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PLOT SIZE, REPLICATIONS AND DESIGN PRECISION IN MAIZE EXPERIMENTS UNDER DROUGHT CONDITIONS

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ABSTRACT

The main objective of present investigation was to determine the optimum plot size and number of replications, as well as the efficiency of split plot design vs. randomized complete blocks design in maize experiments under drought stress and non-stress conditions. Two field experiments were conducted at Agric. Exp. Sta. of Cairo Univ., Giza in 2002 and 2003 seasons. In both experiments, the split plot design was used where main plots were devoted to irrigation regimes (stress and non-stress) and split plots to maize genotypes (two in experiments I and nine in experimentsII). Results of experiment I showed that the optimum plot size was 10.5 and 12.6m^2 for Giza-2 and 10.5 and 14.7 m^2 for SC-10 under control and water stress, respectively. Optimum number of replications ranged from 4 to 5 under non-stress and 7 to 8 under stress. Results of experiment II indicated that drought stress caused a significant reduction of 41.9% in grain yield, which was accompanied with reductions in all yield components and increases in days to 50% silking and anthesis-silking interval. Significant differences were found among studied genotypes in drought tolerance. The best crosses in grain yield under both stress and non-stress conditions were SC-10 and TWC-324. Results of experiment I and II showed that relative precision of split plot design was higher than that of R.C.B.D. Relative precision was higher for sub plots than for main plots and under non - stress than stress conditions.

Key Words: *Zea mays, Drought tolerance, Plot size, Replications, Design precision, Split plot, R.C.B.D.*

INTRODUCTION

Field experiments conducted on maize (*Zea mays* L.) under different water regimes indicated that yield decrease resulting from soil moisture deficit depends upon numerous factors such as the growth stage at which the moisture deficit develops, the severity and duration of water deficiency, and the susceptibility of the examined genotype. Soil moisture deficit, during flowering stage of maize, severely affects the development of reproductive structures and may ultimately decreases grain yield (Denmead and Shaw 1960 and Lorens *et al* 1987). Variability was detected among maize genotypes in grain yield and yield components under optimal and drought treatments. Grain yield of single crosses was not severely reduced even by the extreme drought stress compared with three way crosses ,and it was concluded that these single crosses are less affected to some extent by water stress (EL-Sheikh 1999).

One of the greatest sources of experimental error in field experiments is that due to soil moisture variability.The different irrigation stress regimes may have different effects on soil heterogeneity with respect to soil moisture content. So, for these reasons, it is very important to study optimum plot size and number of replications suitable for different field soil moisture conditions. EL- Rassas (1982) reported that the optimum number of replications for corn trials is 6 – 8 replicates, with the optimum plot size ranging from 14 to 26 m^2. Ashmawy (2004) reported that long and narrow plot was more efficient as it decreases variance per basic unit and increases the efficiency of experimental designs.

It is very important that the experimenter chooses the appropriate design to control the experimental error and have the best estimate in order to assure the most reliable results and, consequently to increase the efficiency of experiment (Leilh 1985). Considerable interest has been focused on the use of split plot design and such information should help agronomists and plant breeders in planning more efficient experiments to attain desirable high precision. Split plot design was more efficient than randomized complete block design (R.C.B.D.) in evaluating maize yield (El-Bakry 1980, Abd El-Halim *et al* 1989 and Mohammed and Ashmawy 1996).

The objectives of the present investigation were to : 1-determine the optimum plot size and number of replications in maize experiments conducted under drought stress and non-stress conditions. 2- study the differential response of maize genotypes to water deficits ; and, 3- test the efficiency of split plot design relative to randomized complete block design.

MATERIALS AND METHODS

The present investigation was carried out in two experiments at the Agric. Exp. Stat. of Fac. Agric., Cairo University. The date of sowing was May 29^{th} and June 8^{th} in 2002 and 2003 seasons, respectively.The experimental plot consisted of rows of 6 m long and 70 cm wide. Kernels were planted in hills spaced 30 cm on one side of the ridge. The hills were thinned to one plant per hill before the 1^{st} irrigation. Nitrogen fertilization at a rate of 90 kg N/faddan in the form of Urea (46.5% N) was side dressed to plants into two equal doses and directly before the second and the third irrigations. Other agricultural practices (e.g. pesticides) were conducted as commonly adopted in farmer's fields in the district.

The two experiments consisted of two irrigation regimes:1- conventional irrigation treatment, in which the first irrigation was applied 21 days after sowing, then the other six irrigations were applied at a 15 day interval and 2-irrigation stress treatment, by skipping the fourth, fifth and sixth irrigations.

Experiment I

A split plot design with main plots arranged in a R.C.B.D and four replications was used. The two irrigation regimes, i.e. full (conventional) and stress irrigation were devoted to the main plots. The two cultivars, i.e., the synthetic cultivar Giza-2 and the single cross SC-10 were assigned for subplots. Each subplot consisted of 34 rows.

Four uniformity trials were therefore considered: Trial1: evaluating Gz-2 under conventional irrigation,

Trial2: evaluating Gz-2 under stress irrigation,

Trial3: evaluating SC-10 under-conventional irrigation and

Trial4: evaluating SC-10 under stress irrigation. In 2003 season, the same four uniformity trials were carried out.

Experiment II

Experiment II included nine maize genotypes. They were the single crosses SC-10, SC-122, SC-123 and SC-129, the three ways crosses TWC-310, TWC-320, TWC-321 and TWC-324 and the synthetic cultivar Gz-2. This experiment was also sown in a split plot design with the main plots in R.C.B.D. and four replications were used. Water supply treatments occupied the main plots; meanwhile the nine genotypes occupied the subplots.

The characters recorded on all plants for the two experiments were: 1- number of days to 50% silking, 2- anthesis-silking interval (ASI) in days, 3- plant height in cm, 4- number of ears per plant, 5-number of rows per ear, 6- number of kernels per row, 7- weight of 100 kernels in g and 8- grain yield per plant in g (adjusted to 15.5% grain moisture).

Data of each trial in experiment I were analyzed separately to study the effect of plot size (in terms of the number of adjacent basic units grouped to form a larger plot) on the variance per basic unit and number of replications. Each row of 6m long and 70cm wide was considered as a basic unit (4.2 m^2). The different combinations of plot sizes were determined as well as the number of basic units. Data were analyzed on electronic facilities of the Central Laboratory for Designs and Statistical Analysis using a programme modified by Galal and Abou- El-Fittouh (1971), to determine the optimum plot size in field maize yield trials using the estimates: variance per basic unit (v_x), average yield (Y) and coefficient of variability (C.V.) for each of the various selected combinations of plot size. There were 6 combinations ranging in size from 1 to 34 basic units. Two principle methods were used to estimate the optimum plot size: 1- the maximum curvature method of Federer (1955) and 2- comparable variance method suggested by Keller (1949).

The equation proposed by Hayes *et al* (1955) was used to determine the theoretical number of replications necessary to bring down the coefficient of variation to 5% of the mean. Analysis of variance was used in this study to estimate standard errors for five different plot sizes and a wide range of replications from 2 to 10 to reach this status. A combined analysis of variance was computed across two seasons (2002 and 2003) after testing the homogeneity of variance according to Cochran and Cox (1957). All above mentioned statistical analyses were adopted after Snedecor and Cochran (1980).

Data of experiment I and experiment II were analyzed to estimate the precision of split plot design relative to randomized complete blocks design (R.C.B.D.). The precision of an experiment is affected by the number of degrees of freedom available for estimating experimental error.Precision estimates of split plot design relative to R.C.B.D was proceeded according to Cochran and Cox (1957). In both experiment I and experiment II, the regular analysis of variance of split plot design was preceded according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

I : Plot size and number of replications

This experiment included two genotypes (Gz-2 and SC-10) and two irrigation treatments. The results will be presented and discussed under two groups; the first includes Gz-2 and the second SC-10

1- Optimum plot size

Giza- 2 trials

Data presented in Table (1) showed that grain yield/plot for Giza-2 was reduced from 1.41 and 1.60 kg under control to 1.29 and 1.11 kg under water stress when plot size was one basic unit and from 68.96 and 54.25 kg under control to 43.93 and 37.65 kg under drought when plot size was 34 basic units in 2002 and 2003, respectively.

The results in Table (1) showed that coefficient of variability (C.V. %) values decreased as the plot size increased from the smallest to the largest plot size. The data of Gz-2 revealed that the observed C.V. estimates decreased under control from 16.64% to 2.57% in 2002 and from 20.37% to 10.97% in 2003 season. Meanwhile under stress, it decreased from 27.07% to 9.31% and from 35.83% to 19.01% in 2003 season. The same trend was shown by the estimated C.V. values for Giza-2 under both irrigation treatments. Results in Table (2) show that variance per basic unit area (V_x) for Giza-2 generally decreased with the increase in plot size either under control or stress conditions. V_x estimate under control in 2002 and 2003 seasons decreased from 0.091 to 0.002 and from 0.107 to 0.031, from the

Table 1. Mean yield in Kg per plot ($\overline{Y}$) and coefficient of variability (C.V.) (observed; Ob. and estimated; Est. values) for Gz-2 and SC-10.

Plot size in basic units	2002			2003		
	$\overline{Y}$	C.V. (Ob.)	C.V. (Est.)	$\overline{Y}$	C.V. (Ob.)	C.V. (Est.)
Gz-2 under Control						
1	1.41	16.64	17.03	1.60	20.37	17.36
2	3.45	12.70	12.79	2.58	15.72	16.18
4	7.80	8.47	9.62	5.17	11.89	15.07
17	27.89	9.77	5.29	21.97	16.86	13.00
34	68.96	2.57	3.98	43.93	10.97	12.11
SC.10 under Control						
1	2.05	11.01	11.47	1.88	9.56	10.06
2	4.09	8.28	8.26	2.89	6.92	6.86
4	8.19	6.28	5.95	5.78	4.99	4.68
17	34.79	3.06	3.00	24.57	2.12	2.11
34	69.59	2.08	2.17	49.15	1.39	1.44
Gz-2 under Stress						
1	1.29	27.07	24.90	1.11	35.83	34.62
2	2.58	20.93	21.28	2.21	30.13	30.25
4	5.17	15.41	18.18	4.43	26.08	26.43
17	21.97	18.05	13.08	18.82	18.05	19.95
34	43.93	9.31	11.18	37.65	19.01	17.43
SC-10 under Stress						
1	1.45	28.79	25.25	1.22	31.72	36.21
2	2.89	22.19	22.59	2.45	23.39	23.54
4	5.78	16.34	20.23	4.90	15.86	15.31
17	24.57	21.55	16.05	20.82	12.54	6.23
34	49.15	12.51	14.37	41.46	2.29	4.05

smallest plot size (one basic unit) to the largest one (34 basic units), respectively.

Under stress in 2002 and 2003 seasons, V_x decreased from 0.122 to 0.015 and from 0.157 to 0.044 when plot size increased from one to 34 basic units, respectively. On the other hand, increasing plot size increased variance among plots. It reached its maximum by increasing plot size from one basic unit to 34 basic units for control in 2003 and stress in 2002 and 2003 seasons, and to 17 basic units for control at 2002 season.

According to the maximum curvature method, the coefficient of variability was used as an indicator to the optimum plot size and it is graphed on the Y axis in relation to various plot sizes on the X axis (Figs 1,2,3, and 4). The optimum plot size was considered to be the point on the curve, where the rate of change for Y estimate per increment of X is greatest, so called "The region of Maximum Curvature". For Gz-2 experiments the point of maximum curvature was 15.117 m^2 and 5.486 m^2 for 2002 and 2003 under control treatment, respectively. Therefore the optimum plot size under control was 10.3 m^2 as the average of two seasons (the optimum plot size for control was 4 and 2 basic units, respectively and therefore the optimum plot size was 3 basic units.

Table 2. Variance per basic unit V_x and variance among plots $V_{(x)}$ for different plot sizes of Gz-2 and SC-10 under control and stress irrigation treatments in 2002 and 2003 seasons.

Plot size and shape			Total No.	Variance per basic Unit Vx				Variance among plots V(x)			
Size	Rows	strips	plots	Gz.-2		SC-10		Gz.-2		SC-10	
				2002	2003	2002	2003	2002	2003	2002	2003
				Control							
1	1	1	136	0.091	0.107	0.051	0.032	0.091	0.107	0.051	0.032
2	1	2	68	0.043	0.045	0.027	0.018	0.171	0.179	[illegible]	[illegible]
2	2	1	68	0.065	0.086	0.031	0.017	0.258	0.343	0.124	[illegible]
4	2	2	34	0.024	0.036	0.017	0.009	0.378	0.582	0.265	0.141
17	17	1	8	0.031	0.073	0.004	0.002	9.078	21.12	1.145	[illegible]
34	17	2	4	0.002	0.031	0.002	0.001	2.546	35.76	2.085	[illegible]
				Stress							
1	1	1	136	0.122	0.157	0.173	0.151	0.122	0.1574	0.1732	0.151
2	1	2	68	0.052	0.106	0.067	0.061	0.208	0.4230	[illegible]	0.342
2	2	1	68	0.098	0.117	0.147	0.107	0.392	0.4683	[illegible]	[illegible]
4	2	2	34	0.039	0.083	0.056	0.038	0.634	1.3348	[illegible]	[illegible]
17	17	1	8	0.054	0.040	0.097	0.024	15.73	11.5478	[illegible]	6.806
34	17	2	4	0.015	0.044	0.033	0.001	16.74	51.2194	37.8223	0.921

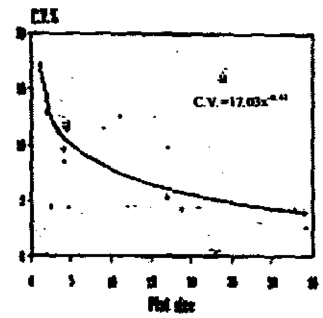

Fig. 1. Relationship between plot size and coefficient of variability for Giza-2 under control in 2002 season.

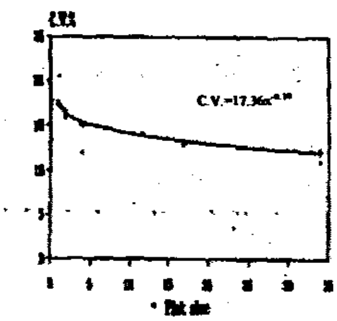

Fig. 2. Relationship between plot size and coefficient of variability for Giza-2 under control in 2003 season.

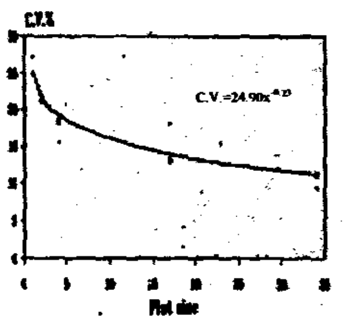

Fig. 3. Relationship between plot size and coefficient of variability for Giza-2 under stress in 2002 season.

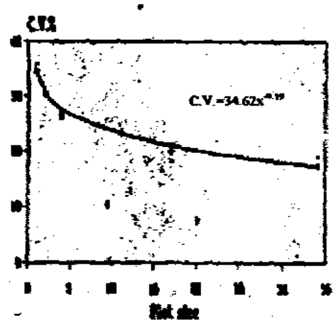

Fig. 4. Relationship between plot size and coefficient of variability for Giza-2 under stress in 2003 season.

Meanwhile optimum plot size for 2002 and 2003 under stress treatment was 14.494 m^2 and 17.131 m^2, respectively (the optimum plot size was 15.8 m^2 for the average of two seasons). Therefore the optimum plot size under stress irrigation was 4 basic units for two seasons.

The variance among plots V(x) was computed for each experiment for each type of plot combination then divided by the number of basic units per plot (x) so that the variance would be comparable with that of the individual basic unit plot. Comparable variance (v) of each plot size was compared with that of basic unit as percent relative information (R.I.). The variance of basic units was assumed to contribute 100% relative information (R.I.) (Table 3).

As plot size increased, relative information decreased, while comparable variance of yield increased. For example, the values of comparable variance increased from 0.107 to 1.05 for control treatment in 2003 season and from 0.157 to 1.511 for drought stress as plot size increased from one to 34 basic units, respectively.

Since the comparable variance and relative information permit similar interpretation of the analysis of the data, only the latter will be considered. The data in Table (3) indicate mean decrease in relative information percentage on an individual unit difference, it is less noticeable as plot size increases more than 2 basic units for control and stress treatments for 2002 and 2003 seasons, the data further suggested that the relative information changed with a relatively small amount after this point. Abnormal values of relative information may be due to the heterogeneity of soil, i.e., the large value of estimated soil heterogeneity index (b).Therefore the recommended plot size by using maximum curvature method together with comparable variance method for Giza-2 cultivar ranged from 2 to 3 basic units (8.4 to12.6 m^2 with an average of 10.5 m^2) for recommended irrigation treatment and from 2 to 4 basic units (8.4 to 16.8 m^2 with an average of 12.6 m^2) for stressed irrigation treatment.

Table 3. Comparable variance (v) and relative information percentages (R.I.) of various plot sizes in basic units for Gz-2 and SC-10 in 2002 and 2003 seasons under control and stress irrigation treatments.

Plot size in basic units	Gz- 2				SC-10			
	2002		2003		2002		2003	
	V	R.I. (%)	V	R.I.(%)	V	R. I.(%)	V	R.I.(%)
				Control				
1	0.091	100.0	0.107	100.0	0.051	100.0	0.032	100.0
2(1x2)	0.086	105.8	0.089	120.2	0.053	95.9	0.035	92.6
2(2x1)	0.129	70.5	0.089	62.2	0.062	81.9	0.033	98.5
4	0.095	95.8	0.127	73.3	0.066	77.3	0.035	91.4
17	0.354	17.1	1.240	8.6	0.067	76.1	0.027	118.5
34	0.074	122.9	1.050	10.2	0.062	82.3	0.024	133.3
				Stress				
1	0.122	100.0	0.157	100.0	0.1732	100.0	0.151	100.0
2(1x2)	0.104	117.3	0.212	74.4	0.134	129.2	0.121	124.7
2(2x1)	0.196	62.2	0.234	67.2	0.293	59.2	0.214	70.58
4	0.159	76.7	0.334	47.0	0.223	77.6	0.151	100.00
17	0.925	13.2	0.679	1.4	1.649	10.5	0.401	37.66
34	0.492	24.8	1.511	10.4	1.112	15.6	0.027	5.59

Single Cross SC- 10 trials

Data presented in Table (1) indicated that for SC-10 grain yield was decreased due to water stress from 2.05 and 1.88 kg/plot under control to 1.45 and 1.22 kg/plot under water stress when plot size was one basic unit and from 69.59 and 64.03 kg/plot under control to 49.15 and 41.64 kg/plot under water stress when plot size was 34 basic units in 2002 and 2003 seasons, respectively. Values of observed C.V. of SC-10 decreased from 11.01% to 2.08% and from 9.56% to 1.39% in 2003 under control treatment (Table1). Meanwhile, the observed C.V. for SC-10 under stress treatment decreased from 28.79% to 12.51% and from 31.72% to 2.29% in 2002 and 2003 seasons, respectively.

Table (2), showed that variance per basic unit area (v_x) for SC-10 under control in 2002 and 2003 seasons decreased from 0.0508 to 0.0018 and from 0.0324 to 0.0007 when unit increased from one basic unit to 34 basic units plot size, respectively. Under stress in 2002 and 2003 seasons V_x decreased from 0.1732 to 0.0327 and from 0.1509 to 0.0008, from one to 34 basic units plot size, respectively. On the other hand, variance among plots ($V_{(x)}$) reached its maximum by increasing plot size from one basic unit to 34 basic units under control in 2002 and 2003 seasons and under stress in 2002 season and to 17 basic units under stress in 2003 season.

The equations defined for 2002 and 2003 for SC-10 under control and stress are illustrated in Figs (5 through 8). For SC-10 the point of maximum curvature was 12.195 m^2 and 11.902 m^2 for 2002 and 2003 seasons under control treatment, respectively (the optimum plot size for control treatment was 12.05 m^2 as an average of two seasons), the optimum plot size was 3 basic units for the control treatments of 2002 and 2003 seasons.

Under water stress experiments, the point of maximum curvature for SC-10 was 11.313m^2 and 27.312m^2 for 2002 and 2003 seasons, respectively. Therefore, the optimum plot size as an average of two seasons was 19.31 m^2 and thus the optimum plot size was 3 and 7 basic units (average of the two seasons is 5 basic units) for stress treatment, respectively.

Comparable variance (V) for SC-10 of each plot size was compared with the basic unit. In 2002 season for SC-10, it was observed that as plot size increased, relative information (R.I.) decreased while comparable variance of yield increased (Table 3). For example, data showed that the values of comparable variance increased from 0.1732 to 1.649 under stress treatment in 2002 season as plot size increased from one to 17 basic units. This trend is less noticeable as plot size increases more than 2 basic units for control and stress irrigation treatments in 2002 and 2003 seasons.

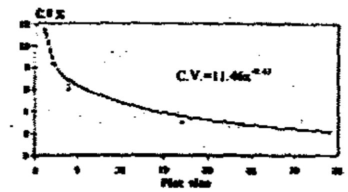

Fig. 5. Relationship between plot size and coefficient of variability for SC-10 under control in 2002 season.

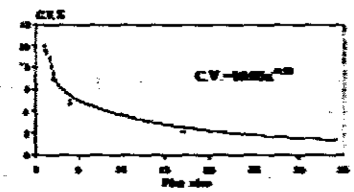

Fig. 6. Relationship between plot size and coefficient of variability for SC-10 under control in 2003 season.

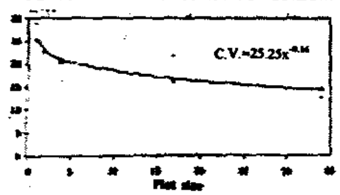

Fig. 7. Relationship between plot size and coefficient of variability for SC-10 under stress in 2002 season.

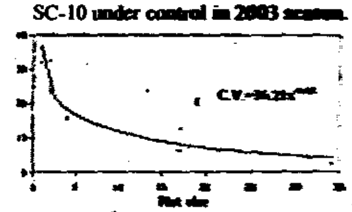

Fig. 8. Relationship between plot size and coefficient of variability for SC-10 under stress in 2003 season.

According to the two methods (maximum curvature and comparable variance) the recommended optimum plot size for SC-10 is therefore ranging from 2 to 3 basic units (8.4 to 12.6 m^2 with an average of 10.5m^2) for control irrigation treatment, and from 2 to 5 basic units (8.4 to 21 m^2 with an average of 14.7m^2) for stressed irrigation.

2- Optimum number of replications

The theoretical number of replications for various plot sizes are presented in Table (4). It was clearly noticed that the theoretical number of replications decreased as the plot size increased. These results were found for Gz-2 and SC-10 in the two seasons for control irrigation treatment. Meanwhile under stress irrigation treatment for Gz-2 and SC-10 due to the fluctuation from one plot size to the other, the large number of replications helps to withstand the decrease in yield due to stress conditions. The relationship between number of replications, plot size and standard error are illustrated in Figs. (9 through 12) for Giza2 and Figs. (13 through 16) for SC-10.

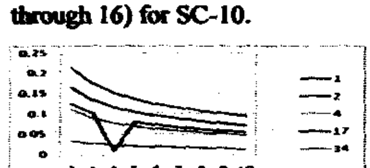

Fig. 9. The relationship between standard error for different plot sizes and various number of replications for Giza-2 under control irrigation in 2002 season.

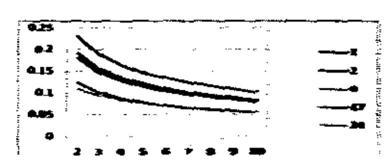

Fig. 10. The relationship between standard error for different plot sizes and various number of replications for Giza-2 under control irrigation in 2003 season.

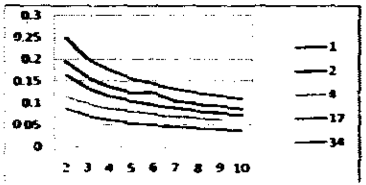

Fig. 11. The relationship between standard error for different plot sizes and various number of replications for Giza-2 under stress irrigation in 2002 season.

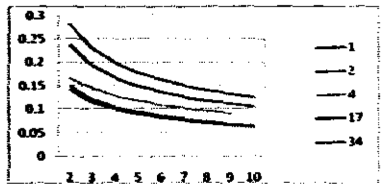

Fig. 12. The relationship between standard error for different plot sizes and various number of replications for Giza-2 under stress irrigation in 2003 season.

Fig. 13. The relationship between standard error for different plot sizes and various number of replications for SC-10 under control irrigation in 2002 season.

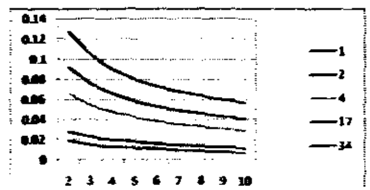

Fig. 14. The relationship between standard error for different plot sizes and various number of replications for SC-10 under control irrigation in 2003 season.

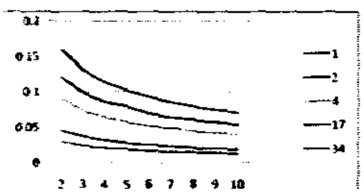

Fig. 15. The relationship between standard error for different plot sizes and various number of replications for SC-10 under stress irrigation in 2002 season.

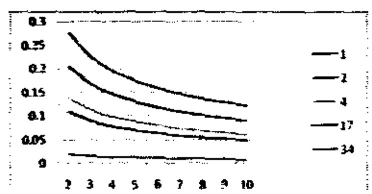

Fig. 16. The relationship between standard error for different plot sizes and various number of replications for SC-10 under stress irrigation in 2003 season.

Table 4. Theoretical number of replications for different plot sizes of Gz-2 and SC-10 under the two irrigation treatments (control and stress) in 2002 and 2003 seasons.

Plot size	Number of replications							
	Control				Stress			
	Gz-2		SC-10		Gz-2		SC-10	
	2002	2003	2002	2003	2002	2003	2002	2003
1	11	17	5	4	29	51	33	40
2(1x2)	5	7	3	2	12	35	13	16
2(2x1)	8	13	3	2	23	38	28	29
4	3	6	2	1	9	27	11	10
17	4	11	1	1	13	13	19	6
34	1	5	1	1	3	14	6	1

Results showed that standard error decreased as the number of replications and plot size increased, but the rate of decrease was more obvious due to increase in number of replications than that due to increasing plot size. This was clear for G.2 and S.C.10 under control irrigation treatment in both seasons. The relationship between standard error and number of replications for different plot sizes showed that the rate of decrease in standard error reached its maximum when using 4 and 7 replicates for Gz-2 under control and stress treatments, respectively. Meanwhile, for SC-10 it reached its maximum when using 5 and 8 replicates for the two irrigation treatments, respectively, EL- Rassas 1982, found that in corn trials, the optimum number of replicates was (6 – 8) replicates.

II: Performance of nine genotypes under drought

Combined analysis of variance across two seasons of the thirteen studied traits is presented in Table (5). Mean squares due to irrigation regimes were significant or highly significant for all studied characters, except for 50% silking and A.S.I. Genotypes differ significantly for all studied traits except for 100 kernel weight and number of rows/ear. Mean squares due to irrigation x genotypes interaction were significant or highly significant for all studied traits except for A.S.I, and row/ear .Mean squares due to seasons x genotypes x irrigation regimes were significant only for plant height. Thus, the performance of genotypes varies with water supply for most traits, confirming previous results (France and Turelle 1953; Downey 1971, El-Sayed, 1998 and Atta, 2001).

Table 5. Combined analysis of variance for studied traits over 2002 and 2003 seasons.

Source of variation	d.f.	50% Silking	ASI	Plant height	Ears/ plant	rows/ ear	kernels/ row	100 kernel Weight	Grain yield/plant
Years (Y)	1	4.445	7.562	7885**	0.001	140.8**	156.283	90.250	541.861
Reps in Year	6	1.551	14.030	159.44	0.012	9.130	124.488	115.547	2292.775
Irrigations (I)	1	4.237	787.738	7269**	41.818**	217.6**	3042.21**	4601.4**	166373**
(Y) x (I)	1	1.756	15.867*	4395**	0.063	173.8**	76.672	108.594	852.324
Error (a)	6	2.724	2.533	28.438	0.014	1.900	95.526	130.774	3243.914
Genotypes (G)	8	5.504*	7.269*	124.9**	0.082**	1.089	71.78*	29.061	1969.53**
(Y) x (G)	8	2.681	2.743	75.54**	0.014	0.560	2.089	22.622	42.346
(I) x (G)	8	6.6664*	6.886	56.5**	0.229**	1.088	87.74*	159.13*	1777.1*
(I) x(G) x(Y)	8	1.270	3.760	125.3**	0.010	0.823	4.890	26.060	69.401
Error (b)	96	2.740	3.813	42.075	0.008	0.956	34.170	67.181	702.752

*, ** indicate significance at 0.05 and 0.01 probability levels, respectively.

Means combined across seasons for the thirteen studied traits of 9 maize cultivars evaluated under drought stress and non-stress (control) conditions are presented in Table (6).

Table 6. Means of agronomic and yield characteristics of nine maize genotypes under water stress and non-stress conditions (Data are combined over two seasons 2002 and 2003).

Genotypes	Days to 50% silking	ASI (days)	Plant ht cm	Ears/ plant	Rows/ ear	Kernels/ row	100 kernel wt g	Grain yield / plant g
					Control			
Giza-2	51.9	2.8	186.0	1.6	14.5	39.9	61.7	157.9
SC-10	51.8	1.8	187.7	1.6	15.0	43.6	62.2	175.9
SC-122	52.6	1.2	186.1	1.5	14.5	41.6	59.9	182.6
SC-123	35.4	2.1	183.0	1.8	14.1	34.4	57.6	132.5
SC-129	35.4	3.0	188.2	1.5	14.3	46.3	62.8	157.2
TWC-310	52.6	3.2	186.4	1.9	13.8	43.6	63.7	156.9
TWC-320	53.3	1.8	185.4	1.8	13.9	39.2	54.0	146.9
TWC-321	52.6	3.1	186.8	1.7	14.5	43.8	61.2	158.7
TWC-324	51.9	2.3	188.7	1.7	14.3	47.1	63.0	189.8
Aver. (no-stress)	25.2	2.4	186.5	1.7	14.3	42.2	60.7	162.1
					Stress			
Giza-2	51.4	7.3	174.1	0.77	11.9	30.9	52.5	85.7
SC-10	52.5	8.2	174.8	0.6	11.4	34.9	49.2	110.4
SC-122	52.6	5.2	175.2	0.8	11.8	34.2	49.6	95.0
SC-123	51.8	8.9	165.4	0.7	11.8	34.8	49.7	107.4
SC-129	52.7	7.8	178.4	0.6	12.1	29.3	48.9	79.4
TWC-310	55.1	5.7	175.5	0.5	11.7	32.5	41.9	85.9
TWC-320	52.6	7.2	169.3	0.5	11.4	32.2	55.8	103.3
TWC-321	53.4	6.7	166.3	0.4	12.2	32.6	47.4	78.3
TWC-324	53.6	6.3	171.3	0.4	11.9	35.5	49.5	100.0
Aver. (stress)	52.9	7.0	172.3	0.6	11.8	33.0	49	97.1
Reduction (increase) %	+1.3	+191.7	-7.6	-47.1	-17.5	-21.8	-18.6	-41.9
L.S.D. (0.05) 1	-	2.62	8.74	0.09	1.41	8.80	11.89	30.49
L.S.D. (0.05) 2	1.95	-	7.64	0.10	-	6.88	13.64	31.22

L.S.D. (0.05) 1 to compare two irrigation treatments at the same genotype.
L.S.D. (0.05) 2 to compare nine genotypes at the same irrigation treatment

Mean grain yield/plant ranged from 132.5 g (for SC-123) to 189.8 g (for TWC-324) under non-stress with an average across all genotypes of 162.0 g and from 78.4 g (for TWC-321) to 110.7 g (for SC-10) under water stress conditions with an average of 94.1 g. The highest yield cultivars under drought stress were SC-10 followed by SC-123, TWC-320 and TWC-324 while the highest yielding cultivars under non-stress was TWC-324 followed by SC-122, SC-10 and TWC-321. Therefore, the best crosses in grain yield under both stress and non-stress conditions are SC-10 and TWC-324; they could be considered as drought tolerant genotypes. Reduction in grain yield/plant due to water stress ranged from 18.8 % SC-123 to 58.6 % for TWC-321 with an average of 41.9 %. The lowest reduction in grain yield due to drought stress was exhibited by SC-123, TWC-320 and SC-10. Drought stress caused a significant reduction in grain yield/plant by 41.9%. This reduction in grain yield due to water stress was associated with reduction in all yield components, i.e. 38%, 12.2%, 17.5%, 21.8% and 18.6% reduction for ear weight, ear diameter, number of rows/ear, number of kernels/row and weight of 100 kernels. Moreover, drought stress caused a reduction in plant height (7.6%). On the other hand, drought stress caused an increase in all flowering traits, i.e. delay in 50% silking (1.3%) and elongation in A.S.I. (191.7%).

Genotypic differences in maize drought tolerance in this experiment, expressed by grain yield/plant and its components were obvious. Genotypes that performed well under water stress for grain yield performed also well for one or more yield components. Significant genotypic differences in maize drought tolerance, exhibited in this experiment, could give the confidence to the plant breeder in the possibility of improvement of this important characteristic via conventional breeding programs.

III- Relative precision of split plot design vs. R.C.B.D.

The experimental design plays an important role in the agricultural research. It is very important to choose the efficient experimental plan according to the expected efficiency. The efficiency of experimental designs can be estimated using experimental data. It is expected that experimental data can provide the researcher with all the information that he needs. Split plot design is so constructed that the error term for the randomized complete block design is partitioned into two parts: error (a) which is generally larger and error (b) which is smaller than the error for a randomized complete block experiment.

The increase in efficiency of a split plot experiment as compared with a (R.C.B.D.) experiment is obtained by the increased precision for the sub plot treatment and interaction at the expense of precision for the main plot treatments; the B and A x B effects are usually estimated more accurately than the main plot treatments. In the experiment I (two genotypes experiment) average of relative efficiency combined across the two seasons for the main plots was 93.82%, and 71.01%, for sub plots was 110.51% and 85.84% for non-stress and stress irrigation treatments, respectively (Table 7). In experiment II (nine genotypes experiment) average of relative efficiency combined across seasons was 92.49, 70.92 % for main plots and 140.51, 96.23 % for sub plots under non-stress and stress irrigation conditions, respectively (Table 8).

It is obvious that the relative precision percentages of the split plot design relative to randomized complete block design (R.C.B.D.) were higher for sub plots than those for main plots which is logic because the precision of sub plots comparable with main plots in split plot design is more accurate than in R.C.B.D. This trend was clear in all studied characters (except plant height, 100-kernel weight) under both irrigation treatments in 2002, 2003 and combined across the two seasons. Moreover, in general the

Table 7. Relative precision (R.P.) (%) estimates of split plot design relative to randomized complete blocks design for maize traits in experiment I.

Character	Plot	2002		2003		Combined	
		Control	Stress	Control	Stress	Control	Stress
50% Silking	Main plot	95.48	66.79	55.03	70.74	75.26	68.77
	Sub plot	105.49	87.58	169.05	71.93	137.27	79.76
A.S.I	Main plot	71.34	61.72	88.12	75.29	79.73	68.51
	Sub plot	125.22	97.81	99.23	87.72	112.23	92.77
Plant height	Main plot	120.25	97.21	128.04	92.78	124.15	94.99
	Sub plot	74.00	61.75	41.84	58.99	57.92	60.37
Ears/plant	Main plot	52.21	43.91	88.17	66.78	70.19	55.45
	Sub plot	100.00	71.98	164.81	91.22	132.41	81.60
rows/ear	Main plot	115.48	97.22	90.88	88.10	103.18	92.66
	Sub plot	93.71	100.00	105.66	89.91	99.68	94.96
Kernels/row	Main plot	89.03	97.80	90.79	71.55	89.91	84.68
	Sub plot	153.14	81.45	101.78	92.80	127.46	87.13
100-kernel weight	Main plot	110.41	51.54	134.52	81.82	122.47	66.68
	Sub plot	95.50	77.70	88.63	97.22	92.07	87.46
Grain yield /plant	Main plot	67.64	66.78	99.98	51.44	83.81	59.11
	Sub plot	131.45	100.12	100.01	97.92	115.73	99.02
Average	Main plot	93.14	70.62	94.50	71.39	93.82	71.01
	Sub plot	113.95	86.98	107.07	84.70	110.51	85.84

Table 8. Relative precision (R.P.) (%) estimates of split plot design relative to randomized complete blocks design for maize traits in experiment II.

Character	Plot	2002		2003		Combined	
		Control	Stress	Control	Stress	Control	Stress
50% Silking	Main plot	91.55	56.72	89.33	77.21	90.44	66.97
	Sub plot	94.72	91.44	100.09	80.54	97.41	85.99
A.S.I	Main plot	66.31	57.44	56.15	50.21	61.23	53.83
	Sub plot	97.56	90.78	98.15	82.92	97.90	86.85
Plant height	Main plot	155.72	111.30	101.12	100.73	128.42	106.02
	Sub plot	97.81	94.62	94.89	92.03	96.35	93.33
Ears/plant	Main plot	58.25	50.12	65.95	60.61	62.10	55.37
	Sub plot	110.02	92.00	103.64	96.12	106.83	94.06
rows/ear	Main plot	99.07	80.41	71.34	66.14	85.21	73.28
	Sub plot	110.80	100.52	102.58	91.52	106.69	96.02
Kernels/row	Main plot	110.29	66.94	90.48	96.09	100.39	81.52
	Sub plot	122.64	87.46	100.66	100.51	111.65	93.99
100-kernel weight	Main plot	165.83	149.99	109.61	82.80	137.72	116.15
	Sub plot	97.58	97.96	99.46	101.36	98.52	99.66
Grain yield /plant	Main plot	108.69	54.29	47.37	36.00	77.98	45.15
	Sub plot	137.65	105.56	107.46	112.49	122.56	109.03
Average	Main plot	100.29	72.78	84.68	69.06	92.49	70.92
	Sub plot	109.13	96.36	99.89	96.11	104.51	96.23

relative precision (R. P.) of the split plot vs. R.C.B. design was higher under non-stress (control) than under water stress conditions.

Under non–stress (control) data combined across seasons for experiment I (Table 7) showed that the relative precision of split plot vs. R.C.B.D was 137.27, 112.23, 132.41, 57.92, 99.68, 127.46, 92.07 and 115.73% for sub plots, while it was 75.26, 79.73, 70.19, 60.37, 70.19, 103.18, 127.46, 122.47 and 83.8% for main plots concerning 50 % silking, A.S.I, plant height, ears/plant, rows/ears, kernels/row,100–kernel weight and grain yield/plant, respectively. For experiment II (Table 8), under control treatment, combined data across seasons showed that the relative precision of split plot vs. R.C.B.D. was 97.41, 97.90, 106.83, 96.35, 106.69, 111.65, 98.52 and 122.56% for sub plots and 90.44, 61.23, 62.10, 128.42, 85.21, 100.39, 137.72 and 77.98% for main plots, concerning the previous traits in the same order, respectively (Fig. from 17 to 24).

Under water stress conditions, data combined over season for experiment II (Table 7) exhibited that the relative precision percentage of the split plot design vs. R.C.B.D concerning 50% silking, A.S.I, plant height, ears/plant, rows/ear, kernels/row, 100- kernel weight and grain yield/plant was 78.76, 92.77, 81.60, 60.37, 94.96, 87.13, 87.46 and 99.02% for sub plots, while it was 68.77, 68.91, 55.45, 94.99, 92.66, 84.68, 66.68 and 59.11% for main plots, respectively. For experiment II (Table 8), under stress treatment, combined data across seasons showed that relative precision of split plot design vs. R.C.B.D. was 85.99, 86.85, 94.06, 93.33, 96.02, 93.99, 99.66 and 109.03% regarding sub plots and 66.97, 53.83, 55.37, 106.02, 73.28, 81.52, 116.15 and 45.15% regarding main plots for the previous traits in the same order, respectively (Fig. 17 through 24).

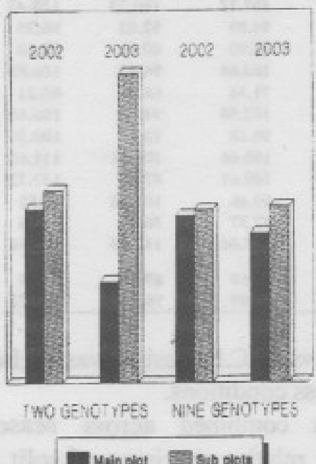

Fig. 17. The relative precision of main plots and sub plots in split plot design for days to 50% silking of maize in 2002 and 2003 seasons.

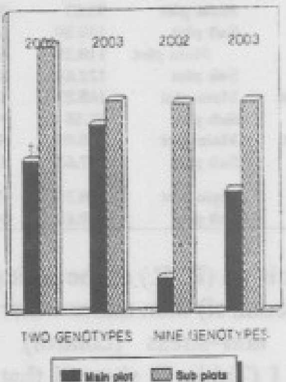

Fig. 18. The relative precision of main plots and sub plots in split plot design for ASI of maize in 2002 and 2003 seasons.

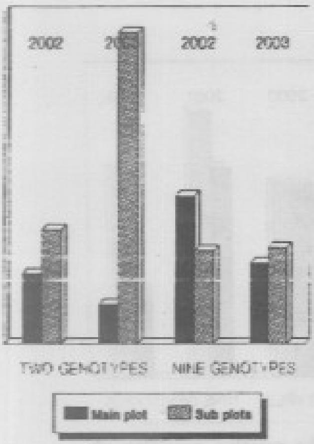

Fig. 19. The relative precision of main plots and sub plots in split plot design for plant height of maize in 2002 and 2003 seasons.

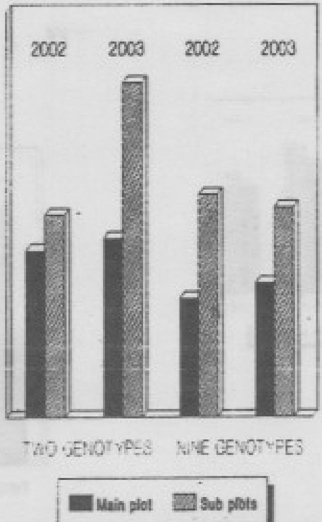

Fig. 20. The relative precision of main plots and sub plots in split plot design for ears/plant of maize in 2002 and 2003 seasons.

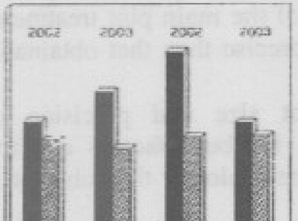

Fig. 21. The relative precision of main plots and sub plots in split plot design for 100-kernel weight of maize in 2002 and 2003 seasons.

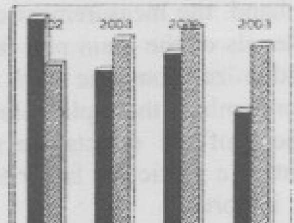

Fig. 22. The relative precision of main plots and sub plots in split plot design for rows/ear of maize in 2002 and 2003 seasons.

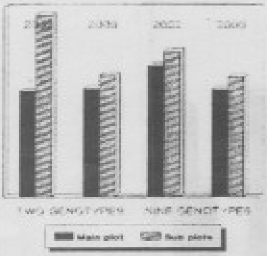

Fig. 23. The relative precision of main plots and sub plots in split plot design in number of kernels/row for maize in 2002 and 2003 seasons.

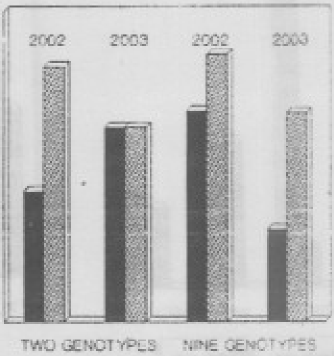

Fig. 24. The relative precision of main plots and sub plots in split plot design in grain yield /plant for maize in 2002 and 2003 seasons.

With the split plot design, the precision for the measurement of the effects of the main plot factor is scarified to improve that of the sub plot factor and its interaction with the main plot factors which will be more precise than that obtainable with a randomized complete block design. On the other hand, the measurement of the effects of the main plot treatments (i.e., the levels of the main plot factor) is less precise than that obtainable with a randomized complete block design.

Concerning the split plot design, plot size and precision of measurement of the effects are not the same for both factors and the assignment of a particular factor to either the main plot or the sub plot is extremely important.

Results of the present study indicated that splitting was generally important since it reduces the efficiency for main treatment and increases that of split plot treatments and interaction, the first is due to the large size of the main plot which is less efficient in soil variability and the latter is due to less soil variability between the split plots than between the main plots of replicates. Similar results were obtained by El–bakry, (1980), Mohammed (1981), Moursi *et al* (1983) and Saad (1985)

REFERENCES

Abd-El-Halim, A. A., F.M. EL-Rayes, T. A. Mohamed and A.M.A. Saad (1989). Estimation of optimum plot size and shape for faba bean yield trials. Annals, Agric. Sci., Moshtohor, Zagazig Univ. 27 (2): 825 – 839.

Ashmawy, F. (2004). Increasing precision of field experiments in maize using uniformity trials. J. Agric. Mansoura Univ., 29(3) :1065 -1076.

Atta, M. M. (2001). A study of combining ability and heterosis for drought tolerance in some maize populations. Ph. D. Thesis, Fac. of Agric., Cairo Univ., Egypt.

Cochran, W. G. and G. M. Cox (1957). Experimental designs (2 nd ed.) John Wiley and Sons. Inc., New York.

Denmead, O. T. and R. H. Shaw (1960). The effect of soil moisture stress at different stages on development and yield of corn. Agron. J. 52: 272 – 274.

Downey, L. A. (1971). Effect of gypsum and drought stress on maize (*Zea mays* L.) growth ,light absorption and yield. Agron. J. 63 : 569-573.

EL-Bakry, A. E. (1980). A study of optimum plot size and relative efficiency using experimental data for some major field crops. M. Sc. Thesis Fac. of Agric. Al-Azhar Univ. Egypt.

EL-Rassas, H. N. (1982). Precision of some statistical procedures in evaluating yield and yield components of some cereal crops. Ph. D. Thesis, Fac. of Agric., Cairo Univ., Egypt .

EL-sayed, M. Y. M. (1998). Studies on drought tolerance in maize. M. Sc. Thesis. Fac. Agric., Cairo Univ., Egypt.

El-Sheikh, M. H. (1999). Response of some maize genotypes to water stress . Alex.J.Agric.Res.44(1): 61 - 77.

Federer, W. T. (1955). Experimental design. Theory and Application .McMillan Co., New York, USA.

France, C. J. and J. W. Turelle (1953). Irrigation corn. USDA farmers Bull., 2059.

Galal, H. E. and H. A. Abou EL-Fittouh (1971). Estimation of optimum plot size and shape for Egyptian cotton yield trials .Alex. J. Agric. Res. 19 : 233 - 238.

Gomes, K. A. and A. A. Gomes (1984). Statistical Procedures for Agricultural Research .2nd ed., John Wiely and Sons, Inc., New York, USA.

Hayes, H. K., F. R. Immer and D. C. Smith (1955). Methods of Plant Breeding. McGraw- Hill Book Co. New York, ed.2, pp.551.

Keller, K. R. (1949). Uniformity trial on hops (*Humulus lupulus*) for increasing the precision of field experiment. Agron. J. 41: 389 – 392.

Leilh, A. A. (1985). Study on the efficiency of some experimental designs. Ph. D. Thesis. Fac. of Agric., Mansoura University, Egypt.

Lorens, G. F., J. M. Bennett and L. B. Loggaie (1987). Differences in drought resistance between two corn hybrids. II. Component analysis and growth rates. Agron. J. 79: 808 -813.

Mohammed, T.A. and F. Ashmawy (1996). Relative efficiency of some experimental designs in maize yield (*Zea mays*. L.). Egypt. J . Agric .Res, 75 (3):827-841.

Mohammed, T. A. (1981). Relative efficiency of some experiment designs. M. Sc. Thesis, Faculty of Agriculture. Ain Shams Univ., Egypt .

Moursi, M. A., N. Nor EL-din, A. Abd EL- Halim and A. Abd EL-Kareem (1983). Relative efficiency of some experimental designs. Crop Sci. 1 : 335 – 346

Saad, A. M. M. (1985). Relative precision of some statistical procedures in evaluating the characteristics of cotton cultivars. Ph. D. Thesis., Fac. Agric. Sci., Moshtohor, Zagazig. Univ., Egypt.

Snedecor, G. W. and G. W. Cochran (1980). Statistical Methods. 7th Ed. The Iowa State Univ. Press, Ames, Iowa, U.S.A .

مساحة القطعة التجريبية وعدد المكررات وكفاءة تصميم التجارب الحقلية للذرة الشامية تحت ظروف إجهاد وعدم إجهاد الرى

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[1] قسم المحاصيل – كلية الزراعة – جامعة القاهرة – الجيزة
[2] المعمل المركزى لتصميم التجارب والتحليل الاحصائى – مركز البحوث الزراعية - الجيزة

تهدف هذه الدراسة الى تحديد المساحة الامثل للقطعة التجريبية وعدد المكررات الامثل والكفاءة النسبية لتصميم القطع المنشقة فى التجارب الحقلية للذرة الشامية تحت ظروف الاجهاد وعدم الاجهاد المائى. أجريت تجربتين حقليتين فى كلا من موسمى 2003 ، 2004 فى محطة التجارب بكلية الزراعة – جامعة القاهرة بالجيزة. كان التصميم المستخدم هو القطع المنشقة خصصت فيه القطع الرئيسية لمعاملتى الرى (الرى الكامل ورى الإجهاد التى منعت فيه الرية الرابعة والخامسة والسادسة) ووزعت التراكيب الوراثية للذرة فى القطع المنشقة واستعمل صنفين من الذرة فى التجربة الاولى و 9 أصناف فى التجربة الثانية. أظهرت النتائج ان انسب مساحة للقطعة التجريبية كانت 10.5 ، 12.6 م^2 لصنف جيزة 2 و10.5 ، 14.7م^2 لصنف هجين فردى 10 تحت ظروف الرى التقليدى واجهاد الرى ، على التوالى . ووجد ان عدد المكررات الامثل 4 – 5 للمعاملة التقليدية و 7 – 8 لمعاملة القاسية. أدى إجهاد الرى لنقص معنوى فى محصول النبات قدره 41.9% مصحوبا بنقص فى مكونات المحصول. كانت اكثر الاصناف تحملا للجفاف هى الهجين الفردى هـ. ف 10 والثلاثى هـ.ث 324. كانت الكفاءة النسبية لتصميم القطع المنشقة أعلى من تصميم القطاعات الكاملة العشوائية وكانت الكفاءة النسبية للقطع الشقية أعلى من القطع الرئيسية وتحت ظروف عدم الاجهاد أعلى من تحت ظروف الاجهاد المائى .

مجلد المؤتمر الخامس لتربيه النبات – الجيزه ٢٧ مايو ٢٠٠٧
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