COTTON CROP RESPONSE TO SPRINKLER IRRIGATION SYSTEM IN EGYPTIAN OLD LAND

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Abstract

Sprinkler irrigation is a relatively new method in Egypt mainly used in the newly reclaimed desert areas, while surface irrigation systems are dominant 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 quintar per feddan (metric quintar 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 to-
tual 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 reported 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-Manshia 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 m³/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
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 Shalafan, 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 2720 m³/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 & Bleser (1980) 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}} \times 100 \quad [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 fluctuation tendency. The expression for distribution uniformity (DU) is given by:

\[ \text{DU} = \frac{D_{\text{min}}}{D_{\text{avg}}} \quad [2] \]

Where \( D_{\text{min}} \) = 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:

\[ \text{DU}_{LQ} = \frac{D_{LQ}}{D_{\text{avg}}} \quad [3] \]

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

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

\[ D_{\text{avg}} = \frac{VD}{L} \quad [4] \]

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

\[ D_{\text{avg}} = \frac{qL}{t_{\text{co}}} \quad [5] \]
Where $q_i$ = 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:

$$SE = DU_{lo} \times AE$$

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

$$CU_o = 1 - \frac{\sum [abs (x_i - x)] / (n \times x)}{n}$$

$$CU_d = 1 - \frac{[2/\pi]^{0.5} \times (S/X)}{S/X}$$

Where $x_i$ = 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:

$$CU = \frac{(Average \ low-half \ depth \ of \ water \ received) \times 100}{m}$$

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):

$$CU = 100 - 0.63 \times (100 - DU)$$

or:

$$DU = 100 - 1.59 \times (100 - CU)$$

and the relationship between $CU$ and the standard deviation, $S_o$, of the individual depth of catch observations can be approximated by:
CU = 100 \[1.0 - \left( \frac{SD}{m} \right) \left( \frac{2}{\pi} \right)^{0.5}\]

[12]

Which can be rearranged to give:

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

[13]

Evaluating Sprinkler Uniformity System:

The CU system computed by:

$$\text{System } CU = CU = \frac{1}{2} \left[ \frac{\text{Pn}/\text{Pa}}{\text{Pn}/\text{Pa}} \right]^{0.5}$$

[14]

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

$$\text{System } DU = DU = \frac{1}{4} \left[ \frac{\text{Pn}/\text{Pa}}{\text{Pn}/\text{Pa}} \right]^{0.5}$$

[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_{aq} and AE to compare them with sprinkler irrigation DU, DU_{aq} 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 analysis and water analysis.

<table>
<thead>
<tr>
<th>Soil sample</th>
<th>Soil Mechanical Analysis %</th>
<th>Soil Chemical Analysis mg/100g</th>
<th>Water Analysis ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sand</td>
<td>Silt</td>
<td>Clay</td>
</tr>
<tr>
<td>Bellbise</td>
<td>20</td>
<td>22</td>
<td>58</td>
</tr>
<tr>
<td>Shalaqan</td>
<td>38.53</td>
<td>21.17</td>
<td>40.3</td>
</tr>
</tbody>
</table>

All farm operations such as tillage, fertilization, pest control etc. were carried out in a traditional manner except seed bed preparation in the sprinkler irriga-
tion field, which included sub-soiling to 70 cm 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.

<table>
<thead>
<tr>
<th>Uniformity parameters</th>
<th>Sprinkler irrigation Calculated %</th>
<th>Surface Irrigation Calculated by SRFR %</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUc</td>
<td>93</td>
<td>74</td>
</tr>
<tr>
<td>CUb</td>
<td>93</td>
<td>74</td>
</tr>
<tr>
<td>Du</td>
<td>89</td>
<td>65</td>
</tr>
<tr>
<td>Duq</td>
<td>95</td>
<td>75</td>
</tr>
<tr>
<td>AE</td>
<td>96</td>
<td>65</td>
</tr>
<tr>
<td>S.E</td>
<td>85</td>
<td>42</td>
</tr>
<tr>
<td>S.CU</td>
<td>87</td>
<td>---</td>
</tr>
<tr>
<td>S.DU</td>
<td>81</td>
<td>---</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Sprinkler irrigation</th>
<th>Surface irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>12.48</td>
<td>7.887</td>
</tr>
<tr>
<td>Sample 2</td>
<td>10.416</td>
<td>7.76</td>
</tr>
<tr>
<td>Sample 3</td>
<td>10.91</td>
<td>7.62</td>
</tr>
<tr>
<td>Sample 4</td>
<td>---</td>
<td>8.06</td>
</tr>
<tr>
<td>Mean</td>
<td>11.267</td>
<td>7.832</td>
</tr>
<tr>
<td>Variance</td>
<td>1.167</td>
<td>0.035</td>
</tr>
<tr>
<td>Observations</td>
<td>3.000</td>
<td>4.000</td>
</tr>
<tr>
<td>Pooled Variance</td>
<td>0.488</td>
<td>---</td>
</tr>
<tr>
<td>df</td>
<td>5</td>
<td>---</td>
</tr>
<tr>
<td>t</td>
<td>6.440</td>
<td>---</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t-confidence level 5%</th>
<th>t-Confidence level 1%</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(T&lt; = t) one-tail</td>
<td>t Critical one-tail</td>
</tr>
<tr>
<td>0.001</td>
<td>2.015</td>
</tr>
<tr>
<td>P(T&lt; = t) Two-tail</td>
<td>t Critical two-tail</td>
</tr>
<tr>
<td>0.001</td>
<td>2.571</td>
</tr>
<tr>
<td>t Critical one-tail</td>
<td>3.365</td>
</tr>
<tr>
<td>t Critical two-tail</td>
<td>4.032</td>
</tr>
</tbody>
</table>
Table 4. Effect of different irrigation methods on number of bolls per cotton tree.

<table>
<thead>
<tr>
<th></th>
<th>Sprinkler irrigation</th>
<th>Surface irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of bolls per tree</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>Average number of open bolls</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Average number of closed bolls</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>weight of one boll, (gm)</td>
<td>3.2</td>
<td>2.7</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Sprinkler irrigation</th>
<th>Surface irrigation</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shalaqan</td>
<td>Bellbise</td>
<td>Mean</td>
</tr>
<tr>
<td>Water quantity (m3/feddan)</td>
<td>2350</td>
<td>2475</td>
<td>2413</td>
</tr>
<tr>
<td>Yield (Quentar / feddan)</td>
<td>7.53</td>
<td>11.27</td>
<td>9.40</td>
</tr>
<tr>
<td>water utilization efficiency (Kg/m3)</td>
<td>0.51</td>
<td>0.72</td>
<td>0.43</td>
</tr>
</tbody>
</table>

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 Belbice.
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


استعراض محصول القطن لنظام الرى بالرشع بالأراضي المصرية القديمة

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سعود بحوش الهندسة الزراعية، مركز البيئات الزراعية - الجيزة

تعتبر طريقة الرى بالرشع من طرق الري الحديثة والتي من خلالها يتم ترشيد استهلاك مياه الري. تشمل هذه الطرق عدة دراسات مستقلة تهدف إلى زيادة استغلال مياه الري وتحسين liebeبجيماحة الأراضي المزرعة. من الناحية التقنية، يتم تنفيذ الرى بالرشع بأشكال مختلفة، بما في ذلك استخدام أسلاك بسلاسة أو الخضراء. قد يتم إجراء هذا البحث بعرض دراسة مدى استجابة محصول القطن (صنف جوزه 20) لنظام الرى بالرشع بالأراضي المصرية القديمة، بهدف زيادة إنتاجية المحصول من القطن المحضر وتحسين مياه الري المستخدمة وملاحظة تلك بكميات المياه المستخدمة في الري السطحي.

وقد أجريت الدراسة بمناطق مختلفة على مواسم مختلفة كالآتي:

المنطقة الأولى: بمحافظة الفيوم، بتوزيع تجريبي بكلية الزراعة جامعة عين شمس على 17 شرائح كل شريحة بمساحة (222متر مربع) منهم ثلاث شرائح رى بالرشع، والثلاثة الأربعة الحرة ومساحتها المثلثية أثناء موسم الزراعة عام 1995.

المنطقة الثانية: بمحافظة الإسكندرية، وذلك بمناطق مشروع ميكنة الزراعات الصغيرة على مساحة (341هكتار)، حيث تم توزيع التجربة على مساحة (112متر مربع)، وأيضًا الرى بالرشع والري السطحي في عام 1997 وقدمت النتائج.

اعتماد التهوية لشبكة الرى بالرشع والري السطحي، وكفاءة التوزيع DU، وكفاءة التخطيط AB، وأيضًا بعدو كفاءة النظام DU، وكفاءة التوزيع DU، وكفاءة التخطيط AB، وأيضًا بعدو كفاءة النظام DU، وكفاءة التوزيع DU، وكفاءة التخطيط AB، وأيضًا بعدو كفاءة النظام DU.

وقد تم تسجيل القياسات المجرفة لمحصول القطن لكل نظام، وأظهرت النتائج أن نظام الرى بالرشع أدى إلى زيادة الإنتاجية بمقدار 22% في المتوسط وتوقف كمية المياه المستخدمة بمقدار 8% في المتوسط مقارنة بالري السطحي بالأراضي القديمة.