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OPTIMUM PLOT SIZE, SHAPE AND NUMBER OF REPLICATIONS FOR SUNFLOWER YIELD TRIALS

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Abstract

Two sunflower uniformity trials were conducted at Sakha Agric. Exper. Station during 1996 and 1997 summer seasons. In each trial, 640 basic unit were used. The basic unit was two rows (3.0x0.6m). Seed yield obtained from the adjacent basic units were arranged to obtain the various combinations of plot size and shapes. Thereafter, optimum plot size, plot shape and number of replications required to evaluate sunflower field experiments were determined. As plot size (x) increased the variance per basic unit (Vx) and coefficient of variability (CV%) tended to decrease.

The results obtained could be summarized as follows:

1. Soil heterogeneity index was 0.739 in 1996 and 0.698 in 1997 with an average of 0.718.

2. Optimum plot size was ranged from 4.159 to 5.095 m2 by Smith method. Using the maximum curvature, the optimum plot size was found to be 11.326 m2.

3. The variance is affected by the plot shape and its direction. This would indicated that, there is fertility gradient within the experiment soil.

4. The relationship between the coefficient of variability (CV.) and plot size (X) were expressed by the following equations:

C.V. = 26.81 x -0.8648 for the first season

C.V. = 28.78 x -0.8609 for the second season.

5. Plot shape was important for small size plots. However, long and narrow plots were recomended.

6. Effect of number of replications and plot size on the differences between means were indicated increasing the number of replication was more effective in detecting the differences between means than increasing plot size.

INTRODUCTION

For the valid inference and accuracy in probability, randomization and replication are necessary, as suggested by Fisher. Local control is equally important for reduced the experimental error consequently increasing the precision of the field experiments. Local control includes choosing the optimum size and shape of plots, the division of blocks and their position in the experimental fields, which chiefly depend on the homogeneity the experimental area and the nature of the crop under test. Several factors have to be taken into consideration, as the cost and soil type. In order to locate the optimum plot size and the effect of plot shape on the precision of evaluation, uniformity trials have been suggested.

Different estimates of the optimum plot size were reported by several investigators for various crops i.e., Hatheway (1961), El-Kalla (1967), El-Bakry (1980), El-Rassas (1982), Aly (1983), Abd EL-Halim *et al.*, (1989) and Al-Marsafy *et al.*, (1992). There is a general agreement that increasing plot size cause a real decrease in the variance and coefficient of variability.

Several researchers working on different crops stated that long and narrow plot were more effective in reducing coefficient of variability and consequently, the number of replications (EL-Kalla and Gomaa, 1977; Abd El-Halim *et al.,* 1980, 1989. However, Galal and Abou EL-Fittouh, 1971; Khalil *et al.*, 1970; reported that the effect of plot shape in reducing variance per basic unit and coefficient of variability was neglegible.

Increasing number of replications decreases standard error. The precision of the field trials improves more rapidly with an increase in number of replicates than with an increase in plot size (ELKalla, 1967; El Bakry, 1980; and EL-Rassas, 1982; and AL-Marsafy, *et al.*, 1992.

It is very important to secure information that help the experimenter for minimizing this variation in order to assure the most reliable results from the experiment and consequently to increase the precision of the experiment. In Egypt the optimum plot size for sunflower field experiment was not done.

Thus, the main objective of this study were to detect the optimum plot size and shape and number of replicates for sunflower field experiments under the environmental conditions of Sakha Experimental Station.

MATERIALS AND METHODS

Two uniformity trials were conducted at Sakha Experimental Station during summer seasons of 1996 and 1997 using the sunflower cultivar "Mayak". All recommended agronomic practices were followed in the station. Each experiment consisted of 16 strips with 80 rows in each. Each row was 3.0 m long and 30cm apart. The basic unit was two rows (3.0 m x 0.6 m). Therefore, a total of 640 basic units were used in each season. Each plot was harvested separately and weight of seed was determined.

Statistical Analysis :

Variance per basic units and the coefficient of variability were computed for each of 28 selected grouping combination of different plot size and shape as indicated in Table 1. For each plot size the variances of the different grouping combination was calculated. The degrees of freedom were used as weights for their respective variance.

Table 1. Description of the different combination of plot size and shape for sunflower in 1996 and 1997 season.

Serial No.	No. of basic units	Plot shap Across x Along	Plot dimension (m) Width x length	Plot area m^2	No. of plot
1	1	1 x 1	0.6 x 3.0	1.8	640
2	2	1 x 2	0.6 x 6.0	3.6	320
3	2	2 x 1	1.2 x 3.0	3.6	320
4	3	1 x 3	0.6 x 9.0	5.4	213
5	4	3 x 1	1.8 x 3.0	5.4	160
6	4	2 x 2	1.2 x 6.0	7.2	160
7	4	1 x 4	0.6 x 12.0	7.2	160
8	5	4 x 1	2.4 x 3.0	7.2	128
9	5	1 x 5	0.6 x 15.0	9.0	128
10	5	5 x 1	3.0 x 3.0	9.0	128
11	6	3 x 2	1.8 x 6.0	10.8	107
12	6	1 x 6	0.6 x 18.0	10.8	107
13	7	1 x 7	0.6 x 21.0	12.6	91
14	7	7 x 1	4.2 x 3.0	12.6	91
15	8	1 x 8	0.6 x 24.0	14.4	80
16	8	4 x 2	2.4 x 6.0	14.4	80
17	9	9 x 1	5.4 x 3.0	16.2	71
18	9	3 x 3	1.8 x 9.0	16.2	71
19	10	1 x 10	0.6 x 30.0	18.0	64
20	10	5 x 2	3.0 x 6.0	18.0	64
21	12	12 x 1	7.2 x 3.0	21.6	53
22	12	4 x 3	2.4 x 9.0	21.6	53
23	12	6 x 2	3.6 x 6.0	21.6	53
24	16	16 x1	9.6 x 3.0	28.8	40
25	16	4 x 4	2.4 x 12.0	28.8	40
26	16	8 x 2	4.8 x 6.0	28.8	40
27	20	20 x 1	12.0 x 3.0	36.0	32
28	20	5 x 4	3.0 x 12.0	36.0	32
29	20	10 x 2	6.0 x 6.0	36.0	32

Optimum plot size (X opt.)

Two procedures were followed in determining the optimum plot size:

1) The weighed index of soil heterogeneity "b" proposed by Smith (1938) and developed by Federer (1955) was estimated from the empirical relationship between plot size and variance per basic unit according to the following equation.

$$b = \frac{(\Sigma \text{ wi log Xi Vxi}) - (\Sigma \text{ wi log Vxi}) (\Sigma \text{ wi log Xi}) (\Sigma \text{ wi })}{\Sigma \text{ wi (log Xi Vxi)}^2 - (\Sigma \text{ wi log Xi})^2 / (\Sigma \text{ wi})}$$

Where

b = Weighed soil heterogeneity index.

Wi = degrees of freedom associated with V.

Vxi = Variance per basic unit of the ith plot size.

Xi = number of basic units in the ith plot size.

The weight index of soil variability, b, as published by Federer (1955), was calculated. Ignoring cost factors the optimum plot size (x opt.) was determined, using the method developed by Smith (1938), by the equation:

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

Maximum curvature method:

The exponential relationship between the coefficient of variability (C.V.) and plot size (X) was calculated according to the following of logarithmic form:

log C.V. = Log A-B log X

where A and B are the Y-intercept and regression coefficient, respectively.

To determine the point of maximum curvature (C max.), the of A and B were substituted in the following formula which was developed by Galal and Abou-El-Fittouh (1971).

C max [A2 B2 (2B + 1) / (B + 2)]1/(2B+2)

The point of maximum curvature indicates the critical value of the optimum plot size.

Effect of plot shape:

Optimum plot shape, as mentioned by Lessman and Atkins (1963), was determined using "F" test by dividing largest variance values in each combination by the smallest variance within the same size, to obtain the calculated two tail F values at the corresponding degrees of freedom.

D- Magnitude of detected differences:

The true difference between two treatment means which can be detected at a 5% level of significance in 90% of the sunflower experiments was estimated for different plot sizes and number of replications. The estimates were calculated according to the formula presented by Hatheway (1961).

D2 = 2 (t1 + t2)2 C2 / R Xb

Where:

D = true difference desired to be detected (measured as percent of mean.

t1 = the t value at the 0.05 level of prob.

t2 = the t value at 0.20 level of prob.

C = the coefficient of variation among basic unit plot

R = the number of replications

b = soil heterogeneity index.

RESULTS AND DISCUSSION

Soil Variability:

The variance per unit and among plots and their corresponding coefficients of variability for 29 combinations of plot size and shapes for the 1996 and 1997 seasons are shown in (Table 2) respectively. The coefficient of variability ranged from 26.81% for plot size of one basic unit (0.9 m2) to 2.01% for a plot size 20 basic units (36.0 m2) in 1996 season from 28.78% to 2.18% in 1997 season.

The coefficient of variability decreased rapidly at first in the two seasons and then decreased slowly as plot size increased (Figures 1 and 2). These results are in agreement with those obtained by Keller (1949), Hatheway (1961), Abd El-Halim *et al.* (1989) and Al-Maesafy *et al.* (1992).

The fitted equations describing this relationship, C.V. value and plot size were as follows:

C.V. = 26.81 X -0.8648 with a value of r^2 = 0.805 for trial one, and

C.V. = 28.78 X -0.8609 with a value of r^2 = 0.785 for trial two.

The observed and predicted relationship are illustrated in figures 1 and 2

Table 2. Variance (vx) and coefficient of variability (c.v) observed of different plot sizes and shapes for 29 combinations from 640 basic units of sunflower in 1996 and 1997 seasons.

Serial No.	No. of basic units	Total No.of plots	1996			1997		
			V_x	$V_{(\bar{x})}$	C.V.	V_x	$V_{(\bar{x})}$	C.V.
1	1	640	250.69	250.69	27.41	325.00	325.00	28.39
2	2	320	388.10	97.03	17.06	558.09	139.52	18.60
3	2	320	344.70	86.18	16.07	496.37	124.09	17.54
4	3	213	578.46	64.27	13.88	832.98	92.55	15.15
5	3	213	146.37	16.26	6.98	210.77	23.42	7.62
6	4	160	343.27	21.45	8.02	443.69	27.73	8.29
7	4	160	658.88	41.18	11.11	948.79	59.30	12.13
8	4	160	172.02	10.75	5.68	247.70	15.48	6.20
9	5	128	808.14	32.33	9.84	1163.7	46.55	10.74
10	5	128	121.02	4.84	3.81	175.17	7.01	4.17
11	6	107	1007.36	27.98	9.16	1450.9	40.31	10.00
12	6	107	189.09	5.25	3.97	243.49	6.76	4.10
13	7	91	1084.90	22.14	8.15	1562.2	31.88	8.89
14	7	91	101.75	2.08	2.50	146.52	2.99	2.72
15	8	80	1203.29	18.80	7.51	1732.7	27.07	8.19
16	8	80	157.40	2.46	2.72	226.66	3.54	2.96
17	9	71	1560.11	19.26	7.60	2246.5	27.74	8.29
18	9	71	213.00	2.63	2.81	310.29	3.83	3.08
19	10	64	1453.14	14.53	6.60	2092.5	20.93	7.20
20	10	64	290.59	2.91	2.95	130.46	1.30	1.80
21	12	53	172.00	1.19	1.89	2489.4	17.29	6.55
22	12	53	127.76	.89	1.63	183.98	1.28	1.78
23	12	53	334.59	2.32	2.64	569.36	2.22	2.35
24	16	40	2259.39	8.83	5.14	3253.5	12.71	5.61
25	16	40	200.13	.78	1.53	288.19	1.13	1.67
26	16	40	862.36	3.37	3.18	782.56	1.96	2.20
27	20	32	2837.52	7.09	4.61	4086.0	10.22	5.03
28	20	32	161.62	0.40	1.10	232.73	0.58	1.20
29	20	32	428.93	1.07	1.79	528.65	1.31	2.34

Optimum plot size:

The optimum plot size was calculated by the two following methods:

1. Smith's method :

The weighted index of soil variability, b, was calculated as 0.739 for the first season and 0.698 for the second season (Table 3). The values of b indicated that the site is heterogeneous as the b values were near to 1.0. These values were used in computing the optimum plot size which was found to be 2.831 and 2.311 basic units for the two trials, respectively. Consequently, the optimum plot size was (2.831 x 1.8 = 5.095 m2) in the first season and (2.311 x 1.8 = 4.159m2) in the second season.

2. Maximum curvature method:

Both A,B, from the C.V. equations were used to predict the optimum plot and they are given in Table 3. The optimum plot size was 6.396 and 6.189 basic units in the first and second season, respectively. Consequently, the optimum plot size was (6.396 x 1.8m2 = 11.513 m2).

The fitted equation for the C.V. is not as accurate as that of the Smith method. Therefor it expected that, the Smith law to be more accurate.

Table 3. Soil heterogeneity index (b) and optimum plot size for sunflower experiments as calculated by Smith's and maximum curvature methods.

Season	Smith's method			Maximum curvature method			
	b	In basic unit	plot area/ m^2	A	B	In basic unit	plot area/ m^2
1996	0.739	2.831	5.095	26.81	-0.864	6.396	11.513
1997	0.698	2.311	4.159	28.78	-0.860	6.189	11.140
Mean	0.718	2.571	4.628			6.292	11.326

Plot shape :

To determine the effect plot shape in this study, variance ratios (F) of the different 29 combinations of plot shape for the various 14 plot sizes were calculated. These values were compared with the tabulated value at the same degrees of freedom to measure the differences among plot shapes composed of the same number of basic units. The results given in Table 4 indicated that the variances for differently shaped plots differ significantly in most of the cases, for the two seasons, showing that the variance is affected by the shape of the plot and its direction. This would indicated that there is fertility gradient within the experiment soil. The long and narrow plot were more effective in reducing coefficient of variability. Similar results

Table 4. Variance per basic unit (Vx) for different combination of plot shapes and "F" values for sunflowere in 1996 in 1997 seasons.

basic units	Plot shap Across x Along	D.F.	1996 (V_x)	1996 F-Value	1997 (V_x)	1997 F-Value
2	1 x 2	320	388.10		558.09	
2	2 x 1	320	344.70	1.125	496.37	1.124
3	1 x 3	213	578.46		832.98	
3	3 x 1	213	146.37	3.950**	210.77	3.952**
4	4 x 1	160	343.27		443.69	
4	2 x 2	160	658.88	1.919**	948.79	2.138**
4	4 x 1	160	172.02	1.995**	247.70	1.791**
5	1 x 5	128	808.14		1163.7	
5	5 x 1	128	121.02	6.677**	175.17	6.643**
6	3 x 2	107	1007.36		1450.9	
6	1 x 6	107	189.09	5.327**	243.49	5.958**
7	1 x 7	91	1084.90		1562.2	
7	7 x 1	91	101.75	10.662**	146.52	10.662**
8	4 x 2	80	1203.29		1732.7	
8	1 x 8	80	157.40	7.644**	226.66	7.644**
9	3 x 3	71	1560.11		2246.5	
9	9 x 1	71	213.00	7.324**	310.29	7.240**
10	5 x 2	64	1453.14		2092.5	
10	1 x 10	64	290.59	5.001**	130.46	16.039**
12	12 x 1	53	172.00		2489.4	
12	6 x 2	53	127.76	1.346	183.98	13.530**
12	4 x 3	53	334.59	1.945**	569.36	4.372**
16	4 x4	40	2259.39		3253.5	
16	16 x 1	40	200.13	11.289**	288.19	11.289**
16	8 x 2	40	862.36	2.620**	782.56	4.157
20	5 x 4	32	2837.52		4086.0	
20	20 x 1	32	161.62	17.556**	232.73	17.556**
20	10 x 2	32	428.93	6.615**	528.65	7.729**

** Indicate significance at the 0.01 level of probability.

were obtained by (EL-Kalla and Gomaa, 1977; Abd El-Halim *et al.*, 1989. However, Galal and Abou El-Fittouh, 1971; Khalil *et al*, 1973. Therefore, the recommended plot should consist of (0.6m width x 18m length) is better than (1.8m width x 6.0m length). In such cases, the systematic variability is removed by the long and narrow plot.

Differences to be detected :

Table 5 shows the effect of soil variability on the magnitude of the true differences which can be detected for different plot sizes and number or replications. It is evident that increasing in plot size and number of replications reduced the true differences that could be detected for the two seasons. The results obtained in this study indicate that the researcher has a considerable range in selecting size and replications of plots depending on the amount of land under his disposal, where the use of large plots needs a small number of replications and vice versa.

Table 5. Detected differences between treatment means (% of the mean) for different plot sizes and number of replications at 0.05 probability.

		Number of basic units						
Seasons	Rep.	1	2	3	4	5	6	8
First season (1996)	2	97.66	96.27	93.92	69.30	59.68	55.35	46.21
	4	48.83	48.14	46.96	34.59	29.82	27.67	23.07
	6	32.55	32.09	31.30	23.07	19.88	18.47	15.40
	8	24.42	24.06	23.17	17.31	14.91	13.83	11.53
Second season (1997)	2	116.00	114.44	101.91	82.51	71.06	65.96	54.99
	4	58.43	57.11	55.94	41.39	35.53	32.95	27.49
	6	38.95	37.14	35.15	27.50	23.67	21.97	18.33
	8	29.21	28.61	27.97	20.19	17.78	16.47	13.71

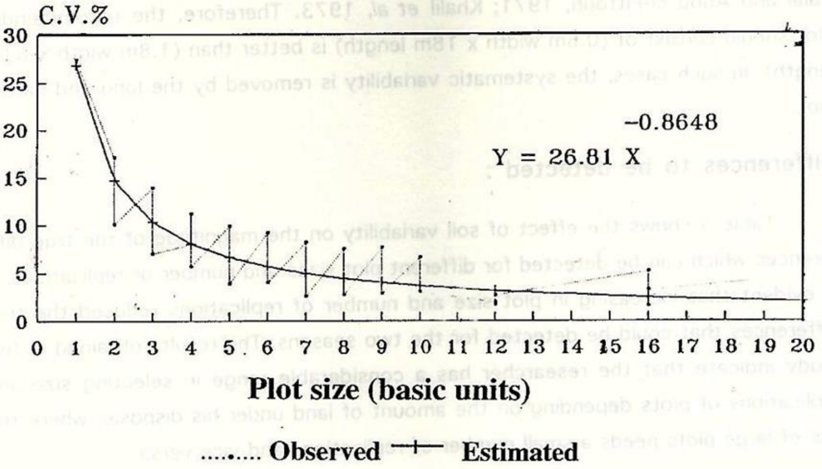

Fig. 1. Relationship between plot size (x) and coefficient of variability (C.V.) for sunflower seed yield, 1996.

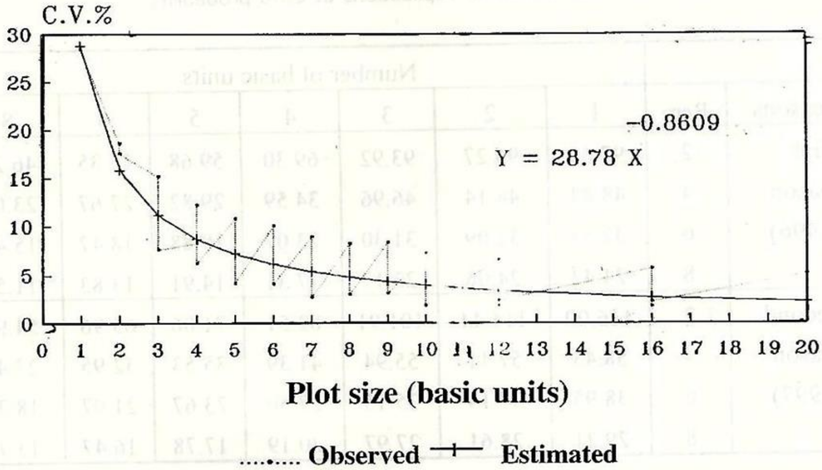

Fig. 2. Relationship between plot size (x) and coefficient of variability (C.V.) for sunflower seed yield, 1997.

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أنسب حجم وشكل وعدد من المكررات فى تجارب عباد الشمس

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قسم الحساب العلمى - المعمل المركزى للتصميم والتحليل الأحصائى - مركز البحوث الزراعية.

أقيمت تجربتان تجانس على محصول عباد الشمس بمحطة بحوث سخا خلال موسمى صيف ١٩٩٦ ، ١٩٩٧ وقد قسمت كل تجربة الى ٦٤٠٠ وحدة تجريبية وكانت مساحة الوحدة التجريبية خطين بأبعاد (٣م x ٦٠سم). وقدر محصور كل قطعة تجريبية على حدة لحساب التوافيق المختلفة لمساحة وشكل القطع التجريبية وذلك لتقدير أنسب حجم وشكل وعدد مكررات فى تجارب عباد الشمس تحت ظروف المنطقة المقامة بها التجربتان.

وتشير النتائج المتحصل عليها أن زيادة مساحة القطعة التجريبية يؤدى الى انخفاض التباين لوحدة المساحة وكذلك معامل الإختلاف ولكن كان معدل هذاالانخفاض أعلا من معدل زياده المساحه حسب معامل عدم تجانس التربة وكانت قيمتة ٠,٧٣٩ فى موسم ١٩٩٦، ٠,٦٩٨ فى موسم ١٩٩٧، وأستخدم هذا المعامل فى حساب اوفق مساحة للقطعة التجريبية والتى تراوحت بين ٥ م٢ فى ١٩٩٦ الى ٢,٤م٢ فى ١٩٩٧ الى ١١,٣٤ م٢، وعند استعمال طريقة أعلى معدل تقعر زادت مساحة القطعة التجريبية المثلى الى ١١,٥٤م٢ , وأظهرت الدراسة أن شكل القطعة التجريبية له تاثير على التباين وهذا يرجع الى عدم تجانس التربة. وقد وجد أن القطعة المستطيلة الشكل أكثر كفاءة من القطعة المربعة وذلك عند ثبات المساحة.

باستعمال معامل عدم تجانس التربة أمكن تحديد عدد المكررات اللازمة لأكتشاف الفروق بين المعاملات ويمكن الإهتداء بهذه النتائج قبل تنفيذ التجارب مستقبلاً.