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ESTIMATION OF OPTIMUM PLOT SIZE AND SHAPE FOR LENTIL YIELD TRIALS

HAMDI, A.[1], E.M.H. SHOKR[2], S.A. SEDHOM[2] AND SALWA A.A. HASSANEIN[1]

1 Food Legume Program, Field Crops, Res. Instit., ARC, Giza, Egypt.

2 Fac. of Agriculture, Moshtohor, Zagazig Univ., Egypt.

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Abstract

A uniformity test was utilized in two field trials each included 720 units (one basic unit = 0.3 m^2). The trials were conducted at Sids experimental research station in 1998/99 and 1999/200 seasons using the lentil variety Giza 51. The objective of this study was to determine the optimum plot size and shape. In analysis using Smith's method, the soil heterogeneity index was 0.7622 and 0.8424 in the first and the second seasons, respectively. The optimum plot size estimated by Smith's method was ranged from 0.9m^2 to 1.5m^2. Results of analyses using the modified maximum curvature technique indicated a plot size range was 2.1-2.4 m^2. While, the results of analyses using the comparable variance (V) and relative information estimate (RI) referred a plot size of 1.5m^2. Plot shape has no significant effect on plot-to-plot variability. Since these methods are based on different criteria, it is expected that the estimates of plot size may not agree with each other. Thus we recommend that the optimum plot size in lentil (net harvested plot area) should be 0.09m^2 with increasing number of replications.

INTRODUCTION

One of the problems facing the researchers working on lentil when conducting their field experiments is the optimum plot size and number of plots required for obtaining high precision. Several factors should be taken in consideration, such as the crop under study, the cost involved, soil variability and difference to be detected. Previous experience has shown that it is almost impossible to get an experimental site that is totally homogenous (Ali, 1983; Modjeska and Rawlings, 1983). Therefore, studying soil heterogeneity is important to determine its level before conducting field experiments, because soil variability affects the optimum plot sizes (Abd El-Halim and Hanna, 1980; Mohamed, 1993). In addition, in field research technique, number and size of replications, care and handling of individual plot samples as well as size and shape of plots are factors that influence the magnitude of experimental errors (Meier and Lessman, 1971). The common procedure used by researchers to measure soil heterogeneity is the uniformity trials, which was developed by Smith (1938). This technique has been used also to determine optimum plot size and shape by several authors (Khalil *et al.*, 1973; Abd El-Halim *et al.*, 1989; Tageldin, 1989; El-Rayes *et al.*, 1993; Nasr, 1997).

Since little information is available on minimizing experimental error in lentil, the present uniformity trial was conducted to measure soil heterogeneity, and to determine the optimum plot size and shape in two lentil varieties.

MATERIALS AND METHODS

Two lentil uniformity trials were conducted at Sids research station, Beni-Suef governorate in 1998/99 and 1999/2000 winter seasons using the variety Giza 51. Sowing was done in November in both seasons, with 6 strips/trial and 120 rows/strip (total basic units = 720 plots/trial). The area of basic unit was 0.9 m^2, consisting of one row, 0.3 m wide and 3 m long. At harvest the central one m/row was collected and the remaining 2 m/row was discarded to avoid border effect, thus the final basic unit area was 0.3 m^2. Plants from each basic unit were bagged, threshed by hand, and cleaned seeds weighed.

Seed yield (g/plot) was separately analyzed for each trial. Variance per basic units, average seed yield (g), and the coefficient of variability was computed for 45-plot size and shape (Table 1). The degrees of freedom were used as weights for their respective combination variance. The following two methods were used to determine the optimum plot size:

1. The weighted index (b) of soil heterogeneity index (Federer, 1955) was calculated. Weighted regression analysis was used to calculate the regression coefficient. Ignoring cost factor, the optimum plot size (x opt.) was determined using the following equation: X opt. = b/ (1-b).
2. Linear regression of log CV on log X was determined. Then the point of maximum curvature (X_0) for the exponential curve, CV = A X^B was determined according to Meier and Lessman (1971) as follows:

$$X_o = [\, A^2B^2\,(2B + 1)\,/\,(B + 2)]^{\,1/(2B + 2)}$$

This equation was converted to a logarithmic form, then A and B were derived from the linear equation (Galal and Abou El-Fittouh, 1971). The plot size immediately beyond this point was considered optimum.

To study the effect of plot shape, two-tail 'F' test was used by dividing the largest variance values in each combination by the smallest variance within the same size, to obtain the calculated 'F' values at the corresponding degree of freedom for each combination.

RESULTS AND DISCUSSION

The variance per basic units (V_x) and among plots ($V_{(x)}$) and their corresponding coefficient of variability (CV%) for 45 combinations of plot sizes and shapes are presented in Tables (1 and 2) for 1998/99 and 1999/2000, respectively. The data in the first season (Table 1) show that (CV%) values ranged from 48.258% for a plot size of one basic unit ($0.3m^2$) to 8.785% for 180 basic unit (54 m^2). Similar trend was observed in the second season, where (CV%) values decreased with increasing of plot size. The data show also that increasing plot size increased the variance among plots, while it decreased the variance per basic unit. However, the reduction of (V_x) values is not proportion with the increase in plot size, and as the plot becomes larger, the reduction rate decreases. This relationship is similar to that reported previously (Meier and Lessman, 1971; Abd El-Halim *et al.*, 1989; Nasr, 1997).

The equation describes the relationship between CV% and plot size has the following general form: $CV = A\,X^B$. The values of A and B were estimated and the equations were defined as:

$CV = 42.599\, X^{0.3405}$ (in 1998/99).

$CV = 55.346\, X^{0.4531}$ (in 1999/200).

Where X is the plot size.

Soil heterogeneity index:

The soil heterogeneity index (b) was estimated in each season according to Smith (1938). The (b) values were 0.7622 and 0.8424 in the first and the second seasons, respectively. Smith mentioned that (b) value should range from 0, indicating completely soil uniformity to 1, indicating random soil variability or independent plot variability across. The high estimates of (b) in the present study reflecting low level of soil uniformity at this experimental site. Therefore, large variability among plots would be expected as shown in Tables (1 and 2). The obtained estimates of (b) were close to each other, referred similar level of heterogeneity in the experimental sites in both seasons, however, different estimates of (b) between seasons was obtained by El-Gamal *et al.* (1990) in cotton.

Estimation of the optimum plot size:

1. Smith's method:

The values of (b) were used to calculate the optimum plot size, which found to be 3.21 and 5.34 basic units in the two seasons, respectively. Thus the optimum plot size is 0.9 m^2 in the first season and 1.5 m^2 in the second season.

2. Maximum curvature method:

The data of the average variance per basic unit and the estimated (CV%) values were used in this method. The values of (CV%) were used as indicator to optimum plot size, and it graphed on the (Y) axis in relation to various plot sizes on the (X) axis (Figure, 1). The optimum plot size was considered to the point on the curve, where the rate of changes for (Y) estimates per increment of (X) is greatest, so it called the point of maximum curvature (X_0). In Figure (1) the values of (X0) were 7 and 8 basic units in both seasons, respectively. Hence the optimum plot size is considered 7 plots (2.1 m^2) in the first season and 8 plots (2.4 m^2) in the second season.

Determination of the optimum plot shape:

The variance ratio (F) for the 33 combinations of plot shapes of the different 14 plot sizes were calculated to determine the effect of plot shape (Table 3). The results indicated that the variances of various plot shapes did not differ significantly in all cases in both seasons and hence it has no effect. Insignificant effect of plot shape was also reported by several researchers (Galal and Abou El-Fittoh, 1971; El-Gamal *et al.*, 1990).

Regarding the two methods used to calculate the optimum plot size, it could be concluded that since these methods are based on different criteria, it is expected that the estimates of plot size may not agree with each other. However, they should provide a range of optimum values that permit flexibility and convenience to the researchers in choosing the size which enable them to detect differences of specified magnitudes between treatment means provided that the number of treatments and the experimental design are known. In addition, estimates of optimum plot size could be affected by several factors such as calculated method, species/variety, location, agricultural practices, size of the basic unit used and the statistical procedures applied. Different estimates of plot size due to the various methods application were also reported by several researchers. For example, El-Kalla *et al.* (1981) found that 5.4 m^2 was the optimum plot size in onion when Smith's method applied, while when maximum curvature method was used, the optimum plot size found to be 7.2 m^2.

In this regard, optimum plot size, in general, should be reached on the basis of both practicability and statistical efficiency. Practically, experimental plot should be sufficiently large to include representative sample of the crop population and allows the elimination of border effects. Plot size should be also sufficient to minimize the effects of slight discrepancies in soil, stand and handling of the experimental materials. The obtained data indicated that the optimum plot size in lentil ranged from 0.9 m^2 to 2.4 m^2 with an average of 1.75 m^2. With the high value of soil heterogeneity, it is recommended to increase the number of replications over the plot size. Therefore, using a plot size of 0.9 m^2 and increasing the number of replications would be the best approach to increase precision of the experiment.

Table 1. Variance and coefficient of variability of different plot sizes and shapes for 45 combinations from 720 basic units of lentil (variety Giza 51) in 1998/99 season.

Serial no.	Plot size and shape No.of basic units			Total no. of plots	Variance		Coefficient of variability CV%
	Size	rows	strip		Per basic unit V_x	Among plots $V_{(x)}$	
1	1	1	1	720	15.885	15.885	48.258
2	2	1	2	360	8.040	32.161	34.332
3	2	2	1	360	9.032	36.127	36.388
4	3	1	3	240	5.763	51.863	29.066
5	3	3	1	240	6.593	59.338	31.090
6	4	2	2	180	4.058	64.930	24.391
7	4	1	4	180	5.331	85.301	27.957
8	5	5	1	144	4.848	121.196	26.659
9	6	2	3	120	2.845	102.415	20.422
10	6	3	2	120	3.164	113.916	21.538
11	6	6	1	120	4.014	144.487	24.257
12	8	4	2	90	2.453	156.987	18.963
13	8	8	1	90	3.789	242.471	23.567
14	9	3	3	80	2.143	173.618	17.727
15	10	5	2	72	2.267	226.712	18.231
16	10	10	1	72	3.230	323.031	21.762
17	12	4	3	60	1.647	237.228	15.541
18	12	6	2	60	1.812	260.867	16.297
19	12	12	1	60	3.194	459.947	21.639
20	15	5	3	48	1.717	386.400	15.867
21	15	15	1	48	2.147	483.146	17.743
22	16	8	2	45	1.867	477.821	16.542
23	18	6	3	40	1.148	371.941	12.973
24	20	10	2	36	1.374	549.414	14.190
25	20	20	1	36	2.160	863.904	17.794
26	24	8	3	30	1.220	702.526	13.372
27	24	12	2	30	1.454	837.457	14.600
28	24	24	1	30	2.011	1158.478	17.171
29	30	10	3	24	0.874	786.603	11.320
30	30	15	2	24	0.756	680.468	10.528
31	30	30	1	24	1.685	1516.641	15.718
32	36	12	3	20	0.972	1259.632	11.937
33	40	20	2	18	1.033	1652.868	12.306
34	40	40	1	18	1.633	2613.206	15.474
35	45	15	3	16	0.682	1381.067	9.999
36	48	24	2	15	0.821	1891.107	10.970
37	60	20	3	12	0.695	255.955	10.092
38	60	30	2	12	0.626	2253.659	9.580
39	60	60	1	12	1.517	5460.182	14.912
40	72	24	3	10	0.625	3240.500	9.573
41	80	40	2	9	0.562	3593.750	9.073
42	90	30	3	8	0.483	3914.714	8.417
43	120	40	3	6	0.476	6847.100	8.349
44	120	60	2	6	0.558	8031.400	9.042
45	180	60	3	4	0.526	17055.33	8.785

Table 2. Variance and coefficient of variability of different plot sizes and shapes for 45 combinations from 720 basic units of lentil (variety Giza 51) in 1999-2000 season.

Serial no.	Plot size and shape No.of basic units			Total no. of plots	Variance		Coefficient of variability CV%
	Size	rows	strip		Per basic unit V_x	Among plots $V_{(x)}$	
1	1	1	1	720	9.313	9.313	52.003
2	2	1	2	360	4.546	18.185	36.335
3	2	2	1	360	5.370	21.479	39.488
4	3	1	3	240	3.210	28.887	30.530
5	3	3	1	240	3.856	34.703	33.463
6	4	2	2	180	2.515	40.235	27.023
7	4	4	1	180	3.249	51.990	30.718
8	5	5	1	144	2.568	64.192	27.306
9	6	2	3	120	1.750	62.998	22.543
10	6	3	2	120	1.682	60.537	22.098
11	6	6	1	120	2.472	88.982	26.791
12	8	4	2	90	1.397	89.436	20.145
13	8	8	1	90	2.078	132.968	24.563
14	9	3	3	80	1.249	101.131	19.041
15	10	5	2	72	1.044	104.437	17.415
16	10	10	1	72	1.787	178.723	22.782
17	12	4	3	60	1.048	150.940	17.447
18	12	6	2	60	0.872	125.516	15.910
19	12	12	1	60	1.571	226.241	12.630
20	15	5	3	48	0.938	211.003	16.502
21	15	15	1	48	1.281	288.184	19.289
22	16	8	2	45	0.794	203.133	15.180
23	18	6	3	40	0.587	190.088	13.053
24	20	10	2	36	0.706	282.468	14.320
25	20	20	1	36	1.263	505.271	19.153
26	24	8	3	30	0.539	310.213	12.506
27	24	12	2	30	0.474	273.218	11.737
28	24	24	1	30	1.096	631.476	17.842
29	30	10	3	24	0.586	527.639	13.048
30	30	15	2	24	0.366	329.617	10.313
31	30	30	1	24	1.010	908.793	17.124
32	36	12	3	20	0.289	374.523	9.161
33	40	20	2	18	0.337	538.912	9.890
34	40	40	1	18	0.917	1466.643	16.315
35	45	15	3	16	0.258	522.125	8.653
36	48	24	2	15	0.277	638.197	8.969
37	60	20	3	12	0.263	946.216	8.737
38	60	30	2	12	0.213	765.307	7.857
39	60	60	1	12	0.683	2457.830	14.081
40	72	24	3	10	0.151	780.056	6.610
41	80	40	2	9	0.169	1083.594	7.012
42	90	30	3	8	0.124	1002.250	5.994
43	120	40	3	6	0.138	1979.900	6.319
44	120	60	2	6	0.088	1272.500	5.066
45	180	60	3	4	0.069	2230.500	4.471

Table 3. Variance per basic units (Vx) for various plot shapes and estimated 'F' values for the lentil variety Giza 51 in 1998/99 and 1999/2000 seasons.

Basic unit	No. of rows	No. of columns	df	1998/99		1999/2000	
				V_x	F value	V_x	F value
2	1	2	360	8.040	1.12	4.546	1.18
2	2	1	360	9.032		5.370	
3	1	3	240	5.763	1.14	3.210	1.20
3	3	1	240	6.593		3.856	
4	2	2	180	4.058	1.31	2.515	1.29
4	4	1	180	5.331		3.249	
6	2	3	120	2.845	1.41	1.750	1.41
6	3	2	120	3.164	1.27	1.682	1.47
6	6	1	120	4.014		2.472	
8	4	2	90	2.453	1.54	1.397	1.49
8	8	1	90	3.789		2.078	
10	5	2	72	2.267	1.42	1.044	1.71
10	10	1	72	3.230		1.787	
12	4	3	60	1.647	1.94	1.048	1.50
12	6	2	60	1.812	1.76	0.872	1.80
12	12	1	60	3.194		1.571	
15	5	3	48	1.717	1.25	0.938	1.37
15	15	1	48	2.147		1.281	
20	10	2	36	1.374	1.57	0.706	1.79
20	20	1	36	2.160		1.263	
24	8	3	30	1.220	1.65	0.539	2.03
24	12	2	30	1.454	1.38	0.474	2.31
24	24	1	30	2.011		1.096	
30	10	3	24	0.874	1.93	0.586	1.72
30	15	2	24	0.756	2.23	0.366	2.76
30	30	1	24	1.685		1.010	
40	20	2	18	1.033	1.58	0.337	2.72
40	40	1	18	1.633		0.917	
60	20	3	12	0.695	2.18	0.263	2.60
60	30	2	12	0.626	2.42	0.213	3.21
60	60	1	12	1.517		0.683	
120	40	3	6	0.476	1.17	0.138	1.57
120	60	2	6	0.558		0.088	

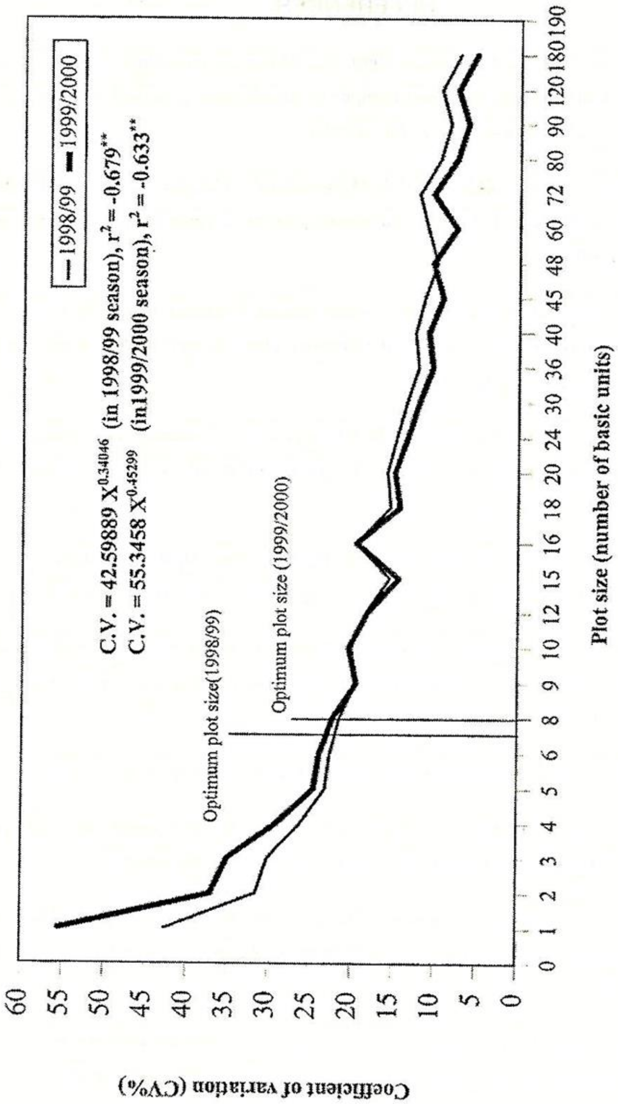

Fig. 1. Relation between plot size and coefficient of variation for Giza 51 in 1998/99 and 1999/2000 seasons.

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تقدير أنسب مساحة وشكل للقطعة التجريبية فى تجارب محصول العدس

أحمد حمدى إسماعيل حمدى[1]، السيد محمد حسن شكر[2]، سيدهم أسعد سيدهم[2]، سلوى عبد العزيز عبد الرحيم حسانين[1]

١ معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – الجيزة – جمهورية مصر العربية.
٢ كلية الزراعة بمشتهر – جامعة الزقازيق (فرع بنها) – جمهورية مصر العربية.

أجرى هذا البحث على صنف العدس جيزة ٥١ لدراسة أنسب مساحة وشكل للقطعة التجريبية لمحصول العدس، وقد أقيمت تجربتى تجانس فى محطة البحوث الزراعية بسدس خلال موسمى ١٩٩٨/٩٩ و ١٩٩٩/٢٠٠٠، وقد إحتوت كل تجربة على ٧٢٠ قطعة تجريبية أساسية مساحة كل منها ٠,٣ م^2.

وقد أظهرت النتائج أن معامل تجانس التربة كان كبيراً فى الموسمين وبلغ ٠,٧٦٢٢ و ٠,٨٤٢٤ مما يدل على إنخفاض تجانس التربة المقامة بها التجربتين، وقد تراوحت أنسب مساحة للقطعة التجريبية المقدرة بطريقة سميث من ٠,٩ م^2 الى ١,٥ م^2، بينما تراوحت هذه المساحة من ٢,١ الى ٢,٤ م^2 عند تقديرها بطريقة أقصى إنحناء، ولم يكن لشكل القطعة التجريبية تأثيراً معنوياً على التباين بين القطع التجريبية وتعزى الإختلافات فى مساحة القطعة التجريبية بين الطريقتين الى إختلاف طريقة التقدير فى كل طريقة، وبناءً على ذلك فان أنسب مساحة صافية (بعد إستبعاد الجوانب) للقطعة التجريبية فى العدس هو ٠,٩ م^2 مع زيادة عدد المكررات.