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STUDIES ON THE INTER-RELATIONSHIP AMONG IRRIGATION AND MAIZE VARIETIES ON YIELD AND WATER RELATIONS USING SOME STATISTICAL PROCEDURES

BY

Khalil, F.A. F. * **and Samia, G. A. Mohamed** **

* Water Requirements and Field Irrigation Research Department; Soil, Water, and Environment Research Institute; Agricultural Research Center; Egypt

** Central Laboratory for Experimental Design and Statistical Analysis; Agricultural Research Center; Egypt.

ABSTRACT

Two field experiments were carried out at Giza Agricultural Research Station during successive seasons 2004 and 2005 to evaluate the effect of four irrigation intervals (irrigation every seven days, irrigation every seven days until silking then irrigation every two weeks, irrigation every two weeks until silking and irrigation every seven days and irrigation every two weeks during the whole season) and two maize hybrids (TWC 310 and TWC 324) on maize yield, its components and some water relations. to determine the most important yield components using different statistical procedures Results showed that irrigation intervals, differed significantly with respect to ear diameter, number of grains per row, number of grains per ear and biological yield (ton/fed) in the first season. Whereas, in the second season irrigation intervals were found to be significant for ear length, ear diameter, number of barren per plants, plant yield, grain yield (Ardab/fed) and biological yield (ton/fed). Results also indicated that both hybrids were not significantly different, except for number of grains per ear in the first season and biological yield in the second season. The interaction between hybrides and irrigation treatments revealed that, to obtain the highest maize yield, yield components and water use efficiency, it could be recommended to plant TWC 310 and irrigate it every seven days. Furthermore, simple correlation analysis revealed that seven yield components were found to be highly significant and correlated with plant yield. Whereas, multiple linear regression analysis exposed five yield components that had the highest contribution to maize plant yield with R^2 equals to 0.938. However, principle component analysis was more efficient than simple correlation analysis and stepwise multiple linear regression analysis, which assigned only four yield components that could accounted for 95.045 % of the total variation. These four yield components were ear length, number of grain per row, number of grain per ear, and 100-grain weight. Therefore, it is recommended to select for these four components in breeding programs for maize hybrids.

The soil moisture constants (% per weight) and bulk density (g cm^{-3}) in the depth of 0-60 cm are shown in Table (2).

Table (2): Soil moisture constants of the experimental field at Giza Agricultural Station

Depth	Field capacity %	Wilting point %	Available water %	Bulk density (g/cm^3)
0 – 15	41.85	18.61	23.24	1.15
15 – 30	33.68	17.5	16.18	1.24
30 - 45	28.36	16.92	11.46	1.20
45 – 60	28.05	16.54	11.51	1.28

Meteorological data at Giza Agricultural Research Station i.e. maximum and minimum temperature (T.max and T.min, °C), wind speed (WS, m/s), relative humidity (RH, %), actual sunshine duration (SS, hour) and solar radiation (SR, cal/cm^2/day) are shown in Table (3).

Table (3): Meteorological data at Giza Agricultureal Research Station in 2004 and 2005 growing seasons

Season	2004					
Month	T.max (°C)	T.min (°C)	WS (m/s)	RH (%)	SS (hour)	SR (cal/cm^2/ day)
June	34.4	23.0	3.5	44	12.0	627
July	33.5	25.3	3.3	46	11.7	613
Augest	34.1	24.6	3.3	48	11.1	577
September	32.9	23.8	4.2	56	10.1	512
October	30.5	20.7	3.7	50	9.2	417
	2005					
June	33.9	23.1	3.9	49	12.0	627
July	35.2	25.1	2.8	43	11.7	613
Augest	35.0	25.0	3.4	48	11.1	577
September	34.0	23.2	4.5	47	10.1	512
October	28.2	18.6	4.3	55	9.2	417

To enhance the process of screening yield components of maize, two weather parameters were included in the analysis i.e. mean air temperature (°C) and solar radiation (cal/cm^2/day). Mean temperature and mean solar radiation for two growth stages were calculated as followed:

1. From planting to the 50 % silking,
2. From planting to maturity.

Mean air temperature at the above mentioned growth stages and base temperature (Tb, the temperature, under which no appreciable growth occurs equals to 10°C as defined by Jones and Kiniry, 1986) were used to calculate growing degree days (GDD, ° C) and as followed:

$$MTemp = (T.max + T.min)/2$$
$$GDD = MTemp - Tb$$

Water relations

1-Actual water consumptive use

Actual evapotranspiration was estimated by the soil sampling method and calculated according to the Israelsen and Hansen (1962) using the following formula:

$$CU = \frac{(\Theta_2 - \Theta_1) X Bd X 60 X 4200}{100 X 100}$$

Where:

CU=the amount of consumptive use in m^3/fed.

Θ_2=soil moisture percentage after irrigation.

Θ_1=soil moisture percentage before next irrigation.

Bd=bulk density in g/cm^3

2- Water use efficiency (WUE)

Water use efficiency values were calculated as (kg/m^3) for the different irrigation treatments by the following equation (Vites, 1965).

$$WUE = \frac{\text{Grain yield (kg/fed)}}{\text{Consumptive use } (m^3/fed)}$$

Statistical procedures:

1. Data were statistically analyzed according to Snedecor and Cochran (1980) and treatment means were compared by least significant difference test (LSD) at 0.05 level of significance.
2. Simple correlation coefficients were computed among the studied characters according to the method described by Steel and Torrie (1980).
3. Stepwise multiple linear regression was used to determine the most important yield components, as independent variables, which significantly contribute to the total variability in grain yield as dependent variable (Draper and Smith 1981).
4. Principle components analysis was used according to the methods of Berenson *et al.* (1983). The basic purpose of principal components is to account for the total variation forming a new set of orthogonal and uncorrelated composite varieties. Hence, the first composite (i.e. principle component) will have the largest variance; the second will have a variance smaller than the first but larger than the third, and so on.

RESULTS AND DISCUSSION

1. Effect of irrigation intervals

Results presented in Table (4) showed the main effects of irrigation intervals on maize yield and its components during 2004 and 2005 growing seasons. Irrigation intervals were found to be significant with four characters: ear diameter (cm), number of grains per rows, number of grains per ear and biological yield (ton/fed) in the first season. These four characters are important yield attributes. Ear diameter and number of grains per rows are indirect indicative of the ability of ear to bear grain (Kiniry and Knievel 1995). Whereas, number of grains per ear is an indirect indication of plant yield (Ouda and Mouhamed 2006). Furthermore, biological yield is a measure of both grain and straw yield.

In the second season, irrigation intervals were found to be significant for number of barren plant, ear diameter (cm), ear length (cm), yield per plant (g), grain yield (Ardab/fed) and biological yield (ton/fed) (Table 4). Number of barren plants is related to final maize yield, where when its number increases the yield decreses (Hassib 1997). It could be concluded that increasing available soil moisture increased yield and yield components. These results are in agreement with the results obtained by El-Marsafawy (1991) and El-Shafeei (1993).

Table (4): Effect of irrigation intervals on yield and yield components during 2004 and 2005 seasons.

Characters	Irrigation intervals									
	I1		I2		I3		I4		L.S.D	L.S.D
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Plant height	249.7	261.6	240.2	260.0	234.5	250.0	230.7	240.6	NS	NS
LAI	7.2	8.3	6.4	8.2	6.2	7.6	5.9	7.5	NS	NS
No. of barren plants	4.7	6.5	5.3	6.8	6.2	9.7	6.7	9.8	NS	2.79
Ear diameter	4.8	4.8	4.8	4.8	4.8	4.6	4.6	4.6	0.109	0.208
Ear length	22.5	23.0	22.4	22.7	22.3	22.2	22.1	21.9	NS	0.592
No. of rows/ear	13.4	13.4	13.0	13.2	12.7	13.0	12.5	12.9	NS	NS
No. of grains/row	49.7	51.1	48.6	50.5	47.2	49.3	46.4	49.2	2.26	NS
No. of grains/ear	649.2	680.1	646.2	655.9	609.7	627.7	596.1	614.0	45.18	NS
Plant yield	225.1	264.8	225.6	260.6	223.8	241.6	223.0	226.3	NS	28.22
100-grains weight	37.0	35.4	34.6	35.1	34.2	35.0	33.9	34.0	NS	NS
Grain yield	19.4	20.2	18.3	20.0	17.7	18.5	15.6	17.9	NS	1.45
Biological yield	10.8	11.9	10.3	10.8	9.4	10.2	8.7	9.7	0.82	0.67

1.2. Effect of maize hybrids:

Results in Table (5) indicated that TWC 310 and TWC 324 were significantly different in number of grains per ear in the first season, whereas in the second season the two hybrids were significantly different in biological yield (ton/fed). The rest of the characters were not significantly different. This could be attributed to the fact that both are three way hybrids, which are genetically close to each other.

1.3. Effect of the interaction between irrigation and maize hybrids

The effects of the interaction between irrigation intervals and maize hybrids on yield and its components are presented in Table (6). In 2004 growing season, the interaction between irrigation every seven days (I1) and TWC 310 (V1) produced the highest value for plant height (cm), LAI, ear diameter (cm), number of rows/ear, number of grain/ear, grain yield (Ardab/fed) and biological yield (ton/fed). Whereas, in 2005 growing season, the highest value of LAI, number of rows/ear, number of grain/ear, plant yield (g), grain yield (Ardab/fed) and biological yield (ton/fed) was obtained under the interaction between irrigation every seven days (I1) and TWC 310 (V1). Therefore, it could be recommended to plant TWC 310 and irrigate it every seven days to obtain the highest yield and its components.

Table (5): Effect of hybrids on maize yield and its components during 2004 and 2005 growing seasons.

Characters	Mean Crosses					
	TWC 310		TWC 324		L.S.D	L.S.D
	2004	2005	2004	2005	2004	2005
Plant height	240.5	256.83	237.00	249.33	NS	NS
LAI	6.49	7.96	6.32	7.78	NS	NS
No. of barren plants	5.58	7.00	5.83	9.42	NS	NS
Ear diameter	4.75	4.78	4.73	4.69	NS	NS
Ear length	22.4	22.68	22.15	22.31	NS	NS
No. of row/ear	13.05	13.13	12.73	13.04	NS	NS
No. of grain/row	48.45	50.57	47.48	49.48	NS	Ns
No. of grains /ear	635.7	661.03	614.97	627.87	22.36	NS
Plant yield	218.3	247.58	250.50	249.17	NS	NS
100-grains weight	35.07	35.18	34.78	34.51	NS	NS
Grain yield	18.43	19.48	17.07	18.79	NS	NS
Biological yield	10.08	11.22	9.55	10.11	NS	0.771

Table (6): The effect of the interaction between irrigation and maize hybrids on yield and its components in 2004 and 2005 growing seasons.

Characters	2004		2005	
	Irrigation X hybrid	Highest value	Irrigation X hybrid	Highest value
Plant height	I1 X V1	250.33	I1 X V2	268.33
LAI	I1 XV1	7.48	I1 X V1	8.73
No. of barren plants	I4 XV 2	7.33	I3 XV2	11.67
Ear diameter	I1 XV 1	4.88	I2 XV 1	4.94
Ear length	I3 X V1	23.20	I1 X V2	23.07
No. of rows/ear	I1 X V1	14.00	I1 XV 1	13.47
No. of grain/row	I1 X V2	49.83	I1 XV 2	51.44
No. of grains/ear	I1 X V1	661.53	I1 X V1	711.63
Plant yield	I1 X V2	229.33	I1 X V1	276.00
100-grains weight	I1 X V2	38.37	I2 XV 1	36.10
Grain yield	I1 X V1	20.27	I1 X V1	20.93
Biological yield	I1 X V1	11.17	I1 X V1	12.54

2. Water relations

2.1. Actual water consumptive use

Seasonal actual water consumptive use as affected by irrigation intervals, maize varieties and their interaction are recorded in Table (7). The results of consumptive use irrespective to irrigation intervals and maize varieties together were 2320 and 2423 m^3/fed for the first and second season, respectively.

Differences between such results may be due to the variation in the weather conditions, especially air temperature.

For irrigation intervals and regardless of maize varities, actual water consumptive use in the first season was 2410, 2329, 2283 and 2261 m^3/fed for irrigation interval I1, I2, I3 and I4, respectively. Values in the second season were 2540, 2416, 2425 and 2313 m^3/fed for the same respective irrigation treatments. These results indicate that consumptive use decreased as the available soil moisture decreased in the root zone of plants (i.e. irrigation maize plants at long irrigation intervals). These results are in agreement with the results obtained by El Marsafawy (1991) and Ashoub *et al* (1996).

For maize hybrids and regardless irrigation regimes, water consumptive use in the first season was 2357 and 2284 m^3/fed for V1 and V2, respectively. The values in the second season were 2458 and 2389 m^3/fed for the same respective varieties.

2.2. Water use efficiency (WUE)

Results of water use efficiency are recorded in Table (7). Such results indicated that irrigation at seven days produced the highest water use efficiency, viz 1.13 kg/m^3 in the first season and was 1.15 kg/m^3 for irrigation every seven days until silking and irrigation every two weeks (I2).

For maize varieties, the obtained results shown that the values of water use efficiency were 1.09 and 1.10 kg/m^3 for hybrid TWC 310 in the two growing seasons, respectively. Whereas the values of water use efficiency for TWC 324 reached to 1.05 and 1.11 kg/m^3 for the same respective seasons.

Results in Table (7) showed that irrigation every 7 days or 14 days with maize hybrid TWC 310 were superior in water use efficiency, as compared with other interactions.

3. Simple correlation coefficients

3.1. In the stage from planting to 50 % silking

Results in Table (8) showed that growing degree days have highly significant and negative correlation with LAI and grain yield/plant (r = -0.89 and -0.95, respectively). Temperature is the primary factor driving crops development, where high temperature increases development and consequently reduces yield (Ritchie and Ne Smith, 1991). Solar radiation was found to have highly significant and positive correlation with LAI and grain yield/plant (r = -0.65 and -0.67, respectively). Leaves are the primary organ for solar radiation interception and photosynthesis. Assimilate production and final yield is positively related to solar radiation interception (Gardner, *et al.*, 1985). Results also showed that LAI was found to have highly significant and positive correlation with grain yield/plant (r =0.97).

Table (7): Water consumptive use (m^3/fed) and water use efficiency (kg/m^3) for maize planted in 2004 and 2005 growing seasons

Irrigation	Hybrids	WCU (m^3/fed)		WUE (kg/m^3)	
		2004	2005	2004	2005
I1	V1	2441	2598	1.16	1.13
	V2	2379	2482	1.09	1.11
	Average	2410	2540	1.13	1.12
I2	V1	2384	2448	1.15	1.15
	V2	2274	2383	1.05	1.14
	Average	2329	2416	1.1	1.15
I3	V1	2312	2449	1.07	1.07
	V2	2253	2400	1.1	1.09
	Average	2283	2425	1.09	1.08
I4	V1	2292	2336	0.97	1.05
	V2	2230	2289	0.94	1.09
	Average	2261	2313	0.96	1.07
	V1	2357	2284	1.09	1.10
	V2	2458	2389	1.05	1.11
Over all average		2320	2423	1.07	1.11

Table (8): Correlation matrix between maize plant yield and growing degree days, solar radiation, and leaf area index at the silking stage over the two growing seasons

Characters	GDD	SR	LAI	PLY
Growing degree days (GDD)	1.00			
Solar radiation (SR)	0.60**	1.00		
LAI	-0.89**	0.65**	1.00	
Yield per plant (PLY)	-0.95**	0.67**	0.97**	1.00

** Significant at 0.01 level.

3.2. In the stage from planting to maturity

Simple correlation coefficient between grain yield/plant and its component are presented in Table (9). The results showed that ear length, ear diameter, number of rows/ear, number of grains/row, number of grains/ear, LAI and 100-grain weight were positively and significantly correlated to grain yield/plant with correlation coefficient values equals to 0.97, 0.98, 0.81, 0.95, 0.85, 0.97 and 0.95, respectively. The above mentioned characters are important yield components. Assimilate production and translocation to the growing grain is done by the leaves (Tollenaar and Daynard 1982). Number of barren plants was found to be negatively and significantly correlated to grain yield/plant with correlation coefficient values equals to -0.87, respectively. These finding are in agreement with those obtained by Hassib (1997), El-Afandy and Abdel-Aziz (2000) and Mohamed *et al.*, (2002).

Table (9): Simple correlation coefficient between maize grain yield/plant and its components

	EarL	EarD	Row/E	Grain/R	G#/Ear	BarP	LAI	100-G	PLY
EarL	1.00								
EarD	0.98**	1.00							
Row/E	0.79**	0.83**	1.00						
Grain/R	0.99**	0.97**	0.77**	1.00					
G#/E	0.86**	0.87**	0.98**	0.84**	1.00				
BarP	-0.95**	-0.92**	-0.69**	-0.96**	-0.77**	1.00			
LAI	-0.95**	-0.96**	-0.85**	-0.92**	-0.88**	0.85**	1.00		
100-G	0.96**	0.95**	0.85**	0.93**	0.91**	-0.86**	-0.96**	1.00	
PLY	0.97**	0.98**	0.81**	0.95**	0.85**	-0.87**	0.97**	0.96**	1.00

** Significant at 0.01 level.

EarL=Ear length, EarD=Ear diameter, Row/E=No. of rows/ear, Grain/E=No. of grains/row, G#/Ear=No. of grains/ear, BarP=No. of barran plants, X7=LAI, 100-G=100-grain weight, PLY=Grain yield/plant

4. Stepwise regression analysis

4.1. In the stage from planting to silking

Number of rows/ear (Row/E) and leaf area index (LAI) in the stage silking were found to be the most important yield components in the stage from planting to silking, which have the highest relative contribution (R^2) to maize plant yield (Table 10). Results also showed that R^2 was high (0.936) and the standard error of estimates was low (SE% = 3.67).

4.2. In the stage of from planting to maturity

In the stage from planting to maturity, five yield components were found to have high relative contribution to maize plant yield. These yield components were ear diameter (EarD), number of barran plants (BarP), ear length (EarL), number of rows/ear (Row/E) and leaf area index (LAI) (Table 10). Results also showed that R^2 was high (0.938) and the standard error of estimates was low (SE% = 3.51). These results were in agreement with the results obtained by Ashmawy and Mohamed (1998) and Mohamed *et al.* (2002).

Table (10): Contributing yield components to maize plant yield as revealed by stepwise multiple linear regression for two growth stages

Stage	R^2	Adj R^2	SE%	Prediction Equation
1. days to silking	0.936	0.935	3.67	$\hat{Y}=523.226-0.112(GGD)^{**}+0.028(SR)-2.195(Row/E)^{**}+11.289(LAI)^{**}$
2. days to maturity	0.938	•.936	3.51	$\hat{Y}=-445.75+98.978(EarD)^{**}-3.682(BarP)^{**}+11.662(EarL)^{**}-4.250(RowE)^{**}+7.144(LAI)^{**}$

** Significant at 0.01 level.

5. Principal component analysis:

Principal component analysis results over two seasons of 2004 and 2005 showed that two independent components were considered (Table 11). The first component accounted for 95.045 % of the total variation. This component included ear length, number of grains/row, number of grains/ear, 100-grain weight and plant yield. The second component accounted for 4.955% of the total variation. This component was represented by ear diameter and number of rows/ear. Principle component analysis showed that these four variables were highly correlated with maize plant yield. This result was in agreement with what was obtained by Ashmawy and Mohamed (1998).

Table (11): Results of principal component analysis over both seasons of 2004 and 2005

Characters	Components	
	1	2
Ear length (cm)	0.352	-0.221
Ear diameter (cm)	0.225	0.651
No. of rows/ear	0.266	0.593
No. of grains/row	0.508	-0.210
No. of grains/ear	0.496	0.064
100-grain weight (g)	0.357	-0.081
Grain yield/ plant (g)	0.351	-0.348
Percentage variance	95.045	4.955
Cumulative variance	95.045	100.00

CONCLUSION

The results indicated that the highest plant yield for maize planted in both growing seasons of 2004 and 2005 was obtained when the plants were irrigated every week throughout the season. Furthermore, the highest yield was obtained for TWC 324 for the two growing seasons. This study also revealed that irrigation every 7 days or 14 days with maize hybrid TWC 310 were superior in water use efficiency, as compared with other interactions.

Three statistical procedures were used to determine the most important yield components. Simple correlation analysis revealed that seven yield components were found to be highly significant and correlated with plant yield. Whereas, multiple linear regression analysis exposed five yield components that had the highest contribution to maize plant yield with R^2 equals to 0.938. However, principle component analysis was more efficient than simple correlation analysis and stepwise multiple linear regression analysis, which assigned only four yield components that could accounted for 95.045 % of the total variation. These four yield components were ear length, number of grains per row, number of grains per ear, and 100-grain weight. Therefore, it is recommended to select for these four components in the breeding programs.

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دراسة العلاقه بين الرى وبعض اصناف الذره الشاميه على المحصول ومكوناته والعلاقات المائيه باستخدام بعض الطرق الاحصائيه

فؤاد أحمد فؤاد خليل *، ساميه جوده عطيه محمد **

* قسم بحوث المقننات المائيه والرى الحقلى – معهد بحوث الاراضى والمياه والبيئه – مركز البحوث الزراعية

** المعمل المركزي لبحوث التصميم والتحليل الإحصائي – مركز البحوث الزراعية

أجريت تجربتان حقليتان بالجيزة خلال موسمي ٢٠٠٤ و٢٠٠٥ لدراسة استجابة محصول الذرة الشامية لتأثير أربعة فترات للري (الري كل ٧ أيام، الري كل ٧ أيام حتى ظهور الحريره ثم كل أسبوعيين حتى الحصاد، الري كل أسبوعيين حتى ظهور الحريره ثم كل ٧ أيام حتى الحصاد، الري كل أسبوعيين طول موسم النمو. واستخدم تصميم القطع المنشقة مرة واحدة في ثلاث مكررات وتم التحليل الإحصائي لكل من تحليل التباين – الارتباط البسيط – الانحدار المتعدد المرحلي وأظهرت الدراسة النتائج التالية:

١- أظهرت معاملة الري علي وجود اختلافات معنوية بين الصفات المدروسة للموسم الزراعي الأول والثاني وحققت صفة قطر الكوز، عدد الحبوب بالصف، عدد الحبوب بالكوز، عدد النباتات الذكر ومحصول البيولوجي للفدان معنويه بالنسبة الموسم الزراعي الأول وكذلك صفة طول الكوز، قطر الكوز، عدد

النباتات الذكر، محصول الحبوب بالنبات، محصول الحبوب بالفدان ومحصول البيولوجي بالفدان فى الموسم الثانى .

٢- أوضحت النتائج عدم وجود فروق معنوية بين الهجين الثلاثي ٣١٠ والهجين الثلاثي ٣٢٤ ماعدا عدد الحبوب بالكوز في الموسم الزراعي الأول والمحصول البيولوجي في الموسم الزراعي الثاني وربما يرجع ذلك لأنهما قريبين فى التركيب الوراثى .

٣- واظهرت النتائج ايضا ان محصول الذره الشاميه كان اعلى فى الموسم الثانى عن الأول وقد يرجع ذلك لتوفر ظروف جويه مناسبه لنموالنباتات فى الموسم الثانى

٤- أوضحت النتائج أن متوسط الأستهلاك المائى لمحصول الذرة الشامية فى منطقة الجيزة تحت ظروف معاملات التجربة تراوح بين ٢٣٢٠، ٢٤٢٣ م٣/ فدان فى الموسم الأول والثانى على الترتيب .

٥- واظهر التفاعل بين الهجن والرى ان التفاعل بين الهجين الثلاثى ٣١٠ والرى كل سبعة ايام اعطى اعلى محصول وأعلى كفاءة استعمالية لمياة الرى.

٦- دلت نتائج تحليل الارتباط البسيط علي وجود ارتباط موجب وعالي المعنوية بين محصول النبات وسبع صفات من مكونات المحصول وهى طول الكوز وقطر الكوز وعدد الصفوف بالكوز وعدد الحبوب بالصف وعدد الحبوب بالكوز ودليل مساحه الاوراق ووزن المائه حبه .

٧- أوضحت نتائج تحليل الانحدار المرحلي أن خمس من الصفات كانت اكثر إسهاما في محصول النبات حيث كانت نسبة المساهمة (R^2) ٠,٩٣٨ .

٨- بينما كان اكثر التحاليل كفاءه هوتحليل المكون حيث اظهرمساهمة اربع صفات فقط بنسبه ٩٥,٠٥ % من الاختلافات الكليه . وهذه الصفات هى: طول الكوز، عدد الحبوب بالصف، عدد الحبوب بالكوز، وزن المائة حبة.

ومما سبق يمكن التوصيه بالاتى:

١- زراعه الهجين الثلاثي ٣٢٤ مع الرى كل اسبوع طول الموسم .

٢- يوصى بالانتخاب لصفات طول الكوز، عدد الحبوب بالصف، عدد الحبوب بالكوز، وزن المائة حبة فى برامج التربيه الخاصه بمحصول الذره الشاميه.