Egypt. J. Agric. Res. , 76 (3) ,1998.

COTTON CROP RESPONSE TO SPRINKLER IRRIGATION SYSTEM !N EGYPTIAN OLD LAND

M.N.S. EL-YAZAL, H. EL-BANNA OSMAN, AND S. EL-KADY

Agricultural Engineering Research Institute, Agricultural Research Center, Giza, Egypt.

(Manuscript received 13 January 1998)

Abstract

Sprinkler irrigation is a relatively new method in Egypt mainly used in the newly reclaimed desert areas, while surface irrigation systems are dominent in old heavy texture soil areas. The main objective of the present study was to investigate the possibility of using sprinkler irrigation system in cotton crop production in the old valley by studying its effect in minimizing water losses and increasing cotton yield. Measured performance parameters and water utilization efficiencies were also studied for both sprinkler and surface irrigation systems. Results indicate that sprinkler irrigation system saved 17.81% of water applied and increased the yield by 22.6% compared to surface irrigation. The water utilization efficiency increased by 51.2% in sprinkler system compared to surface irrigation system.

INTRODUCTION

Cotton is the most important fiber crop used for making textile materials. It can be used in making a wide range of products, from diapers to explosives, than any other fiber.

In 1997 season, Egypt planted 721 thousand feddan of Cotton representing the first important field crop. Average production of cotton is 6-8 metric quantar per feddan (metric quantar is 157.5kg and Feddan is 4200 m2) which is considered the world third highest production (General administration of agricultural economics 1994). Cotton still ranks as a major source of national income of Egypt. The Egyptian economy is heavily dependant on cotton production. Traditionally, Cotton is planted by direct seeding from 5 to 20 seeds manually in dry fields in each hole. Farmers prepare soil for seeding by using same furrows of last crop, furrows spaced 50 to 65cm, the distance between each successive hole in the furrow is from 15 to 25 cm and cotton seeds are planted in rows on one side of the furrow. The total number of cotton plants per feddan ranges from 45, 000 to 50,000. The quantity of irrigation water applied for cotton averages 3150 m3/feddan under the traditional surface irrigation method.

Sprinkler irrigation is a relatively new method in Egypt, that has locally developed mainly over the last four decades. Today, Sprinkler irrigation has been considered to be one of the most important obligatory irrigation systems which have to be applied in the newly reclaimed desert areas. Sprinkler irrigation method is mainly used for irrigating vegetable and fruit crops in Egypt. It is proposed that sprinkler irrigation method be applied in irrigating field crop as well in old valley where land texture is often clay (Table 1) and surface irrigation is used. In doing so it could also increase the production on the national scale. It also could save much irrigation water, that may be used to reclaim and cultivate more desert land areas. Hanson and Patterson (1974) showed that water use efficiencies were highest for drip and sprinkler systems when compared with the effect of sprinkler, furrow, drip and subsurface systems on sweet corn. Badr, 1987 resported that water use efficiency of sugar beet was 8.3 kg/m3 using sprinkler system and dropped to 4.3 kg/m3 when using furrow irrigation system.

MATERIALS AND METHODS

The experiments were carried out in two districts and planted in March 1997 and 1995 and harvested on September 1977 and 1995. The first district was divided into two fields. The area of first field was about 16 feddans (254 x 265m) irrigated with fixed sprinkler system and divided into 23 plots. The total number of cotton plants per feddan is 42,000. The area of second field was one feddan (36.2 x 116m) irrigated with surface irrigation as traditional method. Both fields were at El-Manshya village, Bellbise, El-Sharkya Governorate. Cotton (Giza 85 variety) was planted after Alfalfa crop with 10 seeds manually in each hole. The field was pre-irrigated using last crop furrows. The furrows spacing was 75 cm and the cotton seed in row spacing ranged from 20 to 25 cm.

Figure 1 shows the control head which is located in Bellbise at two sources of the water supply (main canal and shallow well). It consists of centrifugal pump which is driven by Tractor PTO (540 rpm). The pump capacity is up to 90 m^3/h, head is up to 86m, suction connection is DN 80, delivery connection is DN 65. The pump is connected to the main line by a flexible quick hitch hoses. Figure 2 shows the sprinkler irrigation network design. Sprinkler type is single nozzle 5.5 mm (Perrot

ZB22). The discharge of sprinkler is 1.99 m3/hour at 3bar and gross application rate is 0.62 cm/h. Minimum sprinkler pressure is 250 kPa and average sprinkler pressure is 325 kPa. Total water consumption of the sprinkler irrigation is 2475 m3/feddan/season (applied by seven irrigations based on soil moisture content and evapotranspiration ETP).

The second district was at experimental Farm of Faculty of Agriculture Ain-Shams University at Shalaquan, Qalybia Governorate. The experimented field is divided into six sub-plots (23 x 23 m). The first three sub-plots were irrigated by permanent sprinkler irrigation system and second three sub-plots were irrigated by surface irrigation system as shown in Figure 3. Two nozzles sprinkler head 4.5/2.4mm and discharge of each sprinkler 1.5m3/hour at 2.5 bar are used. Irrigation interval was each 7 days based on ETP. Total water applied by sprinkler irrigation system is 2350 m3/feddan/season and 2720m3/feddan/season for the surface irrigation system.

The irrigation water for the different systems under investigation was estimated using the class A Pan evaporation, calculated on 100% ETP. and 100% water application efficiency.

Evaluation of sprinkler irrigation system uniformity and efficiency were done by means of catch container (Can tests) only in Bellbise location. The catch container layout was designed for measuring the uniformity of water distribution along a sprinkler lateral line. By overlapping the right and left hand catch data, the total catch between adjacent lateral portions can be simulated. Tests were conducted in the afternoon and the time of running the experiment was selected where wind speed was virtually calm. Experiment was conducted at fields with no planted crop and the sprinkler lateral was adjusted to minimize differences in elevation. All details for conducting and evaluating field tests are according to the handbook by Merriam and Keller (1978) and Irrigation system design is after Richard H.Cuenca (1989).

Irrigation performance measures

Irrigation performance is usually expressed in terms of efficiency and uniformity. A large number of uniformity and efficiency measures have been defined and used in uniformity studies over the years. The comparative studies of Dabbous (1962), Su (1979), on-farm irrigation committee of ASCE (1978) and Keller & Blieser (1990) provide a good survey of many such measures.

In general, efficiency is defined as the ratio of output to input. For irrigation systems, this general efficiency has been defined as the percentage of water application efficiency and presented by:

$$AE\ \% = \frac{\text{Output}}{\text{Input}} = \frac{\text{Average depth of water catch}}{\text{Average pumped water}} \times 100 \qquad [1]$$

A large number of uniformity expressions are used for producing a single relation which expresses the uniformity of irrigation as a function of depth estimates. This has been formulated from several estimates (Measured or simulated) of irrigation depths at various locations. Uniformity measures are a function only of the variability of irrigation depths. The usual approach is to compute some measure of the dispersion of values, and to express this in a non-dimensional way by comparing it to the average value or other measure of central fluction tendency. The expression for distribution uniformity (DU) is given by:

$$DU = \frac{D_{min}}{D_{avg}} \qquad [2]$$

Where D_{min} = Minimum depth of water infiltrated or depth of water catch, m Low quarter distribution uniformity (DU_{lq}) is one of a variety of terms that have been used to describe irrigation uniformity. DU_{lq} can be related to yield when quarter of the field receiving the least amount of water is under irrigated and the yield response to deficits is linear, and there is no yield response to over irrigation (Solomon, 1985). Du_{lq} can be related to deep percolation losses (and thus irrigation efficiency) with desired application depth. Thus Du_{lq} is a useful uniformity measure and is given by:

$$Du_{lq} = \frac{D_{LQ}}{D_{avg}} \qquad [3]$$

Where D_{LQ} = Average infiltrated depth or Average depth in can of lowest quarter of area.

(D_{avg}) = Average infiltrated depth of total area and is given by:

$$D_{avg} = \frac{VD}{L} \qquad [4]$$

Where VD = volume depth caught or infiltrated volume, m^3/m Gross depth or average depth caught or average infiltrated depth (D_g or D_{avg}), as given by

$$D_{avg} = \frac{q_i\ t_{co}}{L} \qquad [5]$$

Where qi = unit flow rate, l/s/m.

t_{co} = cutoff time,

L = Length of the fields.

System efficiency (SE) may then be given by the following equation:

$$SE = DU_{lq} \times AE \qquad [6]$$

Christiansen's uniformity coefficient (CU_c) and Hawaiian Sugar Planters Association coefficient (CU_H) can be used for both sprinkler and surface irrigation systems (Richard H.Cuenca 1989). Values for these coefficients are given by the following equations:

$$CU_c = 1 - \sum_{i=1}^{n} [abs\,(xi - x)] / (n\,x) \qquad [7]$$

$$CU_H = 1 - [2/\pi]^{0.5}\,(S/X) \qquad [8]$$

Where Xi = depth in can i or infiltrated depth, mm

x = mean depth caught or infiltrated, mm

n = number of cans or measurements,

s = standard deviation of depth caught or infiltrated, mm

The test data for CU > 70% usually forms a bell-shaped normal distribution curve and is reasonably symmetrical about the mean. Therefore, CU can be approximated by:

$$CU = \frac{\text{(Average low-half depth of water recieved)}}{m} \times 100 \qquad [9]$$

Where : CU = coefficient of uniformity.

m = average depth of water caught or infiltrated, mm

The relationship between DU and CU can be approximated as given by Keller & Blieser (1990):

$$Cu = 100 - 0.63\,(100 - DU) \qquad [10]$$

or :

$$DU = 100 - 1.59\,(100 - CU) \qquad [11]$$

and the relationship between CU and the standard deviation, S_D, of the individual depth of catch observations can be approximated by:

$$CU = 100\left[1.0 - \left(\frac{SD}{m}\right)\left(\frac{2}{\pi}\right)^{0.5}\right] \quad [12]$$

Which can be rearranged to give:

$$SD = \frac{m}{(2/\pi)^{0.5}}\left(1.2 - \frac{CU}{100}\right) \quad [13]$$

Evaluating Sprinkler Uniformity system :

The CU system computed by:

$$\text{System } CU = CU\,\frac{1 + [Pn/Pa]^{0.5}}{2} \quad [14]$$

And noting that DU varies as the average discharge of the low quarter (see Eq. 14). The DU system computed by:

$$\text{System } DU = DU\,\frac{1 + 3\,[Pn/Pa]^{0.5}}{4} \quad [15]$$

Where

P_m = minimum sprinkler pressure, kPa (psi)

P_a = average sprinkler pressure, kPa (psi)

The computer program (SRFR) was run by data collected from field in a traditional field trial (Surface irrigation method), SRFR program predicted DU, DU_{lq} and AE to compare them with sprinkler irrigation DU, DU_{lq} and AE and also to compare water use efficiency and yield.

Soil mechanical, chemical analysis and water analysis :

Table 1 presents the averages of three samples of soil mechanical, chemical analysis and water analysis in Bellbise and Shalaqan areas. Soil mechanical analysis showed increased percentage of clay than sand and silt percentage.

Table 1. Soil mechanical chemical analysis and water analysis.

Soil sample	Soil Mechanical Analysis %			Soil Chemical Analysis mg/100g				WaterAnalysis ppm			
	sand	Silt	Clay	P	K	Mg	Na	Fe	Zu	PH	EC
Bellbise	20	22	58	2.4	15.82	214.8	85	5.38	1.6	8.39	0.76
Shalaqan	38.53	21.17	40.3	--	--	--	--	--	--	7	0.8

All farm operations such as tillage, fertilization, pest control etc. were carried out in a traditional manner except seed bed preparation in the sprinkler irrigation field, which included sub-soiling to 70cm depth, deep chiseling to 35-40 cm depth and secondary tillage using combination machines.

During cotton planting seasons of 1997 and 1995, seven random samples 1/400 feddan each, three from the sprinkler system and four from the surface irrigation system under test, were collected for estimating weights of bolls and yield. Statistical analysis (t test) was carried out following the procedures of Gomez and A.A. Gomez (1984).

RESULTS AND DISCUSSION

Table 2 and Figure 4 show that the test data for CU is higher than 70% which formed a bell-shaped normal distribution. Also, they show that sprinkler irrigation system has higher uniformities than surface irrigation.

Data in Tables 3 and 4 indicate that the highest cotton yield obtained when irrigated by sprinkler methods compared with the yield of surface irrigation methods. The yield increased by 22.6%, which may be due to the higher number of bolls per cotton tree and higher weight of boll as given in table 4.

Data presented in table 5 and figure 5 show the relation between quantity of water applied (m3) and produced yield (kg) per feddan. Regarding effect of sprinkler irrigation system in old land, such data show clearly that using sprinkler irrigation system increased the yield production per unit of water in surface irrigation system by 1.73 Quentar/feddan. It is also evident that sprinkler irrigation system in old land saved water by 523 m3/feddan/season compared with surface irrigation system. On the other hand water saved by 17.81% under sprinkler irrigation method, may be due to higher yield and lower irrigation water amount used under sprinkler system. The water utilization efficiency increased by 51.2% compared with surface irrigation method Table 5 and figure 5.

CONCLUSIONS

It is concluded that there is high response of cotton crop to sprinkler irrigation method in old land (Alluvial soil). Higher yield and lower irrigation water requirement were obtained with sprinkler irrigated cotton compared with surface irrigated cotton by 22.6% and 17.81%, respectively.

Table 2. The uniformity parameters for sprinkler irrigation system and surface irrigation.

Uniformity parameters	Sprinkler irrigation Calculated %	Surface irrigation Calculated by SRFR %
CU_C	93	74
CU_H	93	74
DU	89	65
DU_{lq}	95	75
AE	96	65
S.E	85	42
S.CU	87	---
S.DU	81	---

Table 3. Effect of different irrigation method on cotton yield (Quentar/feddan).

	Sprinkler irrigation	Surface irrigation	
Sample 1	12.48	7.887	---
Sample 2	10.416	7.76	---
Sample 3	10.91	7.62	---
Sample 4	---	8.06	---
Mean	11.267	7.832	---
Variance	1.167	0.035	---
Observations	3.000	4.000	---
Pooled Variance	0.488	---	---
df	5	---	---
t	6.440	---	---
t-confidence level 5%		t-Confidence level 1%	
P(T< = t) one-tail	0.001	P(T< = t) one-tail	0.001
t Critical one-tail	2.015	t Critical one-tail	3.365
P (T<=t) Two-tail	0.001	P (T<=t) Two-tail	0.001
t Critical two-tail	2.571	t Critical two-tail	4.032

Table 4. Effect of different irrigation methods on number of bolls per cotton tree.

	Sprinkler irrigation	Surface irrigation
Average number of bolls per tree	20	14
Average number of open bolls	15	10
Average number of closed bolls	5	4
weight of one boll, (gm)	3.2	2.7

Table 5. Effect of irrigation methods on water utilization efficieney.

	Sprinkler irrigation			Surface irrigation			Diffe-rence
	Shalaqan	Bellbise	Mean	Shalaqan	Bellbise	Mean	
Water quantity (m3/feddan)	2350	2475	2413	2720	3152	2936	-17.81
Yield (Quentar / feddan)	7.53	11.27	9.40	7.5	7.83	7.67	+22.6
water utilization efficiency (Kg/m3)	0.51	0.72	0.43	0.43	0.39	0.41	+51.2

ACKNOWLEDGMENT

The authors are grateful to our Allah who created us, gave us knowledge and to whom we will return.

Deep thanks are expressed to Dipl. In. D. Trenker (Chief Technical leader of Small Farms Mechanization Program, SFMP, GTZ), Dipl. Ing. M. Awad (Project Coordinator of Small farms Mechanization Program, SFMP), all staff of Small Farms Mechanization Program (SFMP) and all staff of Shalaqan Experimental farm of Faculty of Agriculture, Ain-Shams University.

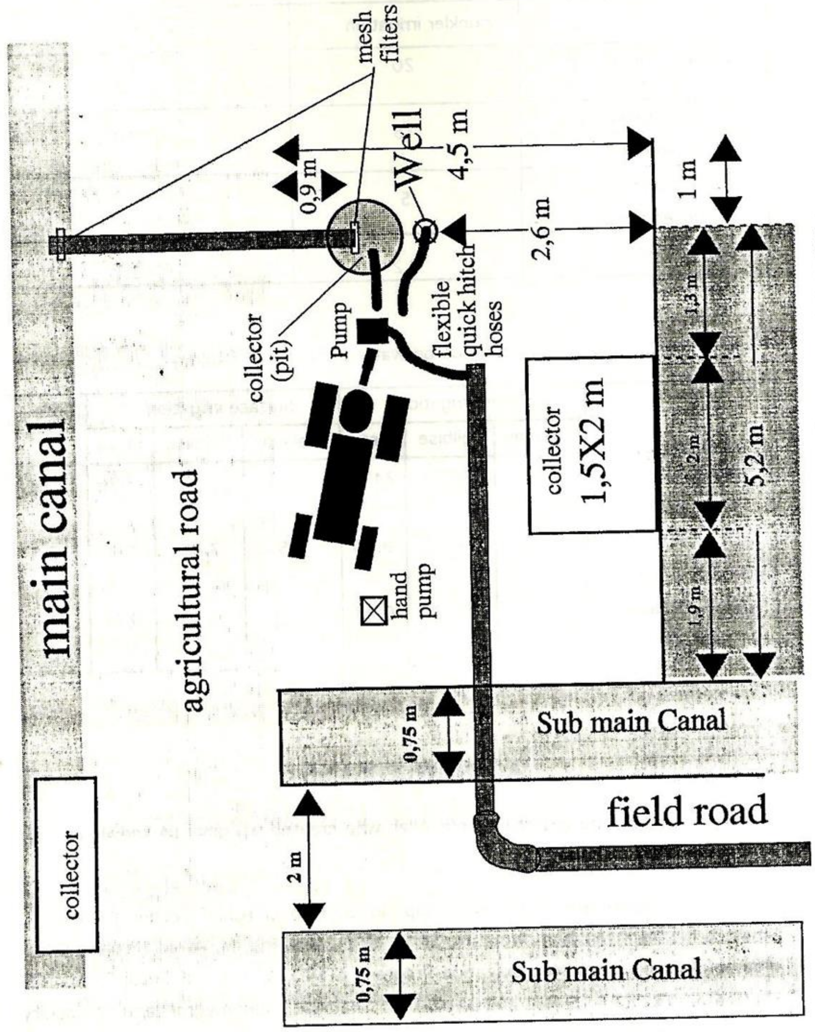

Figure. 1. The control head at two sources of water supply in Bellbise.

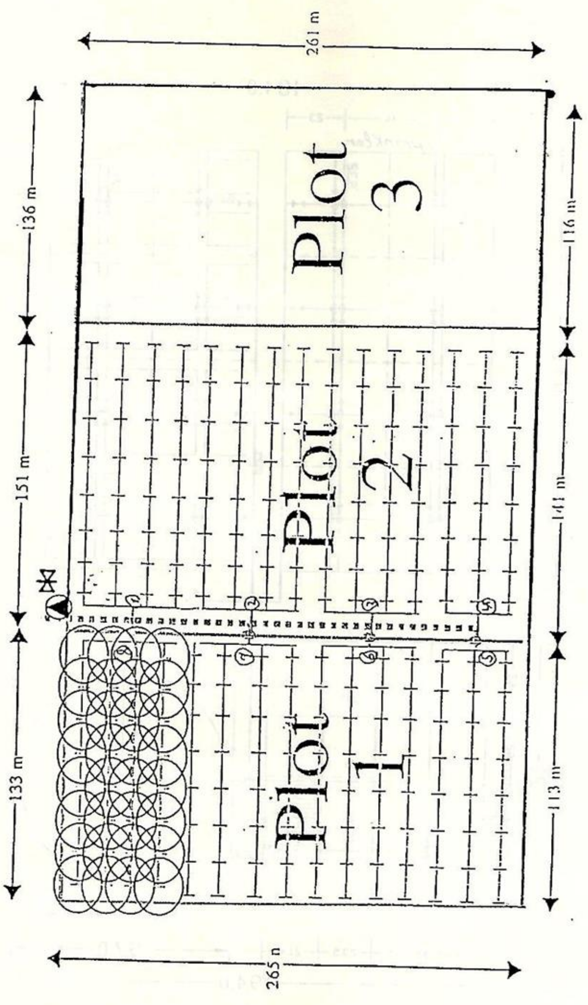

Figure. 2. The sprinkler irrigation network design in Bellbise.

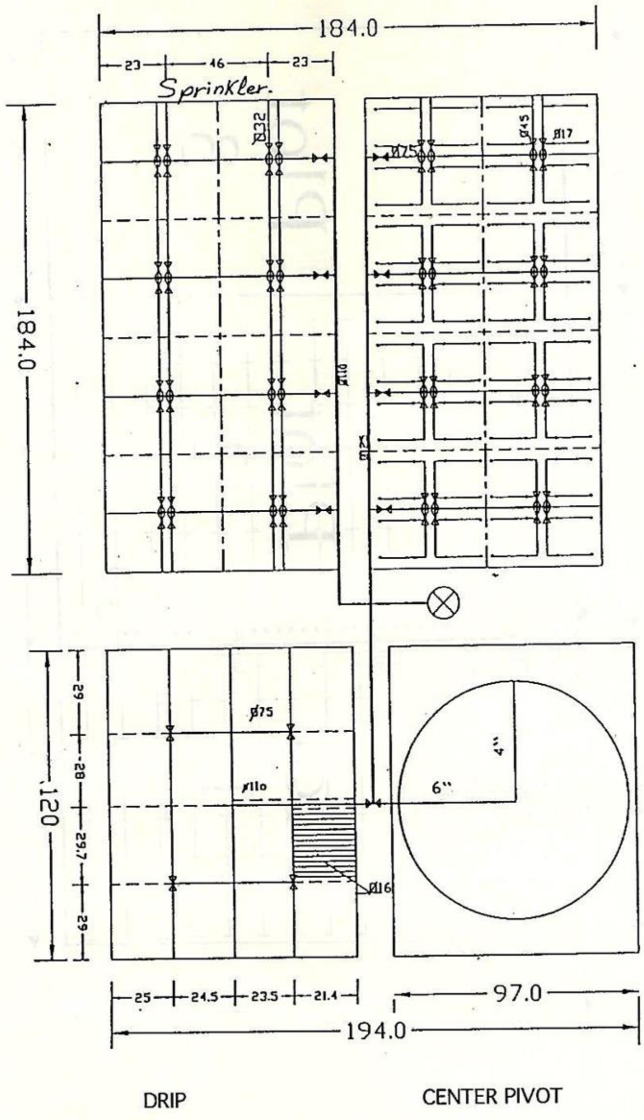

Figure. 3. Layout of irrigation system in shalaqan site (Dims. in MT.).

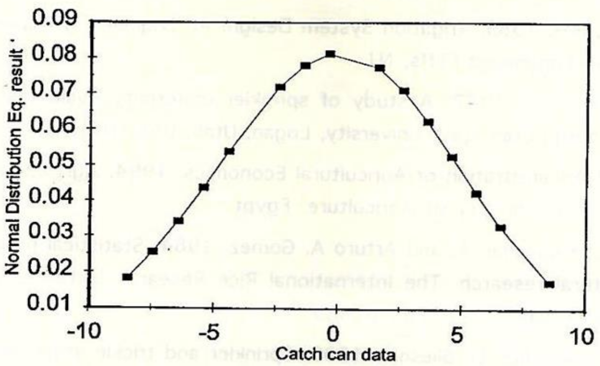

Fig. 4: The test data of catch can is reasonably symmetrical about the mean

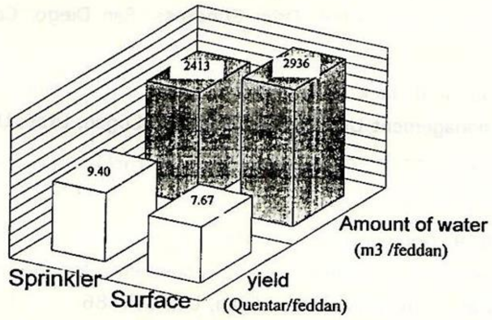

Fig. 5: The effect of irrigation method on water utilization efficiency.

REFERENCES

1. ASCA on-farm irrigation committee. 1978. Describing irrigation efficiency. Journal of the Irrigation and Drainage Division. ASCA 104 IRI) : 35-41.

2. Badr, A.E. 1987. Sugar beet production under sprinkler and furrow irrigation systems Misr J. Agric. Eng. (4): 333-350.

3. Cuenca, R.H. 1989. Irrigation System Design: An Engineering Approach. Prentice-Hall, Englewood Cliffs, NJ.

4. Dabbous, B.J. 1962. A study of sprinkler uniformity evaluation methods. M.Sc. thesis, Utah state University, Logan, Utah, USA, 100p.

5. General Administration of Agricultural Economics. 1994. Agricultural economics, 57-69P, Ministry of Agriculture, Egypt .

6. Gomez, Kwanchai. A. and Arturo A. Gomez. 1984. Statistical procedures for agricultural research. The International Rice Research Institute, Las Banos, Laguna, Philippines, 2ed Ed. pp. 680.

7. Keller J. and Ron D. Bliesner. 1990. Sprinkler and trickle irrigation AVI Publication, New York.

8. Hanson, E.G., and T.C. Petterson. 1974. Vegetable production and water use efficiency as influenced by drip, sprinkler, subsurface and furrow irrigation methods. Proc. Second Intl. Drip. Congress. San Diego, California, USA, pp-97-102.

9. Merriam, J.L and Jack keller. 1978. Farm irrigation system evaluation: a guide for management Utah State University, Logan, Utah, USA.

10. Solomon, K.H. 1985. Global uniformity of trickle irrigation systems. Trans. ASAE. 28 (4), 1151-1158.

11. Su, M. 1979. Comparative evaluation of irrigation uniformity indices. Thesis submitted in partial fulfillment of the requirments for the degree of Master of Science, Utah State University, Logan, Utah, PP 86.

إستجابة محصول القطن لنظام الرى بالرش بالاراضى المصريه القديمه

محمد نبيل سيف اليزل ، حسن البنا عثمان ، شريف أحمد القاضى

معهد بحوث الهندسة الزراعية ، مركز البحوث الزراعية - الجيزة .

تعتبر طريقه الرى بالرش من طرق الرى الحديثة والتى من خلالها يتم ترشيد إستهلاك كميات مياه الرى المعطاه فى كل رية. وهذه الطريقه من طرق الرى شائعة الإستخدام فى الأراضى المستصلحة الجديده والتى غالباً ما تكون رمليه القوام وتزرع بالمحاصيل الحقلية أو الخضر. وقد تم إجراء هذا البحث بغرض دراسة مدى استجابة محصول القطن (صنف جيزه ٨٥) لنظام الرى بالرش بالأراضى المصريه القديمه بهدف زياده إنتاجية المحصول من القطن الشعر وترشيد مياه الرى المستخدمة ومقارنه ذلك بكميات المياه المستخدمة فى الرى السطحى.

وقد أجريت الدراسة بمنطقتين مختلفتين على موسمين مختلفين كالأتى :-

المنطقة الأولى: بشلقان محافظة القليوبيه بالمزرعه التجريبية بكلية الزراعة جامعه عين شمس على ٦ شرائح كل شريحة بمساحة (٢٣ x ٢٣ متر) منهم ثلاث شرائح رى بالرش وثلاث شرائح رى سطحى وجمعت البيانات الحقلية أثناء موسم الزراعة عام ١٩٩٥

المنطقة الثانيه : ببلبيس محافظة الشرقية وذلك بمناطق مشروع ميكنة المزارع الصغيرة على مساحة (٢٥٤ x ٢٦٥م) رى بالرش ورى سطحى على مساحة (١١٦ x ٣٦,٢١م) وجمعت البيانات الحقلية أثناء موسم الزراعه فى عام ١٩٩٧ وقد اعتمد التقييم لشبكة الرى بالرش والسطحى على دلائل الإنتظامية CU وكفاءه التوزيع DU وكفاءه التطبيق AE وأيضا بدلائل كفاءه النظام DU, CU, SE لكل نظام من الأنظمة تحت الدراسه.

وقد تم تسجيل القياسات المروفولوجية لمحصول القطن لكل نظام. وأظهرت النتائج أن نظام الرى بالرش أدى الى زياده الأنتاجية بمقدار ٢٢,٦٪ فى المتوسط وتوفير كميات المياه المعطاه بمقدار ١٧,٨١ ٪ فى المتوسط مقارنه بالرى السطحى بالأراضى القديمة.