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DETERMINATION OF OPTIMUM PLOT SIZE AND NO. OF REPLICATIONS UNDER FERTILIZATION CONDITIONS IN ONION

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ABSTRACT

Two field experiments were carried out at the Agricultural Experimental Station of Benha, Kalyobia Governorate, during two successive seasons (2003/2004 and 2004/2005). The aim of this investigation was to determine optimum plot size and number of replications in fertilization experiments for onion yield trials. The experiment included 16 treatments which were the combinations of two bio-fertilizer levels (with bio-fertilizer and without bio-fertilizer) and eight treatments of mineral and organic fertilization (control, N+P+K, ½ N+P+K quantities , ¼ N+P+K quantities, chicken manure, cattle manure, chicken + cattle manure and compost). A split- plot design with three replications were used. Sub plot units were 8 m^2. The total onion yield data were recorded for each plot (kg/plot). Data were used to estimate the convenient plot size, and the suitable number of replications using Smith's and maximum curvature methods.

Statistical analysis revealed the following results:

1- The index of soil heterogeneity (b) was -0.652 and - 0.534 for the two seasons of experimental, respectively, with an average of -0.593 which reflected intermediate variability in the soil.

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

3- The rate of reduction in variance per basic unit and coefficient of variability (C.V.) decreased as the plot size become larger.

4- The relationship between coefficient of variability (c.v.) and plot size (x) were mathematically expressed by the following equations:

C.V. = $23.578\ x^{-0.625}$ for the first season.

C.V. = $20.635\ x^{-0.761}$ for the second season.

5- The optimum plot size, using Smith procedure, was 14. 968 m^2 and 9.168 m^2 in the first and second seasons, respectively while it in the first and second seasons, respectively using maximum curvature technique was23.549m^2 and 19.308m^2.

6- The results indicated that increasing either number of replications or number of basic units reduced the magnitude of variability between plots. The reduction of difference with increasing number of basic units were less than that obtained by equivalent increase in number of replications.

INTRODUCTION

Onion (*Allium cepa L.*) is one of the most important vegetative crops for local consumption and exportation in Egypt. Egyptian onion is famous for its high grade and keeping quality characteristics. Recently, agronomists try to stop or decreasing the amounts of mineral fertilizers and preferring bio and organic fertilizers in order to reduce the environmental pollution and increasing the productivity of onion yield.

Uniformity trails have been used for many purposes, such as to determine optimum plot size and shape, replicate number, soil heterogeneity, relative efficiency of experimental design and to adjust yields of subsequent experiments. Fertilization trails are affected by systematic variation, which is directly related to the position and size of the plot depending mainly on soil fertility gradients. Therefore, the magnitude of experimental error can be reduced by using optimum plot size, shape and number of replications in the experimental design. In the current investigation data from replicated field experiments had been used to measure the Smith's index of soil heterogeneity. The most suitable experiments for this procedure are those involving designs with several plot sizes, such as factorial designs with split-plot.

Smith (1938) used linear relationship between the logarithm of the variance among plots and plot size without cost function to estimate optimum plot size.

Chica and Rodriquez (1967), on onion studies, reported that plot size measuring 6 meters long by 3.72 meters wide (equals six rows) was found to provide the best combination of a low coefficient of variability.

Gupta and Raghavarao (1971), in their study on the weight of onion bulbs, found that the coefficient of variability ranged from 8.39 % to 35 %. The optimum plot size was 75 cm. across rows and 450cm along the rows, with 15 cm. between rows and 15 cm. between plants.

El-Kalla *et al.* (1981) conducted two uniformity trials, they found that the index of soil variability (b) averaged 0.2150, the recommended plot size (including two border rows) was 7.2 m2 for onion trails. Therefore the number of replicated required for detecting 15 % and 20 % difference of the mean would be 13 and 7 replicates, in onion. Ramachander and Pathak (1989) on onion trails showed that the optimum plot size was 48 plants / plot with 3 replications.

Barakat (2002) in onion fertilization experiments showed that, the optimum plot size using Smith's method was (20 m2). According to the Modified Maximum Curvature procedure; the optimum plot size was (40 m2). Where the amount of land is not limited, the use of large plots (4x8=32m2), replicates 4 to 6 and would be satisfactory to obtain reasonable accuracy. In cases where only small amount of land is available smaller plots (2x4=8m2) with more replications at least ten replications should be used to give the same accuracy.

In Egypt few studies covered this research topic for various field crops especially onion. The present investigation aimed to study the effect of plot size and number of replications on the experimental error to obtain the best optimum plot size and suitable number of replications for onion field trails under different fertilization conditions.

MATERIALS AND METHODS

1- Lay out of the experiment :

The present investigation was carried out at Kalyobia Governorate, during the two successive seasons (2003/2004 and 2004/ 2005). The local onion variety Giza 20 was used. The experimental design used was spilt-plot design with three replications. Bio fertilizers treatments were, with bio-fertilizer and without bio- fertilizer and they assigned in the main plots. The organic manures and mineral fertilizers were assigned in the sub plots as follows:

1- control

2-N+P+K (Nitrogen at 90 unit N/ fed. as ammonium nitrate, phosphorus at 60 unit P_2O_5 / fed. as calcium superphosphate and potassium at 100 unit K_2O / fed as potassium sulphate).

3-Half of (N+P+K) quantities.

4-Aquarter of (N+P+K) quantities

5-Chicken manure at 15 m^3/fed. (N 1.308, P 0.57 and K 0.93%) 6-Cattle manure (at 20 m^3/ fed)

7-Chicken manure (at 10 m^3 / fed.) + Cattle manure at (10 m^3/ fed.)

8- Compost at 20 m^3/ fed. (N 1.5-1.8, P 0.5-0.75 and k1.25-1.75%).

Three sources of bio fertilizers were used, potassein (2 lit/ 600 lit water / fed), phosphorine (300 mg / fed.) and biogen (500 mg / fed). The bio-fertilizers were (mixed) combined and added to the soil at transplanting.

Onion seeds were sown in the nursery, the transplants were set out in the field after 70-75 days at which the diameter of transplant bulbs ranged between 1.0 and 1.2 cm. Transplanting distances were 10 cm apart on the sides of each ridge. The experimental unit consisted of 4 ridges each of 4 meters long and 50 cm wide. The area of each plot was 8 m^2 (2 x 4 = 8 m^2). The common agricultural practices were carried out as usually recommended in onion fields. The total yield of onion data were recorded for each plot (kg / plot).

2-Statistical analysis procedures:

Soil variability index :

The procedure reported by Gomez and Gomez (1984) was involved using the basic analysis of variance to estimate the variance for plots of different sizes. These estimates were used to derive a relationship between plot variance and plot size. The number of plot variances that can be estimated through this procedure is only as many as the number of plot sizes available in the design used. The steps of the procedure are:

1- The basic formats of the analysis of variance for a split-plot design are shown in Table 1.

2- Compute estimates of the variances associated with the different plot sizes, following the formulas given in Table 1. In this study, the design is a split-plot design. Hence, there are three between-plot variances corresponding to the three plot sizes as follows:

V'_1 = the variance between plots of a block size

V'_2 = the variance between plots of a main plot size

V'_3 = the variance between plots of a sub plot size

Computation of these variances were based on the mean square values in the analysis of variance Table 1.

3- For each variance estimate V_i obtained in step 2, compute the corresponding comparable variance V_i with the size of the smallest plot in the particular experiment as the base:

$$Vi = v'i / X_i$$

Where: x is the size of the iths plot in terms of the smallest plot involved.

4- Apply the appropriate regression technique to estimate the regression coefficient (b). (the index of soil heterogeneity) from the equation.:

$$\log V_i = \log V_3 - b \log X_i$$

Where Vi and Xi are defined in step 3.

Table 1: Basic format of the analysis of variance for split- plot design and formulas for the computation of variances between plot of various sizes

Source of variation	Degree of Freedom	Mean Square	Variance between plots of various sizes
Replication	r-1	M1	V1= M1
Factor A	a-1		
Error (a)	(a-1)(r-1)	M2	$V2 = \frac{r(a-1)M2+(r-1)M1}{ra-1}$
Factor B	b-1		
A x B	(a-1)(b-1)		
Error (b)	a(r-1)(b-1)	M3	$V3 = \frac{ra(b-1)M3 + r(a-1)M2 + (r-1)M1}{rab-1}$
Total	rab-1		

B- Optimum plot size (*X* opt.)

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 following the equation:

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

The exponential relationship between the coefficient of variability (C.V.) and plot size (X), C.V. = A X^{-B}, was transformed into the logarithmic form:

$$(2) \qquad \log C.V. = \log A - B \log X$$

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

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

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

C- 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 onion experiments was estimated for different plot sizes and number of replications. The estimates were calculated according to the formula presented by Hatheway (1961).

$D^2 = 2 (t_1 + t_2)^2 C^2 / R X^b$

Where:

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

t_1 = the significant value of t in the test of significance.

t_2 = the value of t from its table corresponding step 2(1-p).

b = index of soil variability. Where b is the probability of obtaining a significant difference.

C = the coefficient of variation for plots of one basic unit in size.

R = the number of replications.

X = the number of multiples of the basic unit.

RESULTS AND DISCUSSION

The different combinations of plot size were determined as well as the number of basic units across and along for each plot shape in each combination in 2003/2004 and 2004/2005 seasons are shown in Table 2.

Table 3 shows the basic format of the analysis of variance for split plot design. To determine the difference among mean squares between replications and experimental errors.

Table 2: Description of the different combinations of plot size and shape for onion in 2003/2004 and2004/2005 seasons.

Plots various Size	No. of Basic units	Plot shape across x along	Plot dimension width x length	Plot area m2
1- Sub-Plot	1	1x1	2x4	8
2- Main Plot	8	1x8	4x16	64
3-Replication	16	2x8	8x16	128

Table 3: Results for split – plot design and variance between plots of various sizes for 2003 /2004 and 2004 /2005 seasons

Source of Variation	D.F	Mean square 2003/2004	Variance between plots of various sizes	Mean Square 2004/ 2005	Variance between plots of various sizes
Réplication	2	3.532	3.532	1.917	1.917
Biofertilization (A)	1	3.691		16.124	
Error (a)	2	7.266	5.772	4.946	3.734
Manure + Mineral (B)	7	9.342		17.859	
A X B	7	18.461		11.368	
Error (b)	28	3.071	3.358	3.533	3.554
Total	47				

1. Soil variability index :

The weighted index of soil variability "b" as published by Federer (1955) was calculated as -0.652 and -0.534 for 2003/2004 and 2004/2005 seasons, respectively. The results in the two seasons, b values indicated that soil heterogeneity was intermediate in the fields. Smith (1938) stated that this index (b) varies between zero and one. Zero value indicates perfect uniformity among the basic units, on the other hand, when the units are completely independent, the index would equal one.

2. Optimum plot size :

The results shown in Tables 4 indicated that plot variance increased due to increment in plot size, while the relationship between coefficient of variability and their corresponding plot size, was that of a increase in the coefficients of variability with an increase in plot size. These results are in accordance with findings in other field plot technique problems, among them Chica and Rodriquez (1967), Gupta and Raghavarao (1971), El-Kalla *et al.* (1981) and Barakat (2002) on onion. However, this reduction is not in proportion with the increase in the size of plots, the rate of reduction decreases as the plots become larger, this confirms the fact that the relationship between plot size and the coefficient of variability is exponential in nature.

The coefficient of variability decreased rapidly at first in the two seasons and then decreased slowly as plot size increased (Figures 1 , 2). This relationship was similar to that previously reported by all investigators studying the same problem. This was true in the two seasons. Also, the relative rate of reduction was less with larger plots.

Table 4: Variance and coefficient of variability (C.V.) of different plot sizes and shape of combinations from 128 basic units of onion in 2003/2004 and 2004/2005 seasons.

Plots	Plots size (m^2)	No. of plots	Plot variance	Observed C.V.%	Estimated C.V%
2003/2004 season					
1-Sub-plot	8	48	7.063	3.966	4.322
2 –Main plot	64	6	14.535	4.254	5.748
3-Replications	128	3	85.985	6.101	8.317
2004/2005 season					
1- Sub-plot	8	48	3.834	3.078	5.492
2 –Main plot	64	6	9.892	4.176	5.825
3-Replications	128	3	98.733	4.924	7.368

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

1-Smith's method :

The optimum plot size obtained by utilizing Smith's technique ignoring cost factors, were 1.871 and 1.146 basic units in the first and second season, respectively, as shown in Table 5. Consequently, the estimates of the optimum plot size was (1.871 x 8 =14.968 m^2) in the first season and (1.146 x 8 = 9.168m^2) in the second season. These results are in accordance with finding of El-Kalla *et.al.* (1981) and Barakat (2002) in onion. It showed be noted that Smith (1938) pointed out that area half or double the optimum plot size would be 90% as efficient as the optimum plot size, when b = 0.5.

2- Maximum curvature methods :

Applying the maximum curvature method, as modified by Melier and Lessman (1971) and Galal and Abou-El Fittouh (1971), the relationship between plot size and coefficient of variability is illustrated in (Figures 1 and 2). The coefficient of variability decreased rapidly at first in the two seasons and then decreased slowly as plot size increased.

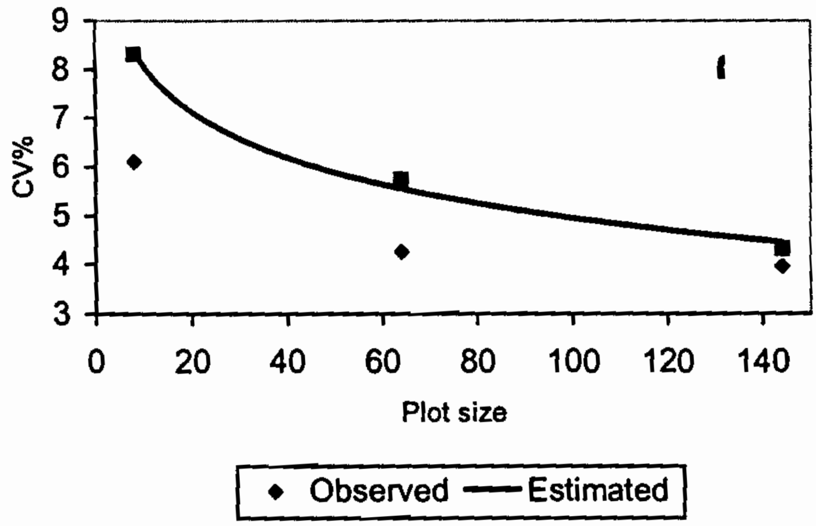

Fig. (1): Relationship between plot size and coefficient of variability (C.V.) for onion in season 2003/2004

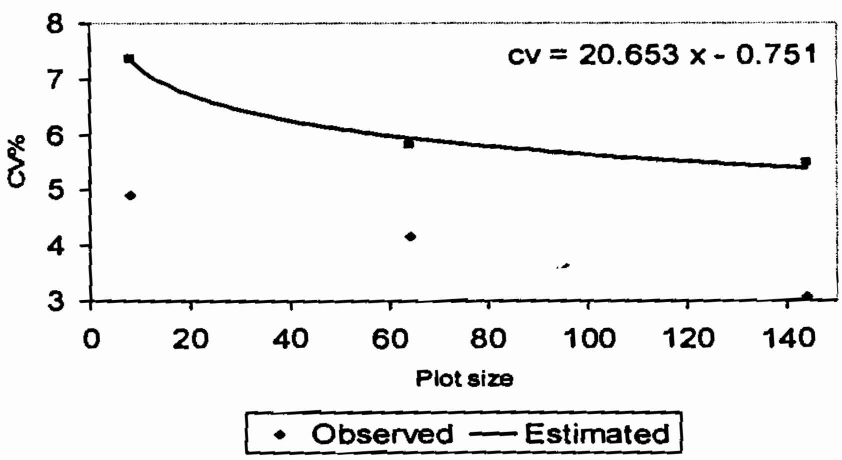

Fig. (2): Relationship between plot size and coefficient of variability (C.V.) for onion in season 2004/2005

The exponential relationships obtained for this investigation described in the two following equations are :

$C.V. = 23.578\ X^{-0.825}$ for the first trial

$C.V. = 20.635\ X^{-0.751}$ for the second trail

Where X is the size of plot in basic units.

The results given in Table 5 indicated that the optimum plot size using the maximum curvature method was 2.945 basic units in the first season and 2.414 basic units in the second season. Consequently, the optimum plot size was 23.549 m^2 (2.954 x 8 = 23.549 m^2) in the first season and 19.308 m^2 (2.414 x 8 = 19.308 m^2) in the second season.

Table 5: Optimum plot size for onion in fertilization experiments as calculated by Smith's and maximum curvature methods.

Season	Optimum plot size								
	Smith's method				Maximum curvature method				
	B	In basic unit	Area/ m^2	Area/ Feddan	A	B	In basic unit	Area/ m^2	Area/ feddan
2003/ 2004	-0.652	1.871	14.968	1/280	23.578	-0.825	2.945	23.549	1/178
2004/ 2005	-0.534	1.146	9.168	1/458	20.653	-0.751	2.414	19.308	1/217
Mean	-0.593	1.509	12.068	1/348	22.116	-0.788	2.679	21.428	1/196

The results of using the two procedures to determine the optimum plot size were :

1- The mean of optimum plot size over all two seasons was 12.068 m2 = 1/348 feddan by using Smith procedure.

2- The mean of optimum plot size over all two seasons was 21.428m^2 = 1/196 faddan by using maximum curvature method. The results of applying the two methods of determining the optimum plot size were different. The maximum curvature method resulted in larger plot sizes than Smith's method for the two seasons. Therefore, it would be better to adopt the larger optimum plot sizes, because the results of fertilization experiments are affected by systematic variation. This variation is directly related to the position of the plot in the field depending mainly on soil fertility gradients. In such cases, the systematic variability is removed by the larger plot size.

3.Detection of significant difference between treatment means:

The results obtained in this study as presented in Table 6, clarify the effect of soil variability on the magnitude of the true differences which can be detected for varying plot sizes and number of replications. These results clearly indicate that increasing plot size and / or number of replications reduced the magnitude of differences detected at a specified probability level. The information indicates that the rate of reduction in the differences is always greater when soil is more variable and when the standard error per plot is large in relation to the mean. Furthermore, it can be noticed from the results that the reduction in the magnitude of differences that could be detected, with increasing plot size was less than that obtained by equivalent increase in number of replications.

The results obtained in this study indicate that the research worker has a considerable range in selecting size and replications of plots, depending on the amount of land under his disposal. Where the amount of land is not limited, the use of large plots (4 x 8 =32 m^2), replicated 4 to 6 times would be satisfactory to obtaine reasonable accuracy. In cases where only small amount of land is available smaller plots (2 x 4 = 8m2) with more replications at least ten replications should be used to give the same accuracy that would result in more efficient use of land.

In general increasing the number of replications reduced the error variance more rapidly than increasing plot size. Similar results were obtained in other field plot technique studies such as : Chica and Rodriques (1967) on onion, Gupta and Raghavaro (1971) on onion, El-Kalla- *et al.* (1981) on onion and tomato, Lobo *et al.* (1984) on tomato, Golaszewski *et al.* (1995) on strawberry and Barakat (2002) on onion.

Table 6: Magnitude of detected differences between treatment mean (% of the mean) for different plots sizes and number of replications (r), for the two seasons.

		Number of replications				
No of basic units		2	4	6	8	10
2003/2004	2	14.44	7.22	4.81	3.61	2.88
	4	9.19	4.59	3.06	2.29	1.83
	6	7.05	3.52	2.35	1.76	1.41
	8	5.84	2.92	1.94	1.46	1.16
2004/2005	2	17.37	8.68	5.79	4.34	3.47
	4	12.00	6.00	4.00	3.00	2.40
	6	9.66	4.83	3.22	2.41	1.93
	8	8.28	4.14	2.76	2.07	1.65

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تقدير أنسب مساحة للقطعة التجريبية و عدد المكررات تحت ظروف التسميد فـــي تجارب البصل

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**** المعمل المركزي لبحوث التصميم و التحليل الإحصائي – مركز البحوث الزراعية –الجيزة.**

أجريت هذه الدراسة في تجربتين حقليتين في محطة بحوث التجارب بمدينة بنها – محافظة القليوبية خلال موسميين متتالين ٢٠٠٣/٢٠٠٤ ، ٢٠٠٤/٢٠٠٥ على محصول البصل صنف جيزة ٢٠. و كان الهدف من البحث هو تقدير انسب مساحة للقطعة التجريبية و كذلك أنسب عدد من المكررات تحت مستويات مختلفة من التسميد الحيوي و العضوي و المعدني على محصول البصل. و قد اشتملت التجربة على ١٦ معاملة و هي مستويان من التسميد الحيوي (تسميد حيوي و بدون تسميد حيوي) ، ٨ معاملات من التسميد المعدني و العضوي (كنترول و N+P+K و ٢/١ كمية N+P+K و ¼ كمية N+P+K و سماد الدواجن العضوي و سماد الماشية العضوي و سماد الدواجن + سماد الماشية و سماد الكمبوست). و أستخدم تصميم القطع المنشقة فى نظام عاملى في ٣ مكررات و كانت مساحة القطعة التجريبية ٨ م^{٢} . و قدرت صفة المحصول الكلي للبصل من كل قطعة تجريبية (كجم/قطعة).

و يمكن تلخيص أهم النتائج المتحصل عليها فيما يلي :

١- كانت قيم دليل عدم تجانس التربة(b) هي -٠,٦٥٢ في الموسم الأول ، -٠,٥٣٤ في الموسم الثاني بمتوسط -٠,٥٩٣ و هذا يدل علي أن درجة تجانس التربة متوسطة.

٢- زيادة مساحة القطعة التجريبية يؤدي إلى انخفاض التباين لوحدة المساحة و كذلك معامل الاختلاف و الا ان معدل الانخفاض لا يتناسب مع معدل زيادة مساحة القطعة التجريبية.

٣- انخفض معدل التناقص لكل من التباين لوحدة المساحة و معامل الاختلاف (c.v.) كلما ذادت مساحة القطعة التجريبية.

٤- أمكن وضع العلاقة بين معامل الاختلاف (خ) و مساحة القطعة التجريبية (س) في صورة رياضية بالمعادلات الآتية:

خ = ٢٣,٥٨٧ س$^{-٠.٨٢٥}$ للموسم الأول
خ = ٢٠,٦٣٥ س$^{-٠.٧٦١}$ للموسم الثاني

٥- أوضحت النتائج أن انسب مساحة للقطعة التجريبية باستخدام طريقة سميث هي ١٤,٩٦٨ م^{٢} للموسم الأول بينما كانت ٩,١٦٨ م^{٢} للموسم الثاني.

٦- أنسب مساحة للقطعة التجريبية باستخدام طريقة أقصي انحناء هي ٢٣,٥٤٩ م^{٢} للموسم الأول و ١٩,٣٠٨ م^{٢} للموسم الثاني.

٧- وجد أن زيادة مساحة القطعة التجريبية أو زيادة عدد المكررات أو كليهما أظهار تقديرات الفرق الحقيقي الممكن اكتشافه في اختبارات المعنوية بين متوسطات المعاملات وبالتالي تحسين كفاءة التجارب نتيجة لزيادة دقة المقارنات بين المعاملات . كما وجد أن زيادة عدد المكررات يكون اكثر فعالية من الزيادة المماثلة في مساحة القطعة التجريبية .