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# EFFECT OF IRRIGATION AT DIFFERENT AVAILABLE SOIL MOISTURE LEVELS, N AND K FERTILIZATION ON MAIZE YIELD AND ITS ATTRIBUTES

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## ABSTRACT

A two-year experiment was carried out at Shalakan Kalubia, Agric. Res. Sta., NRC, Egypt, during 2000 and 2001 seasons. The study aimed to investigate the effect of irrigation, I, at different available soil moisture, (ASM), contents ($I_{40}$, $I_{60}$ and $I_{80}$ %), nitrogen fertilization levels, ($N_{100}$, $N_{110}$ and $N_{120}$ Kg N/fed) and potassium levels, ($K_{12}$, $K_{24}$ and $K_{36}$ kg $K_2O$/fed) on maize yield and some of its attributes. A combined analysis was performed for the two seasons. The obtained results showed that most of the differences among means were significant either regarding the independent factors or their different interactions. Gradual and significant increases in grain yield/fed and most of its attributes were observed as the level of any independent factor was increased. The higher grain yield/fed was produced by the combination of irrigation at 80% ASM and addition of 110 kg N/fed along with 36 kg $K_2O$/fed.

Equilibrity among interaction means showed possibilities of replacement among them. With this respect $I_{60}$% x $N_{100}$ could replace $I_{40}$% x $N_{110}$ Also $I_{80}$% x $N_{110}$ x $K_{36}$ could replace $I_{80}$% x $N_{110}$ x $K_{24}$.

Water consumptive use, WCU, differed according to the season and level of irrigation. The calculated WCU ranged between 1942.0 to 2800.0 $m^3$/fed, distributed in 7 to 12 irrigations. Water use efficiency, WUE differed between 1.31 to 1.79 kg/$m^3$, according to the level of irrigation, being higher for the lower irrigation level.
**Keywords:** maize, corn, *Zea mays* L. irrigation, NK fertilization, WCU and WUE.

## INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in Egypt, due to its acreage, 1.66 million fed, total production 5.69 million ton and cash value. Such production does not cover human local needs, Anonymous (2003).

In addition, Egypt is facing a daily battle to save irrigation (I) water from the over use. Many researchers are convinced that saving irrigation water is possible. Literature showed positive and negative relationships between watering and maize growth, yield attributes and grain yield. The positive relationship was observed between frequent irrigation and plant height, no. of leaves/plant, (Abdou, 2005), no. of rows/ear, (El Shafeei, 1993), no. of kernels/row, (El-Ganayni, 2000), no. of kernels/ear and grain index, (Mekkei, 1995), grain yield/fed (Abo El-Kheir, 2000) and (Abdou, 2005).

On the other hand, negative relationship was detected between grain yield/area and higher irrigation, (lewis, 2001). In addition, no effect was detected due to varying irrigation level on some traits, of them no. of grains/ear, (Khedr, 1986) as well as no, of rows/ear, grain index and no. of leaves/plant, (El-Ganayni, 2000).

The promoting effect of N on maize growth and yield is extensively reported in the literature. The difference among the results concerning these respects mainly lie in N level used. Where, some researchers accepted N application up to 140 kg N/fed, (El-Marsafawy, 1995), to 150 kg N/fed (Hassan, 1999), (Soliman *et. al.*, 1999) and to 180kg N/fed, (Tag El-din and Ashmawi, 1999). Different N additions enhanced plant height, no. of leaves/plant and grain yield fed., (Ji Yun Jin, 2001)

Potassium was considered for a near time, in the Egyptian view, as a neglector fertilizer, especially in the old soils. Nowadays, potassium reflects particular problem which lies in its depletion, which amounts about 55.8 kg $K_2O$/fed, yearly (Hamissa *et. al.*, 1971). Such removal of K can cause a tragic problem if not compensated by K fertilization. Regardless the previous specific case of K fertilization in Egypt, potassium in general plays a remarkable role in stomatal opening process which controls evapotranspiration, (Zeiger and Hepler, 1977) and increases water use efficiency, (Rehm and Schmitt, 1997) as well as (Ball, 2001).

Interaction among irrigation and N levels had insignificant effect on some traits as plant height, no. of leaves/plant, no. of rows/ear and 100 kernel weight, (El-Shafeei, 1993). However, grain yield/plant and per fed were significantly affected by this interaction, (El-Ganayni, 2000).

The combination between irrigation and K levels showed significant increments due to increasing the levels of both factors. Such relations were detected on plant height, (Aina, 1980), no. of grains/ear, (El-Marsafawy, 1995) and grain yield/fed, (Abdou, 2005). However, Abd El-Mottaleb (1987) found no significant effect due to the combination I x K in this respect.

Therefore, the present study aimed to study the effect of irrigation at different available soil moisture levels, N and K fertilization and their interactions on the growth and yield of maize, to find out the optimum combination treatment which maximizes grain yield of maize.

## MATERIALS AND METHODS

Two field experiments were carried out in the Agricultural Research Station, National Research Center, at Shalakan, Kalubia Governorate, Egypt, during 2000 and 2001 seasons. In both seasons, maize single cross 10 was planted after onion in June $24^{th}$. The experimental plot area was 10.8 $m^2$, consisting of six rows, each of 3.0m length and 0.6 m apart. Hills were spaced 30 cm apart. Thinning, before the first Irrigation, secured one plant/hill. Harvest was in October $25^{th}$. Some climatic factors prevailing in the site are given in Table (1-a).

The experiment was conducted through a controlled surface irrigation net work, consisting of galvanized pipes, valves and flows meter gauges. Calcium superphosphate (15.5% $P_2O_5$) at 31.0 Kg/fed and potassium sulphate ( 48.0% $K_2O$) at the tested levels were added at once before plowing. Nitrogen was applied as ammonium sulphate (20.6% N), at the tested levels, in two equal parts, before the first and second irrigations. Irrigation was withheld 15 days before harvest. The other agricultural practices were done as usual.

Soil samples were taken at different depths to determine the physical and chemical analysis of the soil. The soil was clay loamy, having 0.75 %. coarse sand, 26.25%. fine sand, 45.24%. silt, 27.56% clay and pH of 7.8. Field capacity (FC) and wilting point (WP) were determined according to Gomma (1993). The FC, WP, available soil moisture (ASM) and Bulk density (Bd) as means over the two seasons were 33.19% , 13.00%, 20.19% and 1.10% gm/cm$^3$, respectively.

**Table 1-a: Weekly means of air temperature (Temp C°) and relative humidity % (RH%) during the two growing seasons at Shalakan, during the two seasons.**

| Date | Week | Temp. C° | | RH % | |
|---|---|---|---|---|---|
| | | 2000 | 2001 | 2000 | 2001 |
| 24 / 6 | 1 | 29.0 | 27.8 | 57.4 | 56.1 |
| 1/ 7 | 2 | 29.7 | 28.3 | 59.0 | 59.7 |
| 8 / 7 | 3 | 31.3 | 29.1 | 55.9 | 56.6 |
| 15 / 7 | 4 | 29.4 | 29.5 | 58.7 | 59.6 |
| 22 / 7 | 5 | 29.4 | 29.9 | 52.9 | 61.0 |
| 29 / 7 | 6 | 30.7 | 30.7 | 55.4 | 61.6 |
| 5 / 8 | 7 | 28.9 | 31.4 | 63.9 | 62.3 |
| 12 / 8 | 8 | 29.8 | 30.5 | 61.9 | 58.6 |
| 19 / 8 | 9 | 30.0 | 29.8 | 59.9 | 55.7 |
| 26 / 8 | 10 | 28.9 | 29.6 | 62.1 | 59.6 |
| 2 / 9 | 11 | 28.8 | 30.4 | 61.3 | 56.6 |
| 9 / 9 | 12 | 28.6 | 28.2 | 63.3 | 57.9 |
| 16 / 9 | 13 | 27.9 | 28.3 | 63.4 | 59.9 |
| 23 / 9 | 14 | 26.9 | 29.3 | 60.7 | 62.3 |
| 30 / 9 | 15 | 25.8 | 25.8 | 67.0 | 60.6 |
| 7 / 10 | 16 | 26.6 | 25.8 | 58.3 | 63.4 |
| 14 / 10 | 17 | 24.4 | 25.9 | 69.6 | 65.3 |
| 21 / 10 | 18 | 21.4 | 23.1 | 66.5 | 65.3 |

Source : Bahtim Agrometeorological Station

**Factors and experimental design :**

Irrigation (I), N and K levels in a factorial experiment (3x3x3) were studied. Irrigation was tested at some levels of available soil moisture (ASM), viz. $I_{80\%}$, $I_{60\%}$ and $I_{40\%}$. Nitrogen levels were $N_{100}$, $N_{110}$ and $N_{120}$ Kg N/fed. Potassium levels were 12, 24 and 36 Kg $K_2O$/fed.

A split-plot design with three replicates was used. The main plots were devoted to the irrigation treatments. The sub plots were assigned for nitrogen levels. The sub-sub ones were occupied by potassium levels. The borders among whole plots and replicates were 2.0 m to avoid water infiltration effects.

**Studied topics :**

**Yield and yield attributors**

At harvest, ten guarded plants were randomly taken from the inner two rows of each sub sub plot, to measure the studied traits. Yield/plot was weighed, hence yield/fed was calculated. Grain moisture was estimated using grain moistures tester and then yield was readjusted to 15.5%. grain moisture. The studied traits were as follows:

1- Plant height, PH (cm). 2- No. of leaves/plant, No L/P.
3- No. of ears /plant, No. E/P. 4- No. of rows/ear, No. R/E.
5- No. of Kernels/row, No. K/R 6- No. of Kernels/ear No. K/E.
7- Grain weight/ear GW/E, (gm).8- Grain index GIX , (gm).
9- Grain yield/plant, GY/P, (gm). 10- Grain yield/fed, GY/fed. (ard)*
* one ard . = 140kg

**Water relationships :**

Soil moisture content was determined beginning with the second irrigation, at 48 hours after irrigation. Soil samples were taken with an auger at 0.0 to 60.0 cm depth from each plot. Samples were immediately transferred in tightly closed aluminum cans, weighed, oven dried at 105°C to a constant weight. Moisture content was determined gravimetrically. Irrigation was practiced when the tested soil moisture content reached the level of every irrigation treatment, 40, 60 and 80% of available soil moisture contents.

Water requirements as expressed in water consumptive use WCU, ($m^3$/fed) which was estimated as the summation of amounts of irrigation water applied in the different irrigations. Moreover, daily WCU was calculated by dividing seasonal WCU by number of days from planting to harvest. Water consumptive use was estimated according to Hansen *et. al.* (1980) as follows:

$$WCU = \left(\frac{e_2 - e_1}{100}\right) (Bd) \left(\frac{SD}{100}\right) (area/m^2)$$

Where :
$e_2$ = Soil moisture percent after irrigation.
$e_1$ = Soil moisture percent before irrigation.
Bd = Bulk density of soil (g/$cm^3$).
D = The irrigation soil depth (cm).
Area/$m^2$ = standard used area, i.e. in Egypt, 1 fed = 4200.8 $m^2$

Table 1-b represents the calculated values in this respect.

**Table (1-b): Seasonal and daily water consumptive WCU ($m^3$/fed) as affected by studied irrigation levels through the two seasons.**

| Variable: I level | Variable: Season | Number of irrigations* | Seasonal WCU $m^3$/ fed | Daily WCU $m^3$/fed |
|---|---|---|---|---|
| $I_{40\%}$ | 2000 | 8 | 2284.7 | 12.7 |
| | 2001 | 7 | 1942.5 | 10.8 |
| $I_{60\%}$ | 2000 | 10 | 2520.3 | 20.1 |
| | 2001 | 9 | 2085.3 | 11.3 |
| $I_{80\%}$ | 2000 | 12 | 2800.0 | 22.33 |
| | 2001 | 12 | 2345.8 | 19.55 |

* Including planting and first (Mohaya) irrigations.

Water use efficiency, WUE, (Kg/m$^3$) was calculated according to Vites (1965) as follows:

$$WUE\ \left(\frac{Grain\ yield, Kg\ /\ fed.}{WCU, m^3\ /\ fed.}\right).$$

**Statistical analysis :**

Data were exposed to the proper statistical analysis of variance. A combined analysis was performed. Means were compared by LSD test at $\alpha_{0.05}$. All statistical analyses were carried out according to Le Clerg *et. al.*, (1966).

## RESULTS AND DISCUSSION

The effect of year and its interactions are excluded in the present study and will discussed in further one. The following ANOVA was used to carry on the combined analysis.

| SOV | df |
|---|---|
| Year, Y. | 1 |
| Replication | 4 |
| Irrigation, I. | 2 |
| Y x I | 2 |
| Error | 8 |
| Nitrogen, N | 2 |
| Y x N | 2 |
| I x N | 4 |
| Y x I x N | 4 |
| Error | 24 |
| Potassium, K | 2 |
| Y x K | 2 |
| I x K | 4 |
| Y x I x K | 4 |
| N x K | 4 |
| Y x N x K | 4 |
| I x N x K | 8 |
| Y x I x N x K | 8 |
| Error | 72 |
| Total | 161 |

**1-Independent factors effect:**

Table 2 shows the combined means of the effect of independent factors, irrigation levels, I, N levels and K levels on maize yield and its attributes.

**a- Irrigation levels effect:**

It is, obvious from Table 2, that most of the studied traits were significantly different by varying irrigation levels, except the no. of ears/plant and no. of rows/ear. A gradual and significant increase was observed on the significantly affected traits as irrigation level was increased, except grain index, where an apposite was quite true, but the difference between the middle and high irrigation level was insignificant. These results declare a promoting effect of frequent irrigation on maize yield and its attributers, due to irrigation at 80% instead of 60 or 40% of ASM. Taller plants grown under irrigation at high available soil moisture may be attributed to the enhancing role of enough watering for cell division, expansion and enlargement and consequently internodes length. Many investigator came to similar results, of them. El-Ganayni (2000), Mekkei (2000) and Abdou (2005). Moreover, the reduction in no. of leaves by increasing the depletion of available soil moisture, could be attributed to a rapid leaf senescence. The present findings are in line with those of Mekkei (2000) and Abdou (2005).

The number of kernels/row showed a positive response to frequent irrigation, (Table 2). This means that such trait was highly affected by water deficit. The greater no. of kernels/row may be attributed to the high availability of soil moisture due to frequent irrigation, and hence high availability of plant nutrients. Number of kernels/ear followed no. of kernels/row, indicating that the former trait may be not tightly controlled by no. of rows/ear which did not significantly respond to varying water level. Moreover, the increase in grain weight/ear, under frequent irrigation, may be accepted by the previous corresponding increments in no. of grains/ear. As previously mentioned, grain index showed different trend, where the heaviest grains were obtained by the lowest irrigation level. It is usual to decide a negative relation between no. of grains/ear and grain index. These results are in accordance with those of El-Ganayni (2000), but in different with those of Abdou (2005) .

**Table 2 : Combined means of the studied traits as affected by levels of independent factors, irrigation (I), nitrogen, N and potassium, K levels.**

| Traits | PH (cm) | L/P No. | E/P No. | R/E No. | K/R No. | K/E No. | GW/E (gm) | GIX (gm) | GY/P (gm) | GY/fed ard. |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | | | | | | | | | | |
| **I at % ASM** | | | | | | | | | | |
| 40 | 238.83 | 13.20 | 17.0 | 13.75 | 38.64 | 5.24.31 | 187.70 | 35.72 | 217.82 | 24.20 |
| 60 | 243.18 | 13.63 | 1.26 | 13.59 | 40.77 | 553.75 | 196.25 | 35.32 | 246.50 | 25.59 |
| 80 | 248.59 | 14.41 | 1.23 | 13.59 | 42.96 | 582.96 | 206.63 | 35.28 | 251.93 | 26.56 |
| LSD at α 0.05 | 0.27 | 0.04 | Ns | Ns | 0.27 | 1.72 | 2.95 | 0.18 | 4.11 | 0.13 |
| **N, Kg/fed** | | | | | | | | | | |
| $N_{100}$ | 238.68 | 13.58 | 1.19 | 13.65 | 39.31 | 536.41 | 189.15 | 35.24 | 224.86 | 24.54 |
| $N_{110}$ | 243.50 | 13.91 | 1.20 | 13.59 | 40.84 | 554.61 | 199.42 | 35.80 | 239.48 | 25.84 |
| $N_{120}$ | 248.43 | 13.76 | 1.26 | 13.52 | 42.24 | 570.00 | 202.02 | 35.28 | 251.91 | 25.98 |
| LSD at α 0.05 | 0.61 | 0.05 | 0.06 | Ns | 0.31 | 1.45 | 1.01 | 0.28 | 1.85 | 0.09 |
| **K, kg/fed** | | | | | | | | | | |
| $K_{12}$ | 239.83 | 13.52 | 1.22 | 13.43 | 40.37 | 541.35 | 184.25 | 33.97 | 222.96 | 24.95 |
| $K_{24}$ | 246.09 | 13.95 | 1.19 | 13.54 | 40.97 | 553.85 | 197.74 | 35.67 | 234.80 | 25.65 |
| $K_{36}$ | 244.69 | 13.78 | 1.25 | 13.80 | 41.03 | 565.82 | 208.61 | 36.69 | 258.49 | 25.76 |
| LSD at α 0.05 | 0.028 | 0.06 | Ns | 0.22 | 0.40 | 1.22 | 1.00 | 0.22 | 1.43 | 0.07 |

For grain yield, it is evident from Table 2 that the frequent irrigation at $I_{80\%}$ significantly out yielded the other two irrigation levels, where, irrigation at

$I_{40\%}$ gave the lowest yield/plant and per fed. These results show that grain yield/plant and consequently per/fed, benefited from the positive effects, on the previous attributers, due to the stimulating role of enough watering, supplied in time needed. The results herein are in harmony with those of Attallah (1996), who found that prolonged irrigation interval resulted in a remarkable reduction in maize grain yield/plant. As irrigation at $I_{40\%}$ had a detrimental effect which seemed extended through a period from early vegetative growth to grain filling stages, no surprise herein that $I_{40\%}$ with prolonging irrigation interval, could subjected corn plants to water stress. With this respect, Chapman (1966) reported that corn was found to be susceptible to drought several weeks before and after flowering. In addition, Casanovas *et. al.*, (2003) decided that drought during flowering negatively affects grain yield in maize. Therefore, irrigation at $I_{40\%}$ might have not supply sufficient watering during flowering stage. In such cases, photosynthesis and efficiency of biological processes are adversely affected the accumulation of plant dry matter, Slatyer (1957). In addition, Silivius *et. al.*, (1977) reported that shortage water results in a limited carbon dioxide exchange.

**b- Nitrogen level effect:**

Table 2 gives the combined means of the studied traits as affected by N level, where, significant effects with all respects, except no. rows/ear were observed. The products were gradually and significantly increased as N level was increased with respect to plant height, no. of ears/plant, no. of kernels/row, no. of kernels/ear, grain weight/ear, grain yield/plant and per fed. These results indicate that additional N was indispensable for enhancing the previous traits. But, the use of $N_{110}$ significantly surpassed the two other levels regarding the no. of leaves/plant and grain index. El-Ganayni (2000) found similar results on plant height, no. of leaves/plant, no. of ears/plant, no. of kernels/ears and grain yield/plant. El-Marsafawy (1995) added that no. of kernels/ear could response to further N addition up to 140 Kg/fed.

Grain yield/fed, as the final result of all contributors was increased from 24.54, to 25.84 and then to 25.98 ard/fed by the increase of N from 100 to 110 and 120 Kg/fed, respectively. Such yield increments might be attributed to the corresponding positive effects previously mentioned on plant height, no. of leaves/plant, no. of ears/plant, no. of kernels/ear, grain weight/ear and grain yield/plant. Generally, nitrogen has major positive roles in plant nutrion namely, component of chloraphll, amino acids, enzymes, vitamins and hormones. Nitrogen plays an important role in carbohydrates utilization. N stimulates development and activity of root, supports the uptake of other nutrients, (Stevenson, 1986). Many authors found similar results, of them Ashoub *et. al.*, (1997), Tag Eldin and Ashmawi (1999), Soliman *et. al.*, (1999), El-Ganayni (2000) and Abdou (2005).

**C- Pottasium level effect :**

Except the number of ears/plant, all the studied traits were significantly increased due to the increase of K level. The first K increment increased both the plant height and number of leave plant, but the second one decreased them. However, both K increments produced significant increase in each of no. of kernels per row, no of kernels per ear, seed index and hence grain weight/ear. This war reflected in the grain yield/plant and the final grain yield/fed. It is understanding to note that the number of rows/ear was not increased unless the K level was increased to 36 Kg $K_2O$/fed i.e, the second K increment was added .

These results clearly indicate that the increase of K level enhanced the growth of maize plants as expressed in plant height and number of leaves/plant. This growth improvements was reflected in all yield attributes and hence the final grain yield/fed. When the use of 12, 24 and 36 Kg $K_2O$/fed produced 24.95, 25.65 and 25.76 ard. fed, respeahaely.

Promoting growth by K use was explained and attributed to different reasons. Zeiger and helper (1977), reported that opening stomata is mainly controlled by K, which increases $CO_2$ uptake through gas exchange and hence increases the rate of photosynthesis Also, Follett *et. al.* (1981) found that adequate K decreases respiration rate. Bhaddal and Malik (1988), added that K is an activator of many enzymes essential for photosynthesis and respiration, leading to form starch and protein. The role of K extends to leaf water potential and osmotic potential at full turgor which were better with K presence than its absence, (Premachandra *et. al.*, 1993). The present results are in full harmony with those of Gelderman *et. al.* (2000), Ji-Yun Jin (2001) and Abdou (2005). Abd El-Mottaleb (1987) found different results .

**2- First order interaction effects:**

**a- Irrigation x Nitrogen interaction (I x N ):**

Table 3 presents the combined means of the studied traits, as affected by the combination I x N. The combined analysis showed significant effects on all studied traits except no. of rows/ear. The results also show that different levels of irrigation succeeded to interact with the levels of nitrogen. It is clear that the differences among irrigation levels under the highest N levels were higher than those of N under the highest level of irrigation. This means that watering may plays a certain role exceeding N one, for enhancing maize yield. This finding is logic, however plant can grow without N fertilization, while the opposite is not true.

**Table 3 : Combined means of the studied traits as affected by levels of irrigation, I, nitrogen, N and their interaction, I x N.**

| Traits<br>Interactions | PH (cm) | L/P No. | E/P No. | R/E No. | K/R No. | K/E No. | GW/E (gm) | GIX (gm) | GY/P (gm) | GY/fed ard. |
|---|---|---|---|---|---|---|---|---|---|---|
| **I x N** | | | | | | | | | | |
| $40xN_{100}$ | 234.61 | 12.94 | 1.13 | 13.56 | 36.96 | 500.59 | 181.62 | 36.23 | 205.22 | 22.94 |
| $40xN_{110}$ | 238.56 | 13.39 | 1.18 | 13.61 | 38.23 | 520.24 | 186.94 | 35.83 | 221.68 | 24.61 |
| $40xN_{120}$ | 243.33 | 13.27 | 1.19 | 13.56 | 40.75 | 552.09 | 134.55 | 35.11 | 226.57 | 25.06 |
| $60xN_{100}$ | 237.55 | 13.56 | 1.22 | 13.61 | 39.48 | 537.54 | 187.10 | 34.78 | 227.40 | 24.56 |
| $60xN_{110}$ | 224.05 | 13.67 | 1.23 | 13.67 | 41.04 | 560.57 | 203.14 | 36.06 | 249.03 | 25.94 |
| $60xN_{120}$ | 247.94 | 13.67 | 1.33 | 13.50 | 41.79 | 563.15 | 198.51 | 35.11 | 263.06 | 26.28 |
| $80xN_{100}$ | 243.89 | 14.23 | 1.23 | 13.78 | 41.50 | 571.09 | 198.73 | 34.72 | 241.95 | 26.11 |
| $80xN_{110}$ | 247.89 | 14.67 | 1.19 | 13.50 | 43.24 | 583.02 | 208.17 | 35.50 | 24.74 | 26.95 |
| $80xN_{120}$ | 254.01 | 14.33 | 1.27 | 13.50 | 44.14 | 594.76 | 213.00 | 35.61 | 266.11 | 26.62 |
| **LSD at $\alpha$ 0.05** | 1.06 | 0.08 | 0.06 | Ns | 0.54 | 2.51 | 1.75 | 0.48 | 3.20 | 0.15 |

Table 3 broadcasts that the highest grain yield/fed was 26.62 ard. Such superior yield was produced by the combination $I_{80\%}$ x $N_{120}$. Abd El-Halem *et. al.*, (1990) and El-Ganayni (2000) found similar results.

**b- Irrigation x Potassium interaction ( I x K ) :**

Table 4 gives the combined means of the combination I x K. All studied traits, except no. of ears/plant were significantly affected. Mostly, the combination $I_{80\%}$ x $K_{36}$ yielded the highest products. This means that the levels of each factor clearly succeeded to interact with the corresponding ones. It is obvious, from Table 4, that the differences among irrigation levels under the same level of K were more clear than those of K under the same level of irrigation. These results draw the attention that water plays an important role exceeding K one for promoting maize yield. The opposite was not true. Follet *et. al.* (1981) explained the positive relationship between irrigation and K. However, well supplied plants with K element has abundant roots which can efficiently utilize soil moisture. In the same time, plant grown under low K supplies have very few roots, thereby resulting in low water use. Yapa *et. al.* (1991) agreed with the present results. They added that high K application could overcome the harmful effects of soil moisture stress. Moreover, El-Ganayni (2000) summarized the relation between soil water and K as any increase in the level of each increased the positive effect of the other. He added that the relative reduction in any level of one of the two factors could be compensated by certain additions of the other one .

**Table 4 : Combined means of the studied traits as affected by levels of irrigation, I, and potassium, K and their interaction, I x K.**

| Traits / Interactions | PH (cm) | L/P No. | E/P No. | R/E No. | K/R No. | K/E No. | GW/E (gm) | G/X (gm) | GY/P (gm) | GY/fed ard. |
|---|---|---|---|---|---|---|---|---|---|---|
| I x K | | | | | | | | | | |
| 40x$K_{12}$ | 234.44 | 12.83 | 1.16 | 13.22 | 37.77 | 489.37 | 169.24 | 33.95 | 194.99 | 23.56 |
| 40x$K_{24}$ | 241.51 | 13.44 | 1.13 | 13.67 | 38.74 | 529.57 | 190.40 | 35.94 | 214.87 | 24.33 |
| 40x$K_{36}$ | 240.56 | 13.33 | 1.21 | 13.83 | 39.42 | 544.99 | 203.47 | 37.28 | 243.60 | 24.72 |
| 60x$K_{12}$ | 240.49 | 13.33 | 1.28 | 13.72 | 39.89 | 547.59 | 185.23 | 33.72 | 236.13 | 25.00 |
| 60x$K_{24}$ | 245.16 | 14.00 | 1.22 | 13.44 | 41.45 | 556.33 | 198.99 | 35.72 | 142.96 | 25.89 |
| 60x$K_{36}$ | 243.89 | 13.56 | 1.28 | 13.61 | 40.97 | 557.34 | 204.52 | 36.50 | 260.67 | 25.89 |
| 80x$K_{12}$ | 244.56 | 14.39 | 1.21 | 13.33 | 43.46 | 578.11 | 198.27 | 43.22 | 237.75 | 25.29 |
| 80x$K_{24}$ | 251.61 | 14.40 | 1.22 | 13.50 | 42.72 | 557.63 | 203.81 | 35.33 | 246.85 | 26.72 |
| 80x$K_{36}$ | 249.61 | 14.44 | 1.26 | 13.94 | 42.71 | 559.13 | 217.82 | 36.28 | 271.20 | 26.67 |
| LSD at $\alpha$ 0.05 | 0.73 | 0.11 | Ns | 0.38 | 0.70 | 2.11 | 1.73 | 0.38 | 2.48 | 0.13 |

**C- Nitrogen x Potassium interaction ( N x K):**

Table 5 includes the combined means of the studied traits as affected by NxK interaction. Only no. of ears/plant and no. of rows/ear were insignificantly affected. Results shows three groups of data. The first included plant height and no. of leaves/plant, where taller plants and greatest no of leaves/plant were recorded on the combination $N_{120}$ x $K_{24}$ . This means that vegetative growth may did not need for additional K over 24 $K_2O$ Kg /fed when $N_{120}$ was applied. The second group contained no. of rows/plant, no. of kernels/ear, grain weight/ear and grain yield/plant. In such group, the maximum values were given by the combination $N_{120}$ x $K_{36}$. These results declare the importance of no. of kernels/row and per ear as well as grain weight/ear for forming good grain yield/plant. The third group, where the actor combination contained $N_{110}$ and $K_{36}$, included only grain weight/ear, grain index, and grain yield/fed. These result focused the importance of grain weight/ear as an important former for grain yields. Anyhow, the combination $N_{110}$ x $K_{36}$ yielded the superior grain yield/fed, i.e. 26.61 ard.

**Table 5 : Combined means of the studied traits as affected by levels of nitrogen, N and potassium, K their interaction, N x K.**

| Traits / Interactions | PH (cm) | L/P No. | E/P No. | R./E No. | K/R No. | K/E No. | GW/E (gm) | GIX (gm) | GY/P (gm) | GY/fed ard. |
|---|---|---|---|---|---|---|---|---|---|---|
| N x K | | | | | | | | | | |
| $N_{100}xK_{12}$ | 234.10 | 13.33 | 1.20 | 13.28 | 39.35 | 521.82 | 177.41 | 34.01 | 211.90 | 24.22 |
| $N_{100}xK_{24}$ | 241.61 | 13.78 | 1.23 | 13.72 | 39.39 | 540.75 | 193.96 | 35.89 | 237.02 | 24.78 |
| $N_{100}xK_{36}$ | 240.33 | 13..61 | 1.16 | 13.94 | 39.19 | 546.66 | 196.08 | 35.83 | 255.64 | 24.61 |
| $N_{110}xK_{12}$ | 240.83 | 14.00 | 1.21 | 13.50 | 40.72 | 549.12 | 186.65 | 33.94 | 222.92 | 25.01 |
| $N_{110}xK_{24}$ | 245.56 | 13.95 | 1.16 | 13.39 | 41.31 | 552.10 | 195.93 | 35.44 | 227.01 | 25.89 |
| $N_{110}xK_{36}$ | 244.11 | 13.78 | 1.24 | 13.89 | 40.49 | 562.62 | 215.67 | 38.00 | 268.52 | 26.61 |
| $N_{120}xK_{12}$ | 244.56 | 13.22 | 1.24 | 13.50 | 41.05 | 553.13 | 188.68 | 33.94 | 234.06 | 25.62 |
| $N_{120}xK_{24}$ | 251.11 | 14.11 | 1.19 | 13.50 | 42.22 | 568.69 | 203.31 | 35.67 | 240.38 | 26.28 |
| $N_{120}xK_{36}$ | 249.61 | 13.94 | 1.35 | 13.56 | 43.42 | 588.18 | 214.07 | 36.22 | 281.30 | 26.06 |
| LSD at $\alpha$ 0.05 | 0.49 | 0.11 | Ns | Ns | 0.70 | 2.11 | 1.73 | 1.38 | 2.48 | 0.13 |

**3- Second order interaction :**

**Irrigation x Nitrogen x Potassium ( I x N x K ) :**

Table 6 gives the combined means of the studied traits as affected by the combination of the three factors I x N x K. Only no. of ears/plant and no. of kernels/row were insignificantly affected. Number, no. of rows/ear was significantly affected by the combination, This result confirmed the similar one previously mentioned with respect to I x K combination, (Table 4) . It seemed that such latter combination received a support from N and significantly maximized the effect on no. of rows/ear. The maximum grain yield/fed, i.e. 27.50 ard was produced by the combination $I_{60\%}$ x $N_{110}$ x $K_{36}$, which was resulted by highest values on no. of leaves/plant (14.83), no of rows/ear (14.0) and grain weight/ear (226.55 gm). Such progressive values were in turn to grain yield/plant and consequently per fed.

**Equilibrity among interaction combinations :**

The equilibrity among some combinations within the interaction may gives a helpful mean for maize production under the use of the three studied factors. To explain the previous assumption, Table 3 shows that the combinations $I_{40\%}$ x $N_{110}$ and $I_{60\%}$ x $N_{100}$ were not significantly different from each other. This equilibrity means that for producing the same grain yield/fed, N level could be decreased from 110 to 100 Kg/fed if watering levels increased from $I_{40\%}$ to $I_{60\%}$ and versa.

Similar results could be observed in Table 6 too. The combinations $I_{60\%}$ x $N_{110}$ x $K_{36}$, $I_{60\%}$ x $N_{120}$ x $K_{24}$ and $I_{80\%}$ x $N_{110}$ x $K_{24}$ were insignificantly varied. Thus, it is clear that any reduction in one factor could be compensated by a certain increase in the level of other one or ones in the combination, to produce the same grain yield/fed. Such results suit a wide preferability of each factor over the other, for forming a combination. Such preferability would be depended on their economic availability.

**Table 6 : Combined means of the studied traits as affected by levels of irrigation, I, nitrogen, N, potassium, K and their interaction, I x N x K.**

| Traits / Interactions | PH (cm) | L/P No. | E/P No. | R/E No. | K/R No. | K/E No. | GW/E (gm) | GIX (gm) | GY/P (gm) | GY/fed ard. |
|---|---|---|---|---|---|---|---|---|---|---|
| I x N x K | | | | | | | | | | |
| 40x$N_{100}$ x$K_{12}$ | 229.15 | 12.67 | 1.15 | 13.33 | 36.20 | 482.10 | 165.50 | 34.35 | 192.05 | 22.33 |
| 40x$N_{100}$ x$K_{24}$ | 237.17 | 12.83 | 1.13 | 13.33 | 37.40 | 497.93 | 183.45 | 36.83 | 208.00 | 23.33 |
| 40x$N_{100}$ x$K_{36}$ | 237.50 | 13.33 | 1.10 | 14.00 | 37.27 | 521.73 | 195.92 | 37.50 | 215.60 | 23.17 |
| 40x$N_{110}$ x$K_{12}$ | 234.17 | 13.00 | 1.15 | 13.17 | 37.65 | 494.65 | 168.17 | 34.00 | 193.03 | 23.67 |
| 40x$N_{110}$ x$K_{24}$ | 242.85 | 13.83 | 1.12 | 13.83 | 38.43 | 531.98 | 19.85 | 35.83 | 212.20 | 24.67 |
| 40x$N_{110}$ x$K_{36}$ | 238.67 | 13.33 | 1.28 | 13.83 | 38.60 | 534.10 | 201.80 | 37.67 | 259.80 | 25.50 |
| 40x$N_{120}$ x$K_{12}$ | 240.00 | 12.83 | 1.17 | 13.17 | 39.45 | 518.35 | 174.05 | 33.50 | 199.90 | 24.67 |
| 40x$N_{120}$ x$K_{24}$ | 244.50 | 12.65 | 1.15 | 13.83 | 40.40 | 558.80 | 196.90 | 35.17 | 224.40 | 25.00 |
| 40x$N_{120}$ x$K_{36}$ | 245.50 | 13.33 | 1.25 | 13.67 | 42.40 | 579.13 | 212.70 | 36.67 | 255.40 | 25.50 |
| 60x$N_{100}$ x$K_{12}$ | 233.15 | 12.83 | 1.22 | 13.17 | 39.13 | 515.05 | 173.25 | 33.67 | 209.45 | 24.17 |
| 60x$N_{100}$ x$K_{24}$ | 240.50 | 14.17 | 1.25 | 13.83 | 40.02 | 553.57 | 198.43 | 35.83 | 246.50 | 24.83 |
| 60x$N_{100}$ x$K_{36}$ | 239.00 | 13.47 | 1.20 | 13.83 | 39.30 | 544.00 | 189.62 | 34.83 | 226.25 | 24.67 |
| 60x$N_{110}$ x$K_{12}$ | 242.50 | 14.17 | 1.30 | 14.00 | 40.35 | 565.15 | 192.77 | 43.00 | 246.70 | 25.00 |
| 60x$N_{110}$ x$K_{24}$ | 245.15 | 13.67 | 1.15 | 13.17 | 42.33 | 556.87 | 198.00 | 35.50 | 228.95 | 26.00 |
| 60x$N_{110}$ x$K_{36}$ | 244.50 | 13.17 | 1.23 | 13.83 | 40.43 | 559.70 | 218.65 | 38.67 | 271.45 | 26.83 |
| 60x$N_{120}$ x$K_{12}$ | 245.83 | 13.00 | 1.33 | 14.00 | 40.20 | 562.57 | 189.68 | 33.50 | 252.23 | 25.83 |
| 60x$N_{120}$ x$K_{24}$ | 249.83 | 14.17 | 1.27 | 13.33 | 42.00 | 558.57 | 200.55 | 35.83 | 252.63 | 26.83 |
| 60x$N_{120}$ x$K_{36}$ | 248.17 | 13.83 | 1.40 | 13.17 | 43.17 | 568.32 | 205.30 | 36.00 | 284.30 | 26.17 |
| 80x$N_{100}$ x$K_{12}$ | 240.00 | 14.50 | 1.23 | 13.33 | 42.72 | 568.30 | 193.47 | 34.00 | 234.20 | 26.17 |
| 80x$N_{100}$ x$K_{24}$ | 247.17 | 14.35 | 1.30 | 14.00 | 40.77 | 570.75 | 200.00 | 35.00 | 256.57 | 26.17 |
| 80x$N_{100}$ x$K_{36}$ | 244.50 | 13.83 | 1.17 | 14.00 | 41.02 | 574.23 | 202.72 | 35.17 | 235.08 | 26.00 |
| 80x$N_{110}$ x$K_{12}$ | 245.38 | 14.83 | 1.17 | 13.33 | 44.15 | 587.55 | 199.02 | 33.83 | 229.02 | 26.35 |
| 80x$N_{110}$ x$K_{24}$ | 248.67 | 14.35 | 1.20 | 13.17 | 43.15 | 567.45 | 198.95 | 35.00 | 239.88 | 27.00 |
| 80x$N_{110}$ x$K_{36}$ | 249.17 | 14.83 | 1.22 | 14.00 | 42.43 | 594.07 | 226.55 | 37.67 | 274.32 | 27.50 |
| 80x$N_{120}$ x$K_{12}$ | 247.85 | 13.83 | 1.23 | 13.33 | 43.50 | 578.47 | 202.32 | 34.83 | 250.03 | 26.35 |
| 80x$N_{120}$ x$K_{24}$ | 259.00 | 14.50 | 1.17 | 13.33 | 44.25 | 588.70 | 212.48 | 36.00 | 244.10 | 27.00 |
| 80x$N_{120}$x$K_{36}$ | 255.17 | 14.67 | 1.40 | 13.83 | 44.68 | 617.10 | 224.20 | 36.00 | 304.20 | 26.50 |
| LSD at $\alpha$ 0.05 | 0.85 | 0.8 | Ns | 0.66 | Ns | 3.65 | 2.99 | 0.65 | 4.28 | 0.22 |

**5- Water relationship :**

**a - Water consumptive use, WCU, ($m^3$/fed).**

Table 1-b gives the number of applied irrigations, seasonal and daily water consumptive use (WCU), for the three irrigation levels during the two seasons. It is obvious that the amount of irrigation and hence the no. of irrigations were increased as irrigation was applied at a higher ASM level. The number of irrigations ranged between 7 to 12 and the water consumptive use ranged between 1942.5 to 2800.0 $m^3$/fed. The corresponding daily WCU was 10.80 and 23.33 $m^3$/fed in respective order. Such previous estimations were recorded when irrigation was at $I_{40\%}$ in the second season and at $I_{80\%}$ in the first season, respectively. These results indicate that WCU varied according to irrigation level and season. In addition, WCU, in general was

somewhat greater in the first season than the corresponding value in the second one. The present trends are in full agreement with those reported by Ainer *et. al.* (1986), Attia *et. al.* (1994), El-Ganayni (2000) and Abdou (2005).

**b- Water use efficiency, WUE, ($Kg/m^3$) :**

Table 7 declares the calculated WUE ($Kg/m^3$), as affected by irrigation levels in the two studied season. In both seasons, irrigation at $I_{80\%}$ achieved the lowest WUE, viz. 1.31 and 1.61 $Kg/m^3$, in the first and second seasons, respectively. These results may be mainly contributed to the corresponding highest irrigation quantity grain yield viz. 2800.0 and 2345.9 $m^3$/fed in the two respective seasons. On the contrary, irrigation at $I_{40\%}$ resulted in the highest WUE, i.e. 1.46 and 1.78 $kg/m^3$ in the two successive seasons, indicating that low grain yield was accompanied by low. Irrigation quantities. At $I_{60\%}$,WUE was in between the other two values. Vites equation gives different results according to its numerator, grain yield ,and denominator, WCU. Many investigators gave different estimation of WUE.

**Table 7: Water use efficiency, WUE, ($kg/m^3$), as affected by irrigation levels, in the two studied seasons.**

| Variables / I. level | Grain yield Kg/fed | | WCU $m^3$/fed | | WUE, $Kg/m^3$* | |
|---|---|---|---|---|---|---|
| | 1st season | 2nd season | 1st season | 2nd season | 1st season | 2nd season |
| $I_{40\%}$ | 3323.0 | 3453.0 | 2284.7 | 1942.5 | 1.46 | 1.78 |
| $I_{60\%}$ | 3542.0 | 3624.0 | 2520.0 | 2025.3 | 1.41 | 1.79 |
| $I_{80\%}$ | 3656.8 | 3780.0 | 2800.0 | 2345.9 | 1.31 | 1.61 |

*** According to Vites (1965).**

From all the above mentioned results, it could be summarized the followings :

- The independent three factors showed significant effects on most of the studied traits, except no. of ears/plant and no. of rows/ear. Gradual and significant increases in grain yield/fed were observed as the level of each factor was increased.
- The significant superior grain yield/fed was produced by the interactions $I_{80}$ x $N_{120}$, $I_{80}$ x $K_{24}$, $N_{120}$ x $K_{36}$ and $I_{80}$ x $N_{110}$ x $K_{36}$
- Equilibrity among combination means was possible either with the first or second order interactions .
- Water consumptive use was ranged between 1942.0 to 2800.0 $m^3$/fed , distributed in 7- 12 irrigations, according to water irrigation level.
- Water use efficiency, varied between 1.31 to 1.79 $Kg/m^3$ and was higher when irrigation was practiced at a lower available of moisture content level.

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# تأثير الرى عند مستويات محتوى رطوبى مختلفة والتسميد الآزوتــى والبوتاســـى على محصول الذرة الشامية وبعض مؤشراته.

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أجريت تجربتان حقليتان بمحطة البحوث الزراعية بناحية شلقان قليوبيــة خــلال عــامى ٢٠٠٠ و ٢٠٠١ لدراسة تأثير ٣ مستويات للرى (I) عند توافر ٤٠ ، ٦٠ ، ٨٠ مــن الرطوبــة الأرضية الميسرة و٣ مستويات من كل مــن التســميد الآزوتــى ( ١٠٠ ، ١١٠ ، ١٢٠ كجــم أزوت/للفدان) والتسميد البوتاسى (١٢ ، ٢٤ ، ٣٦ كجم بو٢أ/للفدان) على محصول الذرة الشامية وبعض مؤشراته ولاستشراف بعض العلاقات المائية، حيث استخدم تصميم القطع الشقية مرتين فى ثلاث مكررات – ووزعت معاملات الرى على القطع الرئيسية ومستويات الآزوت علــى القطــع الشقية الأولى ومستويات البوتاسيوم على القطع الشقية الثانية . وأجرى تحليل تجميعى للموســمين بعد تحليل كل منهما على حدة – استخدم إختبار LSD لمقارنة المتوسطات .

وكانت أهم النتائج كما يلى :

- ظهر التأثير المعنوى للعوامل والتفاعلات المشتركة بينها – ثنائية أم ثلاثية – علــى معظــم صفات الدراسة باستثناء عدد الكيزان/النبات، عدد الصفوف/الكوز.
- كانت هناك زيادة معنوية عند الرى على مستوى رطوبى عالى وزيادة مستوى التسميد الازوتى او البوتاسى . ولقد تحقق اعلى محصول من الحبوب للفدان عند تداخل فعل المستوى العالى من عوامل الدراسة الثلاثة.
- أمكن تحقيق إحلال معاملة عاملية مكان أخرى – وفى هذا الشان ثبت أنه يمكن إحلال المعاملة $I_{40} \times N_{110}$ بدلا من $I_{60} \times N_{100}$ وكذا إحلال $I_{60} \times N_{110} \times K_{36}$ بدلا مــن $I_{60} \times N_{120} \times K_{36}$ أو $I_{80\%} \times N_{110} \times K_{24}$
- تباينت قيم المقنن المائى بين ١٩٤٢,٠ و ٢٨٨٠,٠ م٣/ فدان تبعاً لاختلاف موســم الزراعــة ومعدلات الرى المستخدمة. وينصح تحت ظروف التجربة والظروف المماثلة رى الذرة بحوالى ٢٨٨٠,٠ م٣/فدان موزعة على ١٢ رية خلال موسم النمو مع إضافة ١١٠ كجــم/أزوت و ٣٦ كجم من بو٢أ من البوتاسيوم .