease with each increase in quadrate size. Also, the long and narrow quadrate rectangular shape (1m x 24m) was the most effective in reducing soil variation.

Chaudhary et al (2011) determined optimum size and shape of plot for field experiments using maximum curvature method and fair field Smith's variance method.They found that the variability as judged by coefficient of variation per unit area (cv%) decreased from 19.60 % to 7.62 % with increase in plot size from 1 unit to 100 units. A plot of 14.4sq. m having 3.6m width x 4m length (i.e. rows each of 4m length) a rectangular shape of plot (net) was considered as optimum size and shape of plot for field experiments .

Vytautas and Petras (2012) At Lithuanian University of Agriculture, studied the optimal number of observation, treatment and replication in field experiments. They reported that increasing replication number from 4 to 6 , data accuracy decreases from 4.7 to 2.8 %, increasing replication number to 10, trial accuracy increases to 2.0%. Further increasing replication number from 10 to 37, data accuracy progressively increases from 1.5 to 1.6 %. Also, optimal number of treatments. According to SE and accuracy evaluation, is between 4 to 7. Then the highest accuracy of experimental data is reached .

MATERIALS AND METHODS

Wheat is considered as the important winter crop in Kaferlshikh Governorate, so The objectives of this study were to determine the optimum plot size, shape and number of replications for wheat yield under the soil condition Kafrelshikh governorate.

FIELD LAYOUT: This study was carried out at the experimental farm, Faculty of Agriculture ,Kafrelshikh university, during 2011/2012 winter season.

Misr1 wheat variety planted in rows $3m^2$long and 20cm apart in 8 strips with 100 rows for each strips. Culture practices for growing wheat were carried out as recommended. Grain yield (kg) for each row (basic unit) = (0.2 x 3 = $0.6m^2$) was weighted separately.

STATISTICAL ANALYSIS:

The basic unit was taken as one row 0.2m wide and 3m long(area $0.6m^2$)

Contiguous basic units were combined to form larger plots of varying sizes. Different grouping combinations as shown in table 1 were studied . These varied in size from 1 to 320 basic units which covered a wide range of plot sizes. For each plot size, the weighed average of the variances of the different grouping combinations was calculated .

Two methods are applied on the data sets to determining the optimum plot size :

First: maximum curvature method

1- The exponential relationship between the coefficient of variation (C.V.), and plot size (X),

$$C.V. = A X^{-B} \qquad (2),$$

was transformed into the logarithmic form : **Log C.V. = log A –B log x**

Where A and B are the Y intercept (constant of the equation) and regression coefficient , respectively .

The values of A and B in the above equation were estimated from the data using the principles of linear regression. To determine the point of maximum curvature (C max) of the original exponential curve, the values of A and B were substituted in the following formula which was developed by Galal and Abou El-Fittouh (1971)

$$C\ max = X_0 = [A^2 B^2 (2B+1) / (B+2)]^{1/(2B+2)} \qquad (3)$$

The point of maximum curvature indicates a critical value of the optimum plot size on basic unit basis

2- The weighted index of soil variability, b, as published by Federer (1955) was calculated ignoring cost factors from the empirical relationship between plot size and variance per basic unit according to the following equation :

$$b = \frac{\sum (W_i \log V_x \log X_i) - (\sum W_i \log V_x)(\sum W_i \log X_i) / \sum W_i}{\sum W_i (\log X_i)^2 - (\sum W_i \log X_i)^2 / \sum W_i} \qquad (4)$$

Where: b: weighed index of soil variability

W_i : degrees of freedom associated with S X_i,

logVx: weighed variance per basic unit of the i. plot size and,

X_i: number of basic units in the i. plot size.

The value of 'b' varies between plus and minus infinity. A value close to zero indicates very uniform field or the neighbouring plots are highly correlated while, its value near '1' would indicate a very heterogeneous field or the neighbouring are almost uncorrelated. The value of 'b' obtained this way has come under some criticism because in uniformity trial there is different number of plots for the different plot sizes uniformity the trial the area.

The coefficient of variation is also calculated as:

$$CV = \frac{\sqrt{V(x)}}{\acute{y}} \times 100 \qquad (5)$$

The plot of CV versus plot size (X) can be drawn to verify the Smith's empirical relation

Second : Smith method

The optimum plot size (x opt) was determined , using the method developed by Smith (1938) , by the equation :

The optimum plot size (X OPT) = b/(1-.b) (6)

To study the effect of shape on the variance, Bartlett's test was used for testing the homogeneity of the variances for different combinations within each plot size.

Data were analyzed by using BASIC program designed and planed by Dr.

Ahmed A.M. Atia chief researcher in Central Laboratory for Design and Statistical Analysis Agricultural Research Center.

RESULTS AND DISCUSSION

The basic unit was taken as one row 0.2m wide and 3m long (area $0.6m^2$). Thirty two different grouping combinations as shown in Table 1 were studied They varied in size from 1 to 32 basic units which covered a wide range of plot sizes .

Table (1): Description of the different combinations of plot size and shape for wheat

Serial No.	No. of basic units	Plot shape	Plot dimensions Width X length	Plot area		No. of plot
				.m^2	fadan	
1	1	1 x 1	0.2 x 3.0 =0.6	0.60	1/7000	640
2	2	1 x 2	0.2 x 6.0=1.2	1.20	1/3500	320
3	2	2 x 1	0.4 x 3.0 =1.2			
4	4	1 x 4	0.2 x 12 =2.4	2.40	1/1750	160
5	4	2 x 2	0.4 x 6,0 =2.4			
6	4	4 x 1	0.8 x 3.0 =2.4			
7	8	1 x 8	0.2 x 24 =4.8	4.80	1/875	80
8	8	2 x 4	0.4 x 12 =4.8			
9	8	4 x 2	0.8 x 6.0 =4.8			
10	8	8 x 1	1.6 x 3.0 =4.8			
11	16	2 x 8	0.4 x 24 =9.6	9.60	1/437	40
12	16	4 x 4	0.8 x 12 =9.6			
13	16	8 x 2	1.6 x,6 =9.6			
.14	32	4 x8	0.8 x 24 =19.20	19.20	1/218	20
15	32	8 x 4	1.6 x 12 =19.20			

Basic units = .6m

The variances per basic unit and among plots and their corresponding coefficients of variation for 32 combinations of plot sizes and shapes using the data are shown in table 2. Results showed that, the variance per basic unit area ,as well as, coefficients of variability (c.v.) decreased as plot size increased. It is evident that, the coefficient of variation values of yield decreased with increasing plot size from one basic unit to 32 basic units, Estimates for (c. v.) varied from 3.31 % (one basic unit) to 0.54 % (320 basic unit), also increasing the number of strips (replications) for a fixed plot size reduced the (c. v.) more effectively than increasing the number of rows (basic units). For example, a plot of size 4 basic units resulted in a c. v 1.57 % when the plot consisted of 1 row in 4 strips, while it was 2.14 when the plot consisted of 2 rows in 2 strips, and 2.75 % when the plot consisted of 4 rows in one strip. So , the long and narrow shape was more efficient than the other shapes. The coefficient of variability decreased from 3.308% for a plot size of two basic unit (1.2m^2) to 0.54 % for a plot size of 36 basic units (21.6m^2) .

In agreement with our result is the study of Kassem et al (1971) in their study at Experimental Farm, Faculty of Agriculture, Alexandria University found that the optimum plot size for wheat was 1.2m^2-4.8m^2 under Alexandria soil conditions . Also, Elkalla and Gomma (1977) in their study at the Gammaiza and Sids stations, Agriculture Research Center , found that the optimum plot size for wheat was 3m^2 by using Smith method, while the optimum plot size were 7m^2 at Gammaiza station and 5m^2 at Sids station. Also, El- rasas, H (1982) in his study at Experimental Farm, Faculty of Agriculture, Cairo University, found that the optimum plot size for wheat was 3.2m^2 -6.4m^2 under Cairo conditions. Ashmway et al (2003) at Experimental Farm, Faculty of Agriculture , Al-Azhar University found that the optimum plot size for wheat was 2.8m^2 .on the other hand Chaudhary et al (2011) in their study at north Gujarat condition in India, found that the optimum plot size was 14.4m^2 under north Gujarat condition. All of them found that the long and narrow shape was the best.

Table (2): Estimate of Variance per basic unit area (v x) and coefficient of variation (c. v. %) for different plot size and shapes of wheat

Ser. No.	Plot size and shape No. of basic units			Total No. of plots	Variance per basic among plots		C.V. %
	size	rows	strips		V_x	$V_{(x)}$	
1	1	1	1	640	108.72	108.72	3.308
2	2	1	2	320	52.86	211.43	2.306
3	2	2	1	320	94.37	377.5	3.082
4	4	1	4	160	24.78	396.56	1.579
5	4	2	2	160	45.58	729.24	2.142
6	4	4	1	160	75.04	1200.68	2.748
7	5	5	1	128	86.8	2169.95	2.956
8	8	1	8	80	12.18	779.66	1.107
9	8	2	4	80	21.63	1384.01	1.475
10	8	4	2	80	35.76	2288.52	1.897
11	8	8	1	80	54.02	3457.12	2.332
12	10	5	2	64	42.39	4239.22	2.066
13	10	10	1	64	54.22	5421.7	2.336
14	16	2	8	40	10.74	2748.35	1.039
15	16	4	4	40	17.97	4601.07	1.345
16	16	8	2	40	24.53	6279.84	1.571
17	16	16	1	40	30.7	7858.5	1.758
18	20	5	4	32	19.94	7977.23	1.417
19	20	10	2	32	24.61	9843.56	1.574
20	20	20	1	32	27.8	11119.42	1.673
21	32	4	8	20	8.95	9167.33	0.949
22	32	8	4	20	14.49	14833.01	1.207

23	32	16	2	20	14.97	15324.8	1.227
24	40	5	8	16	9.83	15735.2	0.995
25	40	10	4	16	14.01	22408.27	1.187
26	40	20	2	16	15	23995.47	1.229
27	40	40	1	16	18.14	29030.13	1.351
28	64	8	8	10	6.37	26105.6	0.801
29	64	16	4	10	8.35	34183.82	0.916
30	80	10	8	8	6.66	42641.14	0.819
31	80	20	4	8	10.64	68094.86	1.035
32	80	40	2	8	12.5	80017.14	1.122
33	128	16	8	5	4.41	72291.2	0.666
34	160	20	8	4	4.89	125264	0.702
35	160	40	4	4	8.69	222544	0.935
36	320	40	8	2	2.90	296928	0.54

Table 3 showed the average of yield (y) kg , variance per basic unit (v x) and coefficient of variation (c v) for each plot size in wheat uniformity trials. These results indicated that the coefficient of variation ranged from 3.308% for a plot size of one basic unit (o.6 m^2) to 0.54 % for a plot size of 32 basic units (19.2m^2). The coefficient of variation decreased rapidly with increasing plot size up to 0.6m^2 to 2.4m^2 and then decreased slowly as plot size increased. Figure 1 .In the light of these results the optimum plot size varied from 1 to 4 basic units (i.e. 0.6m^2 to 2.4m^2).

The present results were similar to those reported previously by many workers for different crops, of them, El-kadi *et.al.* (2007), Bayoumi and Demardash (2008) and Chaudhary et al (2011), who reported that, increasing the plot size decreases the variance per basic unit and the coefficient of variation. Many investigators confirmed these results, among them Lessman and Atkins (1963), Kassem et al (1971), El-kalla and Gomaa (1977).and El-Kadi *et.al.* (2007).

However, this reduction is not in proportion with the increase in plot size, the rate of reduction decreases, as the plots become larger. This confirms the fact that the relationship between plot size and the coefficient of variation is exponential in nature.

The exponential relationships obtained for this investigation

C.V.= 15.3 X- 0.68 . which is illustrated in Figure 1

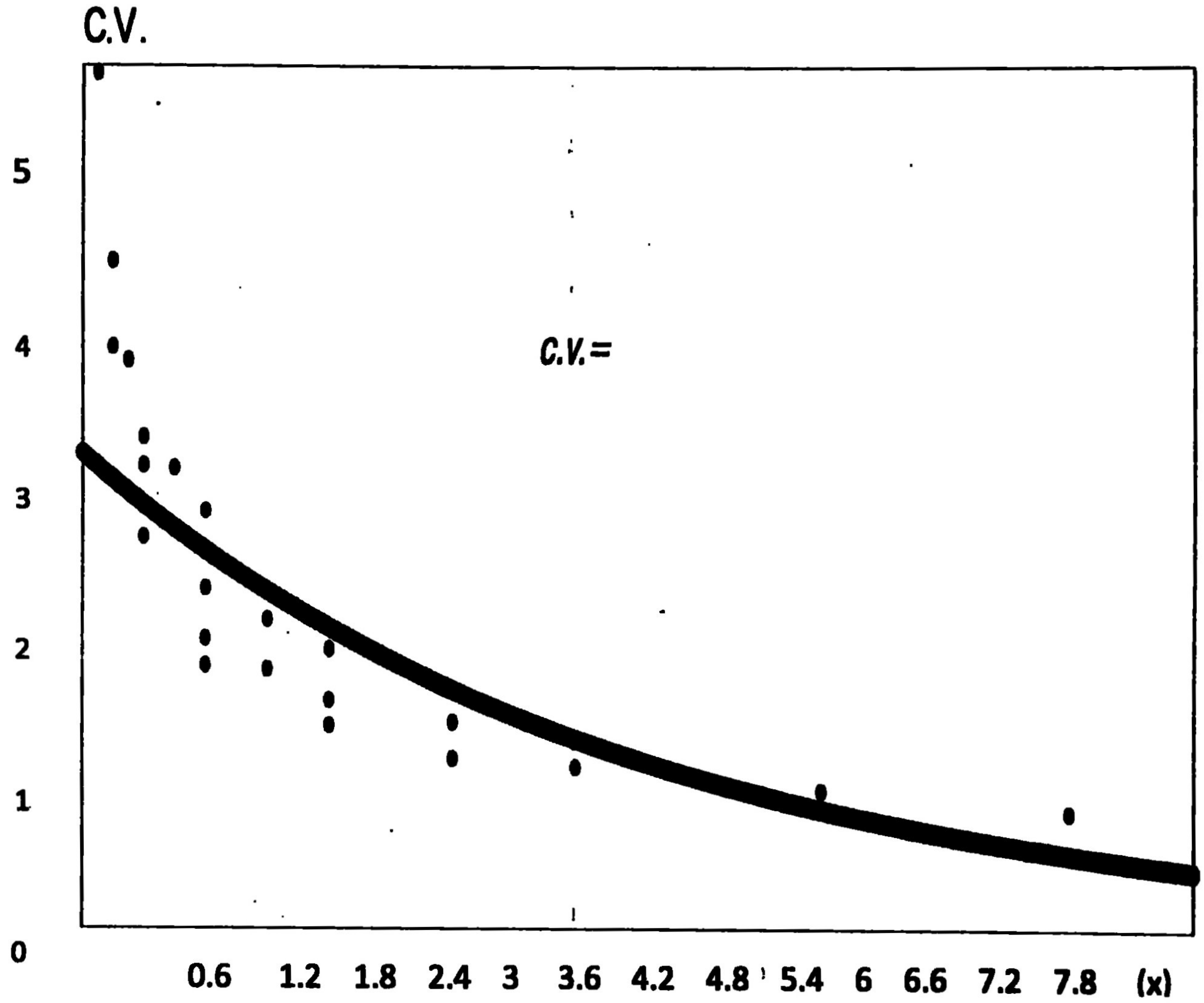

Fig (1) Relationship between plot size (x)and coefficient of variation (cv)

Table (3): Average variance per basic unit (V_X), average yield (Y) and coefficient of variation (C.V.) for each plot size in wheat uniformity trails.

Plot size	V_x	Y	Observed C.V.	Estimated c.v. & C.I.		
				L.E.	E.	U.E.
1	108.72	315.21	3.308	1.884	0.847	4.189
2	73.62	630.42	2.69	1.874	0.843	4.166
4	48.47	1260.85	2.16	1.855	0.835	4.120
5	86.8	1576.06	2.956	1.846	0.831	4.097
8	30.90	2521.70	1.70	1.817	0.820	4.030
10	48.31	3152.13	2.20	1.799	0.812	3.986
16	20.99	5043.40	1.43	1.744	0.789	3.857
20	24.12	6304.25	1.55	1.709	0.773	3.774
32	12.80	10086.80	1.13	1.606	0.729	3.539
40	14.25	12608.50	1.19	1.541	0.701	3.391
64	6.37	20173.6	0.801	1.362	0.620	2.994
80	9.93	25217.00	0.99	1.255	0.570	2.761
128	4.41	40347.2	0.666	0.980	0.439	2.189
160	6.79	50434.00	0.82	0.831	0.365	1.891
320	2.9	100868	0.54	0.365	0.135	0.988

Data presented in table 4 illustrated the optimum plot size from wheat as calculated by Smith's and maximum curvature methods. The general equation v = ax , of the modified maximum curvature technique for estimating the optimum plot size , defines the relationship between the coefficient of variation (c v) and plot size (x). The obtained constants of A and B were 15.3 and 0.680 respectively (Figure 1). Consequently, the results indicated that, the optimum plot size using maximum curvature methods was 4 basic units (4 x 0.6 = 2.4m^2) while, with Smith's method the optimum plot size was 4 basic units, (4 x 0.6 = 2.4m^2)

The index of soil variability , b was 0.52. Theoretically , this index varies between zero and one . A value close to zero indicates very uniform field or the neighbouring plots are highly correlated while its value near '1' would indicate a very heterogeneous. This result indicated that soil heterogeneity was intermediate in the fields .

Table (4): Optimum plot size for wheat as calculated by smith's and maximum curvature methods.

Smith's method				Maximum curvature method				
	Optimum plot size					Optimum plot size		
.b	.in basic unit	Area in .m^2	.fad.	A	B	.in basic unit	.m^2	.fad.
0.52	4	2.4	1/1750	15.3	0.680	4	2.4	1/1750

Data presented in Table 5 illustrates the relationship between number of replications (strips), number of rows in the plot (plot size) and coefficient of variation for grain yield

It is evident that coefficient of variation (c.v.) decreased as the number of strips (replications) or number of rows (plot size) increased. The rate of decrease was more obvious due to increase in number of replications than increasing number of rows in the plot size. The rate of decrease in coefficient of variation (c.v.) became, generally, negligible as number of replications exceeded four.

Table (5): Effect of number of strips (replications) on the coefficient of variation of different number of rows (basic units) in the plot for grain yield trials

Number of rows in the plot (basic units)	Number of strips(replications).			
	2	4	6	8
2	3.308	2.306	1.579	1.107
4	3.082	2.142	1.475	1.039
6	2.748	1.897	1.345	0.949
8	2.332	1.571	1.207	0.801

The results obtained using Bartlett's test as shown in table (6), indicates that, the variances for differently shaped plots did not vary significantly for all the cases indicating that, the shape has no obvious effect in this study .

Table (6): Results of the Bartlett's test for the homogeneity of variances for wheat.

Plot size (sq. m^2)	Chi-square Values	Table Values at 5%
1.2	0.132	3.841
2.4	4.081	7.815
4.8	1.992	14.067
6.0	3.850	16.920
9.6	3.359	23.680
12.0	3.495	30.140
19.2	6.089	43.770

We can conclude that; the optimum plot size was 1.2 m^2-2.4m^2 and the long and narrow shape was the best shape, and the optimum number of replications was four for wheat experiment using the variety Miser 1 under the soil conditions in Kaferlshikh Governorate.

الملخص العربي

التقدير الأمثل لمساحة وشكل الوحدة التجريبية في تجارب القمح

مرفت طلعت المحلاوي - أستاذ و رئيس قسم الإحصاء التطبيقي كلية التجارة- جامعة دمياط

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أجريت تجربة تجانس لمحصول القمح خلال الموسم ٢٠١١ /٢٠١٢ بالمزرعة البحثية بكلية الزراعة جامعة كفرالشيخ ، واستخدم لذلك الغرض صنف القمح الحديث مصر ١ .وقد أجريت هذه الدراسة لتحديد انسب مساحة وشكل للقطعة التجريبية في تجارب القمح نظرا للحاجة الماسة لتلك النوعية من الدراسة للاستفادة بها في تقليل الأخطاء التجريبية للتجارب الحقلية ولقد قسم حقل التجربة ذات الأبعاد (٢٤متر طولا٢٠متر عرضا) إلى ثمانية شرائح متوازية بينما قسمت كل شريحة إلى وحدات أساسية صغيرة كان عددها ١٠٠ وحدة أساسية ذات طول ٣م وعرض ٢٠سم اى أن مساحة الوحدة الأساسية ٠.٦م^{2} وبذلك يكون اجمالى عدد الوحدات الأساسية ٨٠٠ وحدة أساسية وتم تكوين جميع التوليفات ذات الأبعاد والأشكال المختلفة وقدرت صفة المحصول الكلى من كل وحدة تجريبية وتم تقدير جميع الثوابت والمقاييس الإحصائية المختلفة .

ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلي :

١ - زيادة مساحة القطعة التجريبية يؤدى إلى انخفاض التباين لوحدة المساحة وكذلك معامل الاختلاف ،إلا أن معدل الانخفاض لايتناسب مع معدل زيادة مساحة القطعة التجريبية .

٢- انخفض معدل التناقص لكل من تباين وحدة المساحة ومعامل الاختلاف كلما زادت مساحة القطعة التجريبية.

٣ - القطع التجريبية الطويلة الضيقة كانت أكثر كفاءة عن غيرها فمثلا القطعة ذات الأبعاد ١ x ٨ أفضل من القطعة ذات الأبعاد ٨x ١ كذلك القطعة ذات الأبعاد ١x ٤ أفضل من القطعة ٤x ١ وهكذا (الشكل المستطيل أفضل من غيره

٤-أمكن وضع العلاقة الخطية بين معامل الاختلاف ومساحة الوحدة التجريبية في الصورة الرياضية التالية :

$$C.V.= 15.3 X- 0.68$$

٥- أوضحت النتائج أن زيادة عدد المكررات يكون أكثر فعالية من الزيادة المماثلة في مساحة القطعة التجريبية

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