Comparison of surface and center pivot Irrigation systems for water application, yield components and profitability of Wheat, Case study: New Hamdab area, Sudan

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**ABSTRACT**

Wheat is a very important cereal crop in Sudan. The different ways of water applying to the plant, make a differences in both irrigation systems surface and center pivot in term of amount of water application which lead to different in yield. Therefor water productivity and the profitability of the systems will also be different.

The objective of this study is to evaluate the two irrigation system surface and center pivot for water application, productivity, wheat yield and the profitability. The study was carried out for two consecutive seasons 2007/08 and 2008/09 in New Hamdab Agricultural Scheme at Northern Sudan. A comparisons between the two irrigation systems was made for water application, yield and profitability.
systems was carried out in RCBD with three replications. Amount of Water Apply (Aw) was measured using Parshall flume, but for the confidence a two methods were also used; the gravimetric method and the orifice discharge with float method. Yield and the water productivity components were determined, then profitability was estimated. The results showed that surface irrigation system is more water consuming than the center pivot system \((p \leq 0.05)\) with higher yield \((p \leq 0.01)\) in both seasons but has low cost of 100 kg \((p \leq 0.01)\) and \((p \leq 0.05)\) in the first and second season respectively.

**INTRODUCTION**

The great challenge of the agricultural sector is to produce more food from less water, which can be achieved by increasing crop water productivity (Sander and Bastiaanssen, 2004). Demand for wheat in the past has not been very high because the diet of the majority of the Sudanese population was based mainly on Sorghum. At present, wheat consumption has increased and the government is attempting to attain self-sufficiency in this commodity (El Hwary and Yagoub 2011). An adequate water supply is important for plant growth. When rainfall is not sufficient, the plants must receive additional water from irrigation. Various methods of irrigation can be used to supply irrigation water to the plants, each method has its advantages and disadvantages. These should be taken into account when choosing the method which is best suited to the local circumstances. More sophisticated methods of water application are used when larger areas require irrigation. There are three commonly used methods: surface irrigation, sprinkler irrigation and drip irrigation (Brouwer, 1994). Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire field is flooded (basin irrigation) or the water is fed into small channels (furrows) or strips of land (borders). Sprinkler irrigation is similar to natural rainfall. Water is pumped through a pipe system and then sprayed onto the crops through rotating sprinkler heads (Brouwer and Prins, 1989). Usually, on-demand delivery scheduling is more common in pressurized irrigation systems, in which the control devices are more reliable than in open canal systems. The on-demand delivery schedule offers a greater potential profit than other types of irrigation schedules and gives a great flexibility to farmers that can manage water in the best way and according to their needs (Nicola and Sagardoy, 2000). Both irrigation systems surface and center pivot have a certain condition to use and they are designed to supply adequate amount of water to
the plant in order to produce a high yield, but in different ways, these different ways make differences in both systems such as water application amount and so it will lead to different in yield. There for water productivity and the profitability of the systems will also be different. Water productivity, defined as “the ratio of crop production (kg) to the unit of water used (m³)” (ASCE, 1978). The main objective of this study is to comparison the two irrigation systems for water application, wheat yield components, productivity and the profitability.

MATERIALS AND METHODS
This study was carried out in two seasons 2007/08 and 2008/09 in New Hamdab Agricultural Scheme, Northern Sudan. The area located in desert plain and it confined between longitude 31° 06' 08" and 31° 13' 31" E and latitude 17° 55' 11" and 17° 58' 11" N. The soil is classified as typic Haplocombid, fine loamy, mixed, hyperthermic and correlated to Kelly soil series, generally this soil is non-saline, non-sodic and characterized by low chemical fertility and light texture. Comparisons between two irrigation systems were carried out in New Hamdab Agricultural Scheme. Three units of center pivot sprinkler irrigation system and three experimental units of surface irrigation system conducted in New Hamdab Research Station were used. The experiment was arranged in RCBD with three replication. Both systems were sown by wheat crop (Wad Elniel cultivar) and all the agricultural practices were the same. The following parameters were measured:

Water Application (Aw)

Amount of water apply (Aw) was measured for both systems, for the surface irrigation system a Parshall flume was used, but there were two measuring methods were also used for confidence. The first one was the soil moisture content (gravimetric method) then converted to volumetric (θv) thus,

\[
\text{Amount of water applied/irrigation (m}^3) = \theta v \% \times A \times D \\
\]

Where:
A= is the irrigated area (m²)
D= is the profile depth (m)

Water Application (Aw) per season =

\[
\text{Aw/irrigation} \times \text{No. of irrigation} \\
\]

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The second method was using an orifice discharge (Q) and the float method.

Orifice discharge \((m^3/hr) = A.V\) ........................................................................(3)

Where:

\(A\) = is the orifice area \((m^2)\)

\(V\) = is the velocity \((m/hr)\)

Amount of water applied/irrigation \(m^3\) = \(Q \times t\) ......................................................(4)

Where:

\(t\) = is the period of irrigation \((hr)\)

Application water \((Aw)\) per season =

\[Aw\ per\ watering \times No. \ of\ irrigation\] ..................................................(5)

For the center pivot sprinkler irrigation system was used the following formula:

Application water \((m^3)\) = \(q \times h\) .................................................................(6)

Where:

\(q\) = is the pump discharge \((m^3/hr)\)

\(h\) = is the operating hours \((hr)\)

**Water productivity**

Water productivity was calculated using the formula.

Water productivity \((kg/m^3)\) =  \(\frac{Grain\ yield\ (kg/ha)}{Total\ water\ applied\ (m^3/ha)}\) ..................................................(7)

Wheat yield was determined and profitability was estimated using fuel consumption rate and water man cost for center pivot and labors water man cost for surface system.

### RESULTS AND DISCUSSIONS

**Water Application \((m^3/ha)\)**

The results of the statistical analysis show that there is a significant difference at \((p \leq 0.05)\) between two irrigation systems in application of water during the two seasons. The surface irrigation system consumed more water \((8147\ and\ 5565\ m^3/ha)\) compared with center pivot irrigation system \(5557\ and\ 3543\ m^3/ ha\), in first and second season respectively. The amounts of water applied are within the range as found by Ageeb...
(1993) 5040 m³/ha in northern state and Sirelkhatim *et. al*, (2007) 6132 m³/ha in central Sudan. In addition, Hisham 2011 and Hisham *et. al*, 2015, reported the range of water applied was 7000 m³/ha in the same area. Application water in the second season was less in center pivot system, this may be due to operation and maintenance problems.

**Wheat yield (kg/ha)**

There was a highly significant difference in yield at (p ≤ 0.01) in both seasons. The surface system resulted in higher yield (3102 and 2789 kg/ha) in first and second season respectively, due to higher water application as (Farah,1998) reported, yield increase with increasing in water applied to it is maximum of about 9500 and 11500 m³/ha /season then decreased with increasing in water applied over that amount. Also Farah,(1998) found the yield in some studies is 3317, 2690 and 1598 kg/ha which are closely to those obtained by the both irrigation systems except in the second season for center pivot irrigation system which is less

**Water productivity**

Results showed that there was a significant difference at (p ≤ 0.05) between both irrigation systems in water productivity during the two seasons. The highest irrigation water productivity (0.38 and 0.5 kg/m³) was obtained under surface irrigation system and the lowest was (0.15 and 0.28 kg/m³) under center pivot irrigation system (Table 1 and 2). The irrigation water productivity was higher under surface irrigation system compared to center pivot irrigation system. These results are in agreement with those reported by Farah (1987) who stated that water use efficiency ranged from 0.38 to 0.68 kg/m³. In addition, Erneo *et al*. (2003) reported the range of water productivity as between 0.30 and 0.45 kg/m³. The average water productivity across seasons for center pivot was 0.22 kg/m³, in agreement with the findings of Al-Naeem (2008) who reported that the range of water productivity was between 0.17 and 0.30 kg/m³. The results showed that water productivity of the both irrigation systems was generally below the recommended values obtained by FAO (Sander and Bastaiaanssen, 2004).

For all this center pivot resulted higher cost of 100 kg significantly at (p≤ 0.05) in the second season and higher significant at (p≤ 0.01) in the first season, this may be due to the high operation cost.
Table 1. Application water, yield, water productivity and the profitability (cost of 100 kg) of both irrigation systems (surface and center pivot) season 2007/08

<table>
<thead>
<tr>
<th>Treatments</th>
<th>App. water (m³/ha/season)</th>
<th>Yield (kg/ha)</th>
<th>Productivity (kg/m³)</th>
<th>Cost of 100kg (SDG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface irrig.</td>
<td>8147 a</td>
<td>3102 a</td>
<td>0.38 a</td>
<td>11.73 b</td>
</tr>
<tr>
<td>Center pivot irrig. system</td>
<td>5557 b</td>
<td>1578 b</td>
<td>0.28 b</td>
<td>15.21 a</td>
</tr>
<tr>
<td>Sig. level</td>
<td>*</td>
<td>**</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>S.E ±</td>
<td>179.03</td>
<td>67.18</td>
<td>0.01</td>
<td>0.30</td>
</tr>
<tr>
<td>C.V</td>
<td>7.8</td>
<td>8.6</td>
<td>5.37</td>
<td>3.86</td>
</tr>
</tbody>
</table>

*, ** and N.S = significant level at p≤ 0.05, 0.01 and not significant respectively.

Table 2. Application water, yield, water productivity and the profitability (cost of 100 kg) of both irrigation systems (surface and center pivot) season 2008/09

<table>
<thead>
<tr>
<th>Treatments</th>
<th>App. water (m³/ha/season)</th>
<th>Yield (kg/ha)</th>
<th>Productivity (kg/m³)</th>
<th>Cost of 100kg (SDG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface irrig.</td>
<td>5565 a</td>
<td>2789 a</td>
<td>0.50 a</td>
<td>15.41 b</td>
</tr>
<tr>
<td>Center pivot irrig. system</td>
<td>3543 b</td>
<td>518 b</td>
<td>0.15 b</td>
<td>58.05 a</td>
</tr>
<tr>
<td>Sig. level</td>
<td>*</td>
<td>**</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>S.E ±</td>
<td>221.3836</td>
<td>91.9519</td>
<td>0.1089</td>
<td>6.5688</td>
</tr>
<tr>
<td>C.V</td>
<td>8.42</td>
<td>9.63</td>
<td>30.13</td>
<td>30.97</td>
</tr>
</tbody>
</table>

*, ** and N.S = significant level at p≤ 0.05, 0.01 and not significant respectively.

**CONCLUSIONS**

Surface irrigation system consuming more water than center pivot irrigation system. The yield is very high in surface irrigation system due to the higher water used within the reported range. The lower yield in center pivot is due to the less water used which is out of the reported range, so it affect water productivity and the cost of 100 kg. Water productivity is higher in surface irrigation system. Cost of 100 kg is very high in center pivot.
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REFERENCES


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