Innovative Method for Rice Irrigation with High Potential of Water Saving

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Abstract:
Water is considered the major constraint for any policy to increase agriculture productivity. Since the present water supply is limited, water demand is augmenting to face the incessant increase in population. Thus it was necessary to control and manage the available water supply to face overuse problem and minimize water losses from watercourses to improve irrigation efficiency.

Rice is one of the most important crops in Egypt providing a good source of income. It is a main stable food for the majority of the population and has become a cash crop. All the rice cultivated in Egypt is low-land rice. Rice remains an exception such that the areas entitled to cultivate rice are defined by the Ministry of Water Resources and Irrigation (MWRI) to about 46000 hectares per year.

Nonetheless, the areas cultivated with rice in Egypt have been on the increase in violation to the above mentioned policy. About 50% increase in the total rice area, this increases the pressure on the limited water resources in the country and sometimes causes irrigation water shortages during the peak summer seasons. So, saving the water is a necessity demand to face the water gap problem by using innovative method for rice irrigation.

This innovative method has been conducted in 2002 on small research area as an experimental work. After that, through years of 2003 till 2005, whereas the experiments showed good achievement, the Ministry of Water Resources and Irrigation co-operated with Water Management Research Institute for extend this innovative method on different governorates covering all climate and soil conditions in Egypt. These governorates were located on different regions (North Delta, Middle Delta, West Delta and East Delta). This extension works aimed to convince the farmers by using this new method in order to save water. During these extension years we achieved a very good results on water saving by convincing many farmers by this method. The cultivated areas were 50 hectares distributed on different sites.
Then this method through years 2006 and 2007 has been used on large scale on five regions including Fayoum Governorate, Middle Egypt on cultivation area about 150 hectares.

**Planting methods (M): two planting methods were followed in the permanent field, they were:**

**M₁: Traditional transplanting:**
Transplanting of seedlings rice on flat at the hills (4-5 plants) distance of 20 ×20 cm. to give the rate of (25 hills/m²)

**M₂: Transplanting in strips of furrows 80 cm. wide:**
(Top of furrow 45cm. (border) and 35 cm. for bottom tape) Seedlings were transplanting in hills (4-5 plants) 10 cm. apart in the two rows on the bottoms of furrows (tapes) keeping population the same as in the traditional method (25 hills/m²) as recommended.

The results indicated that M₂ treatment gave the highest value of grain yield (t/ha). Also the results indicated that the applied water was reduced from 1459.44 to 9022.5 m³/ha. and water use efficiency was increased from 0.588 to 1.033 Kg/ m³ for M₁ and M₂ treatments respectively.
Water saving was 5937.44 m³/ha. (39.69 %) for M₂ compared with M₁ treatment.
The comparison between the new method and the traditional method of rice cultivation indicate that irrigation water can be reduced by 40%, the production increase by 5%, the water use efficiency can be increased by 75%.

**Introduction:**

Rice is one of the most inefficient in water use because it grown generally under submerged condition in Egypt. It is means stable food for majority of the population and has become exportable crop in Egyptian agricultural system after the free cropping pattern policy. For these reasons, the areas cultivated with rice have been increased. The authorities in Egypt limit the area devoted to rice to be about 46000 hectares every year but the farmers cross this area to almost the double because rice is more profitable crop than other summer crops namely maize and cotton. Consequently the pressure increase on the limited area resources in the country and sometimes causes irrigation water shortage during the peak summer season.
The water resources in Egypt are considered limited although the population increasing continuously. In the sense that they will not have sufficient water resources to meet their agricultural, domestic, industrial and environmental needs.

One of the main strategies to overcome this problem is to achieve better water management policy. Irrigation management under old lands conditions which irrigated by surface irrigation method is very important to improve production and water saving. For increasing water use efficiency of rice can be improved without additional costs to the farmers and consequently water save. So saving water is necessary to face the water shortage in the future. Such saving for irrigation water of rice is like to be achieved by using a new planting and irrigation method with high potential for water saving.

The aim of this study was performed in order to seek a possibility of growing rice cultivar Sakha 104 on strips in order to decrease the amount of irrigation water as well as increasing water productivity.

**Background:**

The traditional method for rice cultivation require that rice seeds be first soaked in sufficient water for 48 hr and then incubated for 24 hr to enhance the germination. Then after that, it were handily broadcasted.

Field preparation and nursery practices performed according to the traditional local management. 30 days old seedlings were transferred from the nursery and transplanted in the permanent field after puddling. The field is usually divided into basins. Transplanting of seedlings rice on flat at the hills (4-5 plants) distance of 20 x 20 cm to give the rate of (25 hills/m²) as recommended. All other cultural practices for rice were followed, the irrigation of rice crop during growing season was applying with 10 cm. The farmers got used to over irrigate their fields where losses of water are great. Hence decreasing of water productivity, therefore it is necessary to find out a new planting method and a new surface irrigation technique.

There are many trails to estimate the amount of water used for land preparation for both nursery and permanent field, raising nursery for 30 days and the amount use during transplanting stage was measured 3983 m³/ha.
Some researchers such Nour and Mahrous (1996) estimated this amount of water and found it 4602 m$^3$/ha, Nour et al (1996) found it 4790 m$^3$/ha, Sorour et al (1998) found it 4495 m$^3$/ha and Atta (2005) found it 4476 m$^3$/ha. Many investigators studied the water requirements of rice at continuous flooding in this respect Abou-Soliman et al (1990) gave a range of 16190-21428 m$^3$/ha, Nour and Mahrous (1994) found this amount of water was 19152 m$^3$/ha and Atta (2005) found it 14870 m$^3$/ha.

The innovative method:

This method is depending on reducing irrigated area by land deviation into furrows. Top of furrow was named (border) and bottom of furrow was named (tape). Every border and tape named (strip). The seedlings were transplanted in bottom of furrow (tape) with using the same plant density as recommended into two rows of plants according to strip width. Planting irrigation was given with enough amount for reaching to puddling then the next irrigation were given for taps only with depth of 7 cm. Accordingly flooding area was less and consequently increased water saving by about 30%-40% using this new method increased irrigation application efficiency and water productivity, however it decreased percolation losses and decreased evaporation.

Conservation of plant density:

Using this method, it achieved new plants distribution as recommended plant density is (25 hills/m$^2$) and in order to survive this density we can use the new method whereas in this method the plant density can be calculated for example as follows:

Furrow with long 10m and wide at 0.8m.
Total area = 10 x 0.8 = 8 m$^2$
No. of hills = 8 x 25 = 200 hills
No. of hills in each row = 200/2 = 100 hills
Distance between hills = 8/100 = 0.1 m
And consequently we can find that, No. of hills per unit area is equal for both new and traditional methods.

Generally in this study the new planting method for rice (strip of furrow 80 cm) was always better than traditional method in reduction of irrigation water applied
and costs while it increase water productivity and grain yield because planting rice on strips perhaps made a good advantages and important proprieties such as:

- Good distribution of plants.
- Less flooding area.
- Water saving 30%-40%.
- Raising water productivity.
- Increasing fertilizers use efficiency.

This innovative method has been conducted in 2002 on small research area as an experimental work. After that, through years of 2003 till 2005, whereas the experiments showed good achievement, the Ministry of Water Resources and Irrigation co-operated with Water Management Research Institute for extend this innovative method on different governorates covering all climate and soil conditions in Egypt. These governorates were located on different regions (North Delta, Middle Delta, West Delta and East Delta). This extension works aimed to convince the farmers by using this new method in order to save water. During theses extension years we achieved a very good results on water saving by convincing many farmers by this method. The cultivated areas were 50 hectares distributed on different sites.

After this extension work, The Minster of Water Resources and Irrigation allowed to forbidden rice cultivation areas (such Fayoum Governorate) to cultivate rice but under using this Innovative method which save the applied water by 40%. The Minster announced this through the media. In addition to the Minster gave his instructions to irrigation districts to use this new method and to be wide used all over Egypt. Then this method through years 2006 and 2007 has been used on large scale on five regions including Fayoum Governorate, Middle Egypt on cultivation area about 150 hectares.

Some piece information about this innovative method have been published in Grid (FAO Journal) Volume 25, 2006, Arabic and English versions.

And Water Management Project in Fayoum recommended this method to be world wide used. And currently Irrigation Improvement Projects applying this new method on the command areas. WUAs now using this method and they doing extension for it.

**Methodology:**

The Innovative method of rice cultivation (on strips) was applied in farmers fields on five governorates under different soil and climate conditions in Egypt in 150 hectares, This study aimed to seek the possibility of growing rice in the bottom of furrows (strips) in order to increase water use efficiency of rice cultivar Sakha 104.
with cropping period (135 days). Some soil physical and chemical properties of cultivated areas are presented in Table (1). A Complete randomized blocks design with four replicates was used.

**Table (1): some physical and chemical properties for the experimental sites**

<table>
<thead>
<tr>
<th>Sites</th>
<th>Sand %</th>
<th>Silt %</th>
<th>Clay %</th>
<th>Soil Texture</th>
<th>pH</th>
<th>EC (dS/m)</th>
<th>F.C. %</th>
<th>W.P %</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Delta</td>
<td>26.7</td>
<td>28.5</td>
<td>44.8</td>
<td>Clay</td>
<td>8.1</td>
<td>1.19</td>
<td>38.34</td>
<td>19.90</td>
</tr>
<tr>
<td>West Delta</td>
<td>27.2</td>
<td>12.8</td>
<td>60.0</td>
<td>Heavy Clay</td>
<td>8.5</td>
<td>1.5</td>
<td>42.30</td>
<td>20.80</td>
</tr>
<tr>
<td>Middle Delta</td>
<td>17.4</td>
<td>19.1</td>
<td>63.5</td>
<td>Heavy Clay</td>
<td>8.3</td>
<td>2.1</td>
<td>41.60</td>
<td>19.60</td>
</tr>
<tr>
<td>North Delta</td>
<td>24.8</td>
<td>32.6</td>
<td>42.6</td>
<td>Clay</td>
<td>7.9</td>
<td>1.2</td>
<td>34.80</td>
<td>20.80</td>
</tr>
<tr>
<td>Middle Egypt</td>
<td>21.1</td>
<td>40.6</td>
<td>38.3</td>
<td>Clay loam</td>
<td>8.0</td>
<td>2.8</td>
<td>36.41</td>
<td>21.30</td>
</tr>
</tbody>
</table>

**Factors of study:**

Planting methods (M): two planting methods were followed in the permanent field, they were:

**M₁: Traditional transplanting:**

Transplanting of seedlings rice on flat at the hills (4-5 plants) distance of 20 × 20 cm. to give the rate of (25 hills/m²) and,

**M₂: Transplanting in strips of furrows 80 cm wide:**

(Top of furrow 45 cm. and 35 cm. for bottom) Seedlings were transplanting in hills (4-5 plants) 10 cm. apart in the two rows on the bottoms of furrows (strips) keeping population the same as in the traditional method (25 hills/m²) as recommended as shown in Fig. (1).

![Fig (1) : Strips of Furrows Diagram (80 cm wide).](image)
Rice variety Sakha 104 was planted in these regions. Field preparation and nursery practices performed according to the traditional local management. Rice seeds were soaked in sufficient water for 24 hours and then incubated for 48 hours to enhance germination. Thereafter, it was broadcasted. Thirty days old seedlings were manually transplanted.

Dates of some cultural practices as follows:

<table>
<thead>
<tr>
<th>Sites</th>
<th>East Delta</th>
<th>West Delta</th>
<th>Middle Delta</th>
<th>North Delta</th>
<th>Middle Egypt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing</td>
<td>May, 20</td>
<td>May, 15</td>
<td>May, 21</td>
<td>May 18</td>
<td>May 16</td>
</tr>
<tr>
<td>Transplanting</td>
<td>June, 20</td>
<td>June, 15</td>
<td>June, 21</td>
<td>June 18</td>
<td>June 16</td>
</tr>
</tbody>
</table>

The fertilizers requirements for the nursery were added according to the recommended doses according to Crops Research Institute, Agricultural Research Center (ARC). Nitrogen fertilizer in the form of ammonium sulphate (20.6 % N) was used at a rate of 140 kg N/ha. Phosphate fertilizer in the form of Calcium superphosphate (15.5 P2O5) at the rate of 70 Kg P2O5 per hectare was added during permanent field preparations. The complementary fertilizers such as potassium and Zinc were applied as recommended in time. All other cultural practices for rice production were followed.

Data Recorded:

(A) Water Management Data:

I. Irrigation Water Measurement:

Irrigation water was measured using water meter (in m³). The amount of water used for land preparation for both nursery and permanent field, irrigation of the nursery for 30 days and through the first seven days after transplanting were measured to be 3983 m³/ha. The amount of irrigation water delivered to each treatment was also, recorded and added to get the total water used. Irrigation of the permanent field started after seven days from transplanting process and stopped before 10 days from harvesting process in all seasons. The water depth at the
irrigation day was about 7 cm for all treatments with 3 days of irrigation interval. (continuous flooding).

2. Water Use Efficiency (WUE) :

It was calculated according to Israelsen and Hansen (1962) as follows:

\[ WUE = \frac{\text{Rice grain yield (Kg/ha.)}}{\text{Total water used (m}^3/\text{ha.)}} \]

(B) Grain Yield (ton/ha.):

The central samples of each field were harvested to determine grain yield in ton/ha as adjusted at 14% moisture content. All data were subjected to analysis of variance according to Cochran and Cox (1957) then treatment means were compared by LSD test.

(C) Economic analysis

In order to identify the difference between the two methods, economic analysis will be applied. This analysis will depend on the following two indicators:

- Net return/m$^3$ of water: This indicator will be calculated by dividing the net return arising from each method by the total amount of water applied

\[ \text{Net Return} / \text{Total water applied} \]

- Benefit cost ratio (B/C) : This ratio is calculated by dividing the total net return for each method by its total costs. The higher ratio refers to the better economic efficiency.

\[ \frac{\text{B/C}}{\text{total net returns}} = \frac{\text{total net returns}}{\text{total costs}} \]

Results and Discussion:

Data for grain yield collected and presented in Table (2). The obtained data showed that, the planting methods had a significant effect on grain yield/ha. The highest grain yield/ha (9.275 t/ha.) was obtained from M$_2$ treatment, while the lowest value was recorded from M$_1$ treatment (8.789 t/ha.). Similar results were obtained by Atta (2005).
Table (2): average of total water used, water saving, grain yield, yield increment and water use efficiency as affected by planting methods for five regions.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Planting Method (M)</th>
<th>Total water used m³/ha.</th>
<th>Water saving (%)</th>
<th>Grain yield (t/ha)</th>
<th>Yield increment (%)</th>
<th>WUE kg/ m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>m³/ha</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Delta</td>
<td>M₁</td>
<td>14871.3</td>
<td>-</td>
<td>9.405b</td>
<td>-</td>
<td>0.632</td>
</tr>
<tr>
<td></td>
<td>M₂</td>
<td>9190.4</td>
<td>5680.9</td>
<td>38.2</td>
<td>9.954a</td>
<td>5.84</td>
</tr>
<tr>
<td>West Delta</td>
<td>M₁</td>
<td>13952.4</td>
<td>-</td>
<td>7.939b</td>
<td>-</td>
<td>0.569</td>
</tr>
<tr>
<td></td>
<td>M₂</td>
<td>8133.4</td>
<td>5819.0</td>
<td>41.7</td>
<td>8.402a</td>
<td>5.83</td>
</tr>
<tr>
<td>Middle Delta</td>
<td>M₁</td>
<td>15628.6</td>
<td>-</td>
<td>8.721b</td>
<td>-</td>
<td>0.558</td>
</tr>
<tr>
<td></td>
<td>M₂</td>
<td>9028.6</td>
<td>6600.0</td>
<td>42.23</td>
<td>9.146a</td>
<td>4.87</td>
</tr>
<tr>
<td>North Delta</td>
<td>M₁</td>
<td>15047.4</td>
<td>-</td>
<td>9.090b</td>
<td>-</td>
<td>0.604</td>
</tr>
<tr>
<td></td>
<td>M₂</td>
<td>9500.0</td>
<td>5547.4</td>
<td>36.87</td>
<td>9.700a</td>
<td>6.71</td>
</tr>
<tr>
<td>Middle Egypt</td>
<td>M₁</td>
<td>15300.0</td>
<td>-</td>
<td>8.830b</td>
<td>-</td>
<td>0.577</td>
</tr>
<tr>
<td></td>
<td>M₂</td>
<td>9260.1</td>
<td>6039.9</td>
<td>39.48</td>
<td>9.365a</td>
<td>6.06</td>
</tr>
<tr>
<td>Over All Average</td>
<td>M₁</td>
<td>14959.94</td>
<td>-</td>
<td>8.797b</td>
<td>-</td>
<td>0.588</td>
</tr>
<tr>
<td></td>
<td>M₂</td>
<td>9022.5</td>
<td>5937.44</td>
<td>39.69</td>
<td>9.313b</td>
<td>5.86</td>
</tr>
</tbody>
</table>

M₁: Traditional method -
M₂: Strips of furrows 80 cm
Table (3): average of water used (m³/ha) before and through irrigation treatments for five regions

<table>
<thead>
<tr>
<th>Irrigation Period</th>
<th>East Delta</th>
<th>West Delta</th>
<th>Middle Delta</th>
<th>North Delta</th>
<th>Middle Egypt</th>
<th>Over all Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A: Before Treatments</strong>*</td>
<td>4128.5</td>
<td>3581.0</td>
<td>4252.4</td>
<td>3971.4</td>
<td>4160.0</td>
<td>4018.66</td>
</tr>
<tr>
<td><strong>B: During Treatments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>10742.8</td>
<td>10371.4</td>
<td>11376.2</td>
<td>11076.0</td>
<td>11140.0</td>
<td>10941.28</td>
</tr>
<tr>
<td>M2</td>
<td>5061.9</td>
<td>4552.4</td>
<td>4776.2</td>
<td>5528.6</td>
<td>5100.1</td>
<td>5003.48</td>
</tr>
<tr>
<td><strong>C: Total Water Used</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>14871.3</td>
<td>13952.4</td>
<td>15628.6</td>
<td>15047.4</td>
<td>15300.0</td>
<td>14959.94</td>
</tr>
<tr>
<td>M2</td>
<td>9190.4</td>
<td>8133.4</td>
<td>9028.6</td>
<td>9500.0</td>
<td>9260.1</td>
<td>9022.50</td>
</tr>
</tbody>
</table>

* Amount of water for land preparation for both nursery and permanent field, as well as rising for 30 days and through 7 days after transplanting.

Grain Yield:

Data for grain yield collected and presented in Table (2). The obtained data showed that, the planting methods had a significant effect on grain yield/ha. The highest grain yield/ha (9.275 t/ha.) was obtain from M2 treatment, While the lowest value was recorded from M1 treatment (8.789 t/ha.). Similar results were obtained by Atta (2005).

![Grain Yield Chart](image)

Though transplanting was done in more intense way by doubling the population within the furrow of the strip, yet the rice crop performed better when transplanted in the bottoms of the furrows (strips) M2 treatment than M1 treatment as shown in Table (2).

Grain yield had higher value with transplanting on strips of furrows (M2). Increase grain yield/ha by 5.86 % using (M2) treatment compared with traditional transplanting (M1) treatment.
This result can be explained that the plant of rice found better environment where, planted with a distance of 45 cm. for M₂ away from the other plant planted in the neighboring furrow though, it may be competing with the other hill planted 10 cm apart within the same row. On other words, the intra-row competition especially for light was minimized against increase in the inter-row competition. The rate of effect of these two competitions was in favour of the intra-row competition resulted in a better environment for rice plants.

**Water Relations:**

**Water used before and through treatments:**

Table (3) showed the amount of water used for land preparation, for both nursery and permanent field, as well as raising for 30 days and through 7 days after transplanting and before treatments application were 4018.66 m³/ha. as average. Similar results were found by Nour and Mahrous (1994), Nour et al., (1996) Sorour et al., (1998) and Atta (2005). The nursery area was about one tenth of permanent field area. Water used through treatments application measured and was found to be 10941.28 and 5003.48 m³/ha. for M₁ and M₂ treatments as average respectively.

![Water Use Graph](image)

**Total water used:** The results showed that total water used by rice according to the different planting methods, where 14959.94 and 9022.5 m³/ha for M₁ and M₂ treatments respectively. From these results, it can be reported that water saved were about 5937.44 m³/ha (39.69 % ), and yield increasing by 5.86 % for M₂ treatment.
Some research workers estimated the water requirement of rice crop and they differed in their estimates. **Abo-Soliman et al., (1990)** gave 16190–21429 m³/ha. **Nour and Mahrous (1994)** gave 19152 m³/ha. for Giza 176 cultivar, **Nour et al., (1996)** gave 14976, 13333 and 14048 m³/ha. as the water needed for Giza 176, Giza 177 and Giza 178 cultivars, respectively.

**Sorour et al., (1998)** gave 14390 m³/ha. for Giza 176 cultivar, **Ghanem and Ebaid (2000)** gave 13755 m³/ha. as water required to irrigate Sakha 101 cultivar and **Awad (2001)** gave 12452 m³/ha. for Giza 178 cultivar from transplanting to harvest. **Atta (2005)** reported that using strips of furrows 80 cm method as a new planting method for transplanting rice Sakha 104 cultivar obtained water saving with 34.8 %, increasing grain yield by 3.4 % and increased water use efficiency from 0.66 to 1.06 kg/m³.

**Water Use Efficiency (WUE):**

Table (2) showed that the highest water use efficiency (WUE) was recorded for M2 treatment (1.032 kg/m³). While the lowest one was recorded for M1 treatment (0.588 kg/m³). This due to the marked reduction in the amount of water used with a significant increase in grain yield. Similar results were obtained by Atta (2005).
Economic analysis

The analysis of the study results revealed that rice cultivation under strip method is more efficient than that under the traditional method.

The net return for rice cultivated under strip method (M2) were calculated at 0.182 $/m³ of water compared to 0.089 $/m³ of water for rice cultivated under the normal method (M1). On the other hand, Benifit cost ratio (B/C) for rice (M2) is higher than that for rice (M1) as shown in table (4). This due to the less amount of water used with rice planted under strip method.

Table (4) Net return per m³ of water and Benifit cost ratio (B/C) for rice according to planting methods.

<table>
<thead>
<tr>
<th>Planting Method</th>
<th>Grain Yield Kg/ha</th>
<th>Total return $/ha</th>
<th>Costs $/ha</th>
<th>Net return $/ha</th>
<th>Water applied m³/ha</th>
<th>Net return($) /m³ of water</th>
<th>Benifit cost ratio (B/C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Variable</td>
<td>Fixed</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>8797</td>
<td>3838.7</td>
<td>1261.4</td>
<td>1246.0</td>
<td>2507.4</td>
<td>1331.3</td>
<td>0.089</td>
</tr>
<tr>
<td>M2</td>
<td>9313</td>
<td>4063.9</td>
<td>1172.0</td>
<td>1246.0</td>
<td>2418.0</td>
<td>1645.9</td>
<td>0.182</td>
</tr>
</tbody>
</table>

Conclusion and Recommendation:

Transplanting rice using strips of furrows 80 cm method (M2) is potentially high for water saving as approximately 40 % will be saved, and 6 % increase in grain yield/ha in addition to 75 % increase in water use efficiency.
This study is a pioneer one. And this method is highly recommended to be used by farmers and policy makers. Further works are recommended to cultivate rice using this new method in very large area all over Egypt.

References


Annex:

Rice Innovative plating Method

Traditional Method

New Method (Strips)
Traditional Method

The New Method (Strips)