J. Soil Sci. and Agric. Engineering, Mansoura Univ., Vol.1 (7): 713-721, 2010

EFFECT OF DIFFERENT IRRIGATION SYSTEMS AND POTASSIUM AND PHOSPHORUS LEVELS ON MAIZE.

El-Agrodi, M. W. M.[1]; H. A. Shams El-Din[2]; G. Labeeb[1] and T. S. H. Khalifa [2]

1- Soil Dept. Fac. of Agric., Mansoura Univ., Egypt .

2- Soil, Water and Environment Res. Inst., A.R.C., Egypt.

ABSTRACT

A field experiment was conducted during summer season of 2008 in Sakha Agricultural Research Station Farm; Kafr El-Sheikh Governorate. This study aimed to clarify the effect of different irrigation systems and potassium and phosphorus fertilization levels on maize crop.

The obtained results can be summarized in;

- Irrigation systems and fertilization levels interaction significantly affect maize grain yield. The highest value of maize grain yield (2.14 ton/fed) was recorded under furrow irrigation system + 125% of P and K recommended dose treatment.
- Increasing P and K fertilizations levels from 50 to 125% of the recommended dose caused an increase in maize stalks yield amounted by 45.11%. The highest mean of maize stalks yield (5.250 ton/fed) was recorded under furrow irrigation system + 125% of P and K recommended dose.
- Furrow irrigation improved maize grain potassium utilization by 24.43% than that of sprinkler irrigation. Potassium uptake by maize grain of furrow irrigation system + 125% of P and K recommended dose treatment was higher than that of sprinkler irrigation system + 50% of P and K recommended dose treatment by 94.53%.
- Furrow irrigation system recorded the highest value of phosphorus uptake by maize grain (8.033 kg/fed) compared with other irrigation systems. 125% of P and K recommended dose recorded the highest value of P uptake by maize grain (9.53 kg/fed) compared with the other fertilization treatments.
- Furrow irrigation system decreased maize water use efficiency by 35.37 and 63.30% less than that of drip and sprinkler irrigation systems, respectively. The highest value (1.64 kg grain / m^3) of water use efficiency for maize was recorded under drip irrigation system + 125% of P and K recommended dose.

Keywords: Maize, K uptake, P uptake, irrigation system, water use efficiency

INTRODUCTION

In the past, water resources of Egypt have been adequate to meet the existing and emerging demand for water by the various sectors. Gradually, Egypt has passed from a state of water abundance to a state of water scarcity. However, agriculture remains the backbone of Egypt's economy and the largest consumer of fresh water where it consumes more than 80% of Egypt's water resources (Abou Kheira, 2005).

Corn (*Zea maize* L.) is one of the most important cereal crop grown in summer season. The local production of the crop is not sufficient to meat the continuous increase of consumption. Therefore, attempts to increase maize production are of great importance.

Egypt is considered to be a heavy user of chemical fertilizers, due to various factors such as the increase in the cropped area, raising the rate of fertilizer application for various crops and the depletion of Nile irrigation water of some nutrients after the construction of the High Dam.

The local production of potassium fertilizers started in 1936, where no potash fertilizers are produced in Egypt due to the lack of resources, although it was reported recently that some local potash deposits had been found (FAO, 2005).

Surface irrigation is inefficient, where, water is used excessively because flow rates are not uniform; labor is wasted in construction of checks, furrows and water manipulation; 10 - 20% of land is wasted in borders, furrow ends and small canals; and poor uniformity and distribution of irrigation water where most of the water movement is due to gravity, resulting in excessive drainage and more nutrients losses. For the mentioned above , it is a must to improve irrigation systems by many options having high fertilizer and water use efficiency such as drip irrigation and sprinkler irrigation.

MATERIALS AND METHODS

A field experiment was conducted at Sakha Agricultural Research Station Farm; Kafr El-Sheikh Governorate. Zea maize (variety, 128). This study aimed to clarify the effect of furrow, drip and sprinkler irrigation systems and potassium and phosphorus fertilization levels on maize yield and potassium and phosphorus uptake.

Surface soil samples (0-30 cm) before plant sowing was taken from all transactions under each irrigation system, air-dried, ground and passed through 2.0 mm sieve to determine some chemical and physical soil properties as shown in Table 1.

The studied factors were three irrigation systems (furrow, drip and sprinkler irrigation systems) and four fertilization levels (50, 75, 100 and 125 % of phosphorus and potassium recommended dose) to form twelve treatments. These treatments were arranged in a randomized complete design with three replicates.

Nitrogen, phosphorus and potassium recommendation for maize are, 120 kg N fed $^{-1}$, 31 kg P_2O_5 fed^{-1} and 48 kg K_2O fed $^{-1}$.

Zea maize (variety, 128) was sown on July 30th, 2008, thinned after 20 days later of sowing to leave one plant in each hill. Each of N, P and K application doses was divided into two equal doses; one was added after 20 days from sowing and the other 20 days later. Other agricultural practices such as weed and insect control were performed according to the Ministry of Agriculture recommendation in North Delta area. Harvesting was done on November, 11th, 2008.

Zea maize received 10 irrigations with drip (1233.747 m^3/fed) and sprinkler (2031.354 m^3/fed) irrigation systems with irrigation interval time of 8 days. The irrigation water amount was calculated to raise the soil water content of the upper 15 cm to field capacity in the first month, of the upper 30 cm in the second month and of the upper 60 cm in the rest period. While it received 8 irrigations with furrow irrigation system (3600 m^3/fed). Irrigation was stopped three weeks before harvesting.

At harvesting stage, grain (14 % moisture) and stalks yields were weighed, sample of each was dried at 70 until the stable weight is reached.

Table (1): The average values of some chemical and physical aspects of the experimental soil (0-30cm) before maize planting:

Irrigation system		Furrow	Drip	Sprinkler
Soil depth (cm)		0-30	0-30	0-30
EC_e dS/m		2.70	2.97	2.71
Soluble cations (meq /L)	Na^+	18.4	18.4	20.2
	Ca^{++}	4.3	4.3	4.8
	Mg^{++}	5.9	6.0	6.5
	K^+	0.3	0.3	0.3
Soluble anions (meq /L)	CO_3^{--}	0.0	0.0	0.0
	HCO_3^-	6.1	5.2	6.7
	Cl^-	12.9	12.9	14.1
	SO_4^{--}	9.9	10.9	10.9
Available (mg/kg)	P	9.11	9.43	9.10
	K	305	297	302
CEC (Meq/100g soil)		39.42	38.91	35.83
pH		8.29	7.72	8.05
OM %		1.23	1.16	1.04
$CaCO_3$ (%)		2.19	2.19	2.17
Particle size distribution (%)	Sand	20.09	20.15	20.64
	Silt	29.05	30.62	28.74
	Clay	47.30	45.90	49.23
Texture grade		clayey	clayey	clayey

Method of analysis:

Soil reaction (pH), total soluble salts, soluble cations and anions, organic matter (OM) content (Walkally Black - method) and available K were determined according to Jackson (1967).

The cation exchange capacity (CEC) was determined as described by Bower *et al.,* (1952).

Available P was determined by sodium bicarbonate method according to Olsen *et al.,* (1954).

Mechanical analysis (sand, silt and clay) and $CaCO_3$% was determined according to the international pipette method (Piper, 1950).

Dry materials of plant organs (oven dry basis) were wet digested with an H_2SO_4 – H_2O_2 mixture as described by Peterburgski (1968). P and K were determined in the wet digested product according to Jackson (1967).

Field water use efficiency (FWUE) was calculated to clarify how many kg of yield is produced from one cubic meter applied (Michael, 1978).

FWUE = Y / a W : Where:

Y = total yield produced (kg / fed.). A W = total applied water (m^3 / fed).

The statistical analysis of the collected data was done according to the method described by (Gomez and Gomez, 1984) and least significant difference (LSD) was used to compare between treatments means.

RESULTS AND DISCUSSION

1- Grain yield:

Data presented in Table (2) show the effect of irrigation systems, fertilization levels and their interaction on maize grain yield.

Data reveal that furrow irrigation system increased maize grain yield by 3.3% and 12.3% over than that of drip and sprinkler irrigation systems, respectively. These results are in agreement with that of Abo Soliman *et al*., (2005) who attributed increases in yield to the highest rate of salt leaching under surface irrigation.

As regard to fertilization levels effect, increasing fertilization level from the lowest level to the highest used level, significantly increased maize grain yield. These increases (based on the yield of the lowest fertilizers level) amounted by 19, 11.2 and 5.9 % in maize grain yield. Similar results were found by Miao *et al*., (2006) who stated that the highest ear and grain yields of corn were obtained by using 30 to 37.5 kg P_2O_5 /fed. So, Hussein (2009) showed that increasing rates of P supply (0, 30, 60 and 90 kg P_2O_5/h) had significantly effect on corn grain yield.

The highest maize grain yield (2.03 ton/fed) were achieved under the treatment of 125% of P and K recommended dose.

Irrigation systems and fertilization levels interaction, significantly affected maize grain yield. The highest value of maize grains (2.143 ton/fed) were recorded under furrow irrigation system + 125% of P and K recommended dose treatment.

Table (2): Effect of irrigation systems, fertilization levels and their interaction on maize grain yield (ton/fed):

Irrigation system / Fertilization levels	furrow irrigation	drip irrigation	sprinkler irrigation	Fert. Treat. means	F-test
50%	1.78	1.74	1.61	**1.71**	**
75%	1.89	1.89	1.71	**1.83**	**LSD**
100%	2.04	1.95	1.75	**1.92**	0.072
125%	2.14	2.02	1.94	**2.03**	0.110
Irr. Treat. means	**1.96**	**1.90**	**1.75**		
F-test	** **LSD** 0.0627 0.0951				
Interaction	**F-test** ** **LSD** $_{0.05}$ **=** 0.125 **LSD** $_{0.01}$ **=** 0.190				

2-Stalks yield:

Data presented in Table (3) show the effect of irrigation systems, fertilization levels and their interaction on maize stalks yield.

Data reveal that irrigation systems, fertilization levels and their interaction, significantly affected maize stalks yield. Maize stalks yield amounted by 4.33, 3.89 and 3.1 ton/fed under irrigation treatment of furrow, drip and sprinkler irrigation systems, respectively. Hence, furrow irrigation system increased maize stalks yield by 11.3% and 39.7% over than that of drip and sprinkler irrigation systems, respectively. Similar trend was found by Selvaraju and Iruthayaraj (1993), since they reported that application of irrigation water in furrows gave higher grain yield of maize.

Data of the Table also, reveal that increasing fertilization level led to increase maize stalks yield up to the highest P and K level used. Increasing P and K fertilization level from 50 to 125% of recommended dose caused an increase in maize stalks yield amounted by 45.11 %. The obtained results are in an agreement with those obtained by Saidou *et al.,* (2003), They reported that maizes Stover (stems and leaves + husks + central axis) yield was significantly higher in the NPK fields than in the fields where no inorganic fertilizer was applied.

The highest maize stalks yield value (5.250 ton/fed) was recorded under furrow irrigation system + 125% of P and K recommended dose and the lowest value (2.73 ton/fed) was achieved under sprinkler irrigation system + 50% of P and K recommended dose.

Table (3): Effect of irrigation systems, fertilization levels and their interaction on maize stalks yield (ton/fed):

Irrigation system / Fertilization levels	furrow irrigation	drip irrigation	sprinkler irrigation	Fert. Treat. means	F-test
50%	3.50	3.29	2.73	**3.17**	**
75%	3.88	3.50	2.87	**3.42**	**LSD**
100%	4.69	3.99	3.01	**3.90**	0.421
125%	5.25	4.76	3.78	**4.60**	0.638
Irr. Treat. means	**4.33**	**3.89**	**3.10**		
F-test	** **LSD** 0.364 0.552				
Interaction	**F-test** ** **LSD $_{0.05}$ =** 0.729 **LSD $_{0.01}$ =** 1.104				

3-Potassium uptake by grain:

Data presented in Table (4) show the effect of irrigation systems, fertilization levels and their interaction on K uptake by maize grain.

The mean of K uptake as affected by irrigation system treatments are 19.58, 18.44 and 15.74 Kg/fed for maize grain under furrow, drip and sprinkler irrigation systems, respectively. From previous data, furrow irrigation improved maize grain potassium utilization by 24.43 % better than that of sprinkler irrigation.

Raising P and K fertilization dose from 50 to 75, 100 and 125 % of recommended dose increased potassium uptake by maize grain from 14.06 to 17.05 kg/fed (21.31 % increase), 18.66 kg/fed (32.79 % increase) and 21.9 kg/fed (55.82 % increase), respectively. These results are in harmony with the results obtained by Saidou *et al.,* (2003). They reported that maize uptake of K (35 kg ha^{-1}) was significantly higher in the NPK fields than in the fields where no inorganic fertilizer was applied. So, Raza *et al.,* (2005) reported that the maximum potassium uptake of maize was obtained when recommended dose was applied.

Potassium uptake by maize grain of furrow irrigation system + 125% of P and K recommended dose treatment was higher than that of sprinkler irrigation system + 50% of P and K recommended dose treatment by 94.53 %.

Table (4): Effect of irrigation systems, fertilization levels and their interaction on K uptake by maize grain (kg/fed):

Irrigation system / Fertilization levels	Furrow irrigation	drip irrigation	sprinkler irrigation	Fert. Treat. means	F-test
50%	15.34	14.60	12.22	**14.06**	**
75%	18.26	18.19	14.70	**17.05**	**LSD**
100%	20.96	19.03	16.00	**18.66**	1.124
125%	23.76	21.93	20.00	**21.9**	1.703
Irr. Treat. means	**19.58**	**18.44**	**15.74**		
F-test	** **LSD** 0.973 1.475				
Interaction	**F-test** ** **LSD $_{0.05}$ =** 1.947 **LSD $_{0.01}$ =** 2.949				

4-Phosphorus uptake by grain:

Data presented in Table (5) show the effect of irrigation systems, fertilization levels and their interaction on P uptake by maize grain.

Data reveal that the highest value of phosphorus uptake by maize grain (8.033 kg/fed) was recorded under furrow irrigation system. Using drip irrigation decreased P uptake by maize grain by 86 % compared to furrow irrigation system. Sprinkler irrigation under the experimental conditions reduced P uptake by maize grain to a large extent (72%) comparing to furrow irrigation.

Table (5): Effect of irrigation systems, fertilization levels and their interaction on P uptake by maize grain (kg/fed):

Irrigation system / Fertilization levels	Furrow irrigation	drip irrigation	sprinkler irrigation	Fert. Treat. means	F-test
50%	6.30	4.83	3.86	**4.99**	**
75%	7.16	5.99	4.86	**8.01**	**LSD**
100%	8.38	7.41	5.53	**7.10**	0.705
125%	10.30	9.40	8.88	**9.53**	1.069
Irr. Treat. means	**8.033**	**6.907**	**5.784**		
F-test	** **LSD** 0.611 0.925				
Interaction	**F-test** ** **LSD $_{0.05}$ =** 1.222 **LSD $_{0.01}$ =** 1.851				

Data of that Table also, reveal that the differences in p uptake by maize grain under the different levels of P and K fertilization treatment means are highly significant. The highest value of P uptake by maize grain (9.53 kg/fed.) was assigned with 125% of P and K recommended dose. These results are in harmony with the results obtained by Ibrahim and Kandil (2007). They studied the effect of different rates of P (15, 25 and 35 kg P_2O_5 / fed) on maize plant, and found that the highest values of grain yield of corn plant per fed in both seasons were obtained with P fertilization rate of 35 kg P_2O_5/ fed. Also, Hussein (2009), showed that increasing rates of P supply (0, 30, 60 and 90 kg P_2O_5/ha), had significantly effect on P content and uptake.

The highest P uptake mean for maize was 10.30 kg/fed which recorded under furrow irrigation system + 125% of P and K recommended dose. The lowest P uptake mean for maize was 3.86 Kg/fed which recorded under sprinkler irrigation system + 50% of P and K recommended dose.

5- Water use efficiency:

Data presented in Table (6) show the effect of irrigation systems, fertilization levels and their interaction on water use efficiency (kg grain/m^3) of maize. Data reveal that irrigation systems significantly affect water use efficiency of maize, where furrow irrigation system decreased maize water use efficiency by 35.37 and 63.30 % less than that of drip and sprinkler irrigation systems, respectively. These results are in adverse trend with that of Iqbal (1994), who outlined that corn water use efficiency under sprinkler irrigation was 1.82 times of that of surface method of irrigation

Data also reveal that increasing of P and K fertilization level, significantly increased maize water use efficiency up to the highest level used. Maize water use efficiency ranged between 0.90 to 1.06 Kg grain /m^3.

The highest value of water use efficiency for maize (1.64 kg grain / m^3) was recorded under drip irrigation system + 125% of P and K recommended dose. The lowest value (0.50 kg grain / m^3) was achieved under furrow irrigation system + 50% of P and K recommended dose.

Table (6): Effect of irrigation systems, fertilization levels and their interaction on water use efficiency on maize (kg grains/m^3):

Irrigation system / Fertilization levels	Furrow irrigation	drip irrigation	sprinkler irrigation	Fert. Treat. means	F-test
50%	0.50	1.41	0.8	**0.90**	**
75%	0.53	1.54	0.84	**0.97**	**LSD**
100%	0.57	1.58	0.86	**1.00**	0.752
125%	0.60	1.64	0.95	**1.06**	1.133
Irr. Treat. means	**0.55**	**1.54**	**0.86**		
F-test	** **LSD**	0.651	0.981		
Interaction	**F-test** **	**LSD $_{0.05}$ =** 1.303		**LSD $_{0.01}$ =** 1.962	

Water use efficiency = grain yield / water applied

Conclusion

It can be concluded that furrow irrigation system gave the highest maize grain yield (Table 2), while drip irrigation system **gave** the highest value of water use efficiency (Table 5), so, if the amount of water used under furrow irrigation system (3600 m^3/fed) was used with drip irrigation system it will be sufficient for sawing the sum of 2.92 feddan which will gave 5.91 ton of grains/fed under the highest fertilization P and K levels.

REFERENCES

Abo Soliman, M. S.; H. E. Osman; M. M. Saied and E. H. Omar (2005). Maize, barley production and water use efficiency as influenced by different irrigation methods in Egyptian old land. " Role and horizons of Agricultural Engineering in the contemporary world". The 13th Conference of the Misr. Society of Agr. Eng., 14-15 December (2005).

Abou Kheira, A. A. 2005. A study of trickle irrigation systems for irrigating some horticultural crops in Delta soils. Ph.D. thesis. Shebin El-Kom, Minufiya University, Egypt.

Bower, C.A.; R.E. Reitemeier and M. Firman (1952). Exchange cation analysis of saline and alkali soil. Soil Sci., 73:251-261. Illus.

FAO (2005). Fertilizer use by crop in Egypt. Land and Plant Nutrition Management Service Land and Water Development Division Food and Agriculture Organization of the United Nations Rome.

Gomez, K.A. and A.A. Gomez (1984). Statistical Procedures for Agricultural Research. 2nd Ed., John Wiley and Sons.

Hussein A.H.A. (2009) Phosphorus use Efficiency by two varieties of corn at different phosphorus fertilizer application Rates. Res. J. of Applied Sciences. 4(2): 85-93.

Ibrahim, S.A and H. Kandil (2007). Growth, Yield and Chemical Constituents of Corn (Zea Maize L.) As Affected by Nitrogen and Phosphors Fertilization under Different Irrigation Intervals. Journal of Applied Sciences Research, 3(10): 1112-1120.

Iqbal, A. (1994). Feasibility of Raingun Sprinkler Irrigation System for Corn (fodder) under Farmer's Conditions. M.Sc Thesis, Dept. of Irrigation and Drainage, University of Agriculture, Faisalabad.

Jakson, M.L. (1967). "Soil Chemical Analysis". Prentice-Hall of India, New Delhi.

Miao, Y.X.; D.J. Mulla; P.C. Robert and J.A. Hernandez (2006). Within-field variation in corn yield and grain quality responses to nitrogen fertilization and hybrid selection. Agronomy Journal., 98(1): 129-140.

Michael, A.M. (1978). Irrigation theory and practice. Vikas Publishing House, New Delhi, 1978.

Olsen, S.R.; C.V. Cale; F.S. Watenable and L.A. Dean (1954).Estimation of available phosphorus in soil by extraction with sodium bicarbonate U.S. Dept., Agric. Circ., 939.

Peterburgski, A.V. (1968). "Hand Book of Agronomic Chemistry". Kolos Puplishing House, Moscow, (in Russian, pp. 29-86).

Piper, C.S. (1950). Soil and Plant Analysis. Inter science Publication. New York.

Raza, W., S. Yousaf, A. Niaz, M.K. Rasheed and I. Hussain (2005). Subsoil compaction effects on soil properties, nutrient uptake and yield of maize fodder (Zea mays L.). Pak. J. Bot., 37(4): 933-940.

Saidou A.; B.H. Janssen and E.J.M. Temminghoff (2003) Effects of soil properties, mulch and NPK fertilizer on maize yields and nutrient budgets on ferralitic soils in southern Benin. Agriculture, Ecosystems and Environment 100: 265–273.

Selvaraju, R. and M.R. Iruthayaraj (1993). Effect of irrigation scheduling, methods of irrigation and nitrogen levels on growth analysis parameters of maize. Madras Agric. J., 80: 562–5.

تأثير طرق الرى المختلفة ومستويات البوتاسيوم و الفوسفور على الذرة

محمد وجدى محمد العجرودى[١] ، حسن على شمس الدين[٢]، جمعة لبيب احمد يوسف [١] و تامر حسن حلمى خليفة[٢]

١- قسم الأراضي- كلية الزراعة- جامعة المنصورة

٢- معهد بحوث الأراضى والمياه والبيئة ـ مركز البحوث الزراعية

أجريت تجربة حقلية على محصول الذرة صيف عام ٢٠٠٨ بالمزرعة البحثية بمحطة بحوث سخا- محافظة كفر الشيخ لتقييم أثر نظم الري المختلفة ومستويات تسميد الفوسفور و البوتاسيوم على محصول الذرة والممتص من الأسمدة وكفاءة استخدامه لمياه الرى

وفيما يلي أهم النتائج المتحصل عليها:

- أثرت نظم الرى ومستويات التسميد والتفاعل بينهما تأثيرا معنويا على محصول الحبوب و سجلت اعلى قيمة له (٢.١٤٣ طن / فدان) تحت نظام الري بالغمر + ١٢٥ ٪ من الموصى به لاسمدة الفوسفور والبوتاسيوم.
- زيادة مستوى التسميد لاسمدة الفوسفور والبوتاسيوم من ٥٠ **الى** ١٢٥ ٪ من الموصى أدت إلى زيادة محصول حطب الذرة بما يعادل ٤٥.١١ ٪.
- سجلت أعلى قيم لمحصول الحطب (٥.٢٥٠ طن / فدان) تحت نظام الري بالغمر + ١٢٥ ٪ من الموصى به لاسمدة الفوسفور والبوتاسيوم .
- الرى بالغمر زاد من استخدام حبوب الذرة للبوتاسيوم بنسبة ٢٤.٤٣ ٪ مقارنة بالري بالرش.
- البوتاسيوم الممتص بواسطة حبوب الذرة تحت نظام الري بالغمر + ١٢٥ ٪ من الموصى به لاسمدة الفوسفور والبوتاسيوم أعلى منه تحت نظام الري بالرش + ٥٠ ٪ من الموصى به لاسمدة الفوسفور والبوتاسيوم بنسبة ٩٤.٥٣٪ على التوالي.
- أعلى قيم لامتصاص الفوسفور فى حبوب الذرة (٨.٠٣٣ كجم / فدان) وسجلت تحت نظام الري بالغمر مقارنة بنظم الرى الاخرى.
- ١٢٥ ٪ من الموصى به لاسمدة الفوسفور والبوتاسيوم حققت أعلى قيم لامتصاص الفوسفور فى حبوب الذرة (٩.٥٢٦ كجم / فدان) مقارنة مع مستويات التسميد الاخرى.
- الري بالغمر أدى إلى نقص كفاءة استخدام الذرة للمياه بنسبة ٣٥.٣٧ ٪ و ٦٣.٣٠ ٪ مقارنة بالري بالتنقيط و الرش، على التوالي.
- سجلت اعلى قيمة لكفاءة استخدام الذرة للمياه (**١.٦٤٠ كجم / م^3**) مع الري بالتنقيط + ١٢٥ ٪ من الموصى به لاسمدة الفوسفور والبوتاسيوم.

قام بتحكيم البحث

أ.د / أحمد عبد القادر طه	**كلية الزراعة – جامعة المنصورة**
أ.د / محمود أحمد عبد الحليم أبو السعود	**مركز البحوث الزراعية**