A Net-back, Revenues and Applied Energy Analysis of Irrigated Wheat Using Pressurized Irrigation Systems under Environmental Desert Multi-Criteria

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Abstract: The two field trials were carried out under four pressurized irrigation systems in season (2012/2013) at the site of NRC Farm, Nubaria, Behaira Governorate, This study aims to investigate the energy feasibility (a net-back, applied and revenues energy Analysis) of cultivating wheat (Triticum aestivum L. cv. Gemmaiza 9), under various pressurized irrigation systems [surface drip (SD), subsurface drip (buried hoses) (BD), fixed sprinkler (FS), semi-portable sprinkler (PS)]. Applied irrigation water amounts are (50, 75 and 100% of calculated applied water and called W1, W2 and W3, respectively). The statistical experiment design was a complete split plots, the main results are: The highest energy efficiency of crop irrigation (EECI) were (PS, W3), (PS, W2), (FS, W3) and (FS, W2) respectively, while the other treatment is semi close. The highest pumping power is (FS, PS, BD) irrigation systems respectively. Otherwise, the highest energy requirements were (SD, W3), (SD, W2), (SD, W1), (FS, W3), (PS, W3) and the other treatment is semi close. The highest applied installing energy is (BD, FS, SD and PS) irrigation systems respectively, as we have seen the last energy parameters lead to the operating and annual total energy As we will see later, it’s crystal clear that the highest applied operating energy is (PS, W3), (BD, W3), (BD, W2), (PS, W2) and (SD, W3) respectively. The highest annual total irrigation energy inputs (ATEI) is (BD, W3), (BD, W2), (BD, W1), (FS, W3), (FS, W2), (FS, W1) likewise SD then PS irrigation systems. The highest energy-applied efficiency (EAE) is (BD, W1), (BD, W2), (BD, W3), (SD, W1), (SD, W2), (PS, W2), while the others treatments are semi close and are not faraway about the last value. The highest value of both of EECI and REC is (BD, W1), (SD, W1), (FS, W1), (PS, W1), (BD, W2), and (SD, W2). By the same token, FS then PS irrigation systems. Conversely, the behavior of both of EECI and EP increases beginning of BD, SD, and FS reaching to PS irrigation systems.

Keywords: Water, Energy, Pumping, Irrigation Pressurized, Sprinkler, Drip, Economy, Wheat, Desert.

1. Introduction

There’s no doubt that, energy is a fundamental factor in the process of economic agricultural development, as it provides all important services that maintain economic activity and the quality of human spirit. Modern farming has become very energy-intensive. Energy in agriculture is significant in conditions of crop production and agro-processing for value adding. The aims of this study were to determine energy consumption and energy indexes in peach production, to investigate the efficiency of energy consumption and to make an economic analysis of peach orchards, according to [1]. Irrigation cost of production unit under the surface micro drip and subsurface micro drip irrigation system for the different water treatments was lower than under the surface drip and subsurface drip irrigation systems for the experimental water treatments, it was doubled under subsurface drip and surface drip irrigation systems comparing with subsurface micro dry and surface micro drip [2]. Mainly regarding basic resources as water and energy, is compulsory. For such purpose a wider overview of how water and energy are used in a PWS is necessary to identify where are located the pouches of energy savings. Any serious ex-ante analysis will require proceed in that way. This general picture of the energy requirements, summarized by adequate performance indicators will give a precise idea about the use of the energy in a PWS, about how much room for improvements exists and last the actions to be

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taken to improve the situation. A new protocol, well resumed by the sentence think globally, act locally, and is the proposed strategy [3]. A new pottery dripper was being invented from biomaterial using local, environmental and cheap materials and working under low-head pressure results low operating pressure and applied energy [4]. The peaches production unit of irrigation costs more under subsurface drip and surface drip irrigation systems was doubled compared with subsurface micro drip and surface micro drip [5].

Closed circuits of drip irrigation system require about half of the water needed by a sprinkler or surface irrigation. Lower operating pressures and flow rates result in reduced energy costs [6]. To meet the growing demand for food, more than half of world cereal production is anticipated to be produced using irrigation by 2050 [7]. Demand for food crops has been increasing in response to a number of factors including a growing global population, expanding economies in developing countries, and rising biofuels production among other factors [8]. When water is inexpensive or free, farmers make irrigation decisions based on water needs and the energy cost of pumping water, not the price of water [9 and 10]. The high energy costs causes the breakeven price of corn to increase, according to [9, 10, 11, 12 and 13]. Several studies analyzed the feasibility of investing in irrigation systems at the farm level [11, 14, 15, 16, 17, 18 and 13]. These studies, however, focus on arid regions where water is scarce and irrigation is vital for crop production. The aforementioned analysis is insightful for arid regions because they demonstrate methods to reduce irrigation costs. However, water is relatively cheap and abundant in the southeastern United States another humid areas, and producers have little incentive to conserve water or increase water use efficiency [16 and 19]. There are many studies that seek to quantify the energy consumption associated with crop production in various countries [20, 21, 22, 23, 24, 25, 26, 27 28, 29, 30 and 31]. Therefore, these studies provide little insight into the profitability of irrigating crops in humid regions such as the southeastern United States, simulated yields for irrigating corn in Iowa, and calculated the breakeven corn price for irrigation on a 52 ha field. They found a breakeven corn price for irrigation of $182.18 Mg⁻¹. Irrigation was not profitable since the average price of corn used to calculate net returns was $79 Mg⁻¹ ($2 bu⁻¹). Although [32]. During the using the energy cost of pumping water as a proxy for the price of water. They found that energy cost slightly influenced water demand, but crop prices have the greatest influence on irrigation water demand. Other economic research on irrigation in humid regions has primarily focused on production risk management [9]. The determining of optimal irrigation scheduling that maximized net returns [33].

List of acronyms and nomenclature

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>BD</td>
<td>Buried drip irrigation systems.</td>
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<tr>
<td>SD</td>
<td>Surface drip irrigation systems.</td>
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<tr>
<td>FS</td>
<td>Fixed sprinkler irrigation systems.</td>
</tr>
<tr>
<td>PS</td>
<td>Portable sprinkler irrigation systems.</td>
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<tr>
<td>W1</td>
<td>50% of wheat irrigation requirements.</td>
</tr>
<tr>
<td>W2</td>
<td>75% of wheat irrigation requirements.</td>
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<tr>
<td>W3</td>
<td>100% of wheat irrigation requirements.</td>
</tr>
<tr>
<td>IS</td>
<td>Irrigation systems.</td>
</tr>
<tr>
<td>WA</td>
<td>Water amounts (m3).</td>
</tr>
<tr>
<td>ATE I</td>
<td>Annual total irrigation energy inputs, (MJ. ha⁻¹-yr⁻¹).</td>
</tr>
<tr>
<td>AWU</td>
<td>Annual water used, (m3. ha⁻¹-yr⁻¹).</td>
</tr>
<tr>
<td>AIEI</td>
<td>Annual total irrigation energy inputs for applying water (MJ. M⁻³-yr⁻¹).</td>
</tr>
<tr>
<td>RCE</td>
<td>Relative consumed energy, (MJ. kg⁻¹).</td>
</tr>
<tr>
<td>ATEO</td>
<td>Annual total irrigation energy outputs, (MJ. ha⁻¹-yr⁻¹).</td>
</tr>
<tr>
<td>EECI</td>
<td>Energy efficiency of crop irrigation, (%).</td>
</tr>
<tr>
<td>NEG</td>
<td>Net Energy Gain (MJ. ha⁻¹).</td>
</tr>
<tr>
<td>EAE</td>
<td>Energy-applied efficiency.</td>
</tr>
</tbody>
</table>

The main aims of research are a Net-back, revenues and applied energy analysis of irrigated wheat using pressurized irrigation systems under environmental desert multi-criteria energy, and efficiencies to determine the economic impact which related to pressurizes irrigation operating head, labors, installing, maintenance and repairs.

2. Materials and methods

The two field experiments were carried out under four pressurized irrigation systems in season (2012/2013) at the site of NRC Farm, Nubaria, Behaira Governorate, the attitude of trial position are 30° 31'44" & 30°36'44"N and longitudes 30°20'19" & 30°26' 50"E. This study aims to investigate the energy feasibility (a net-back, applied and revenues energy Analysis) of cultivating wheat (Triticum aestivum L. cv. Gemmaiza 9), under various pressurized irrigation systems [surface drip (SD), subsurface drip (buried hoses) (BD), fixed sprinkler (FS), semi-portable sprinkler (PS)]. Applied irrigation water amounts are (50, 75 and 100% of calculated applied water and called W₁, W₂ and W₃, respectively). The statistical experiment design was a split plot in two factors where the main factor is irrigation systems and the sub-main factor is the applied water amounts.

The soil texture is sandy loam, poor in organic matter (1.3 %) and CaCO₃ (3.8%). In addition to the soil reaction (pH 8.2), the soil is non-saline (2.6 dSm⁻¹ of the extracted soil paste). Soil water content at field capacity and wilting point were 12.6 and 4.7 % on a weight basis, which carried out after [34].

Soil preparation and fertilization program:

The amounts of wheat fertilizers are applied according to the recommendations of the Field Crop Institute, ARC, Egypt, Ministry of Agricultural and Land Reclamation for wheat crop (Triticum aestivum L. cv. Gemmaiza 9). Farmyard manure (FYM) had been added at the rate of 24 m³. ha⁻¹ was thoroughly mixed with 0 - 30 cm of the surface soil layer before planting in addition to 240 kg superphosphate per hectare (15.5 % P2O5) and 120 kg potassium sulphate (48% K2O). As well as addition recommended dose of nitrogen (100 kg N ha⁻¹) in two equal doses, 4 and 10 weeks after completion germination. Wheat (Triticum aestivum L. cv. Gemmaiza 9) was sown on 10 November.

Irrigation systems:
The pressurized irrigation systems (drip and subsurface drip irrigation system, solid-set sprinkler, and portable sprinkler irrigation systems) consisted of the following components:

a) Drip irrigation systems:

Control head consisted of centrifugal pump (35 m lift and 27 m³ h⁻¹ discharge), driven by a diesel engine, pressure gauges, control valves, inflow gauges, and water source in the form of an aquifer, main line then lateral lines and dripper lines. For traditional drip irrigation, Gr dripper (4 l h⁻¹ discharge, three emitters at one meter) was used. The space between plant rows 25cm. Length of Gr hoses is 0.3 meters. The first position of drip hose is surface irrigation (SD) and the second is subsurface drip (BD) at a depth 20cm.

b) Sprinkler irrigation systems:

Control head consisted of centrifugal pump (65 m lift and 60 m³ h⁻¹ discharge), driven by a diesel engine, pressure gauges, control valves, inflow gauges, water source in the form of an aquifer, main line. The components of semi-portable sprinkler system used usually consists of the following components Tubing- main/sub-mains and aluminum lateral pipes (inside diameters are 150, 110 and 90 mm), respectively, couplers, sprinkler head (1 l h⁻¹) the space of sprinkler is 12 x 12 m, the sprinkler flow is one m³ h⁻¹, other accessories such as valves, bends, plugs and risers. The fixed sprinkler systems used is similar to the portable one except that the location of water source and pumping plant is fixed.

Irrigation requirements:
Irrigation water requirements for wheat were calculated according to the local weather station data at Al-Beharia Governorate, belonged to the Central Laboratory for Agricultural Climate (C.L.A.C.), Ministry of Agriculture and Land Reclamation.
Irrigation process was done by calculating crop consumptive use (mm. day⁻¹) according to [36].

Water requirements for wheat crop were calculated according to the following equation as recommended by [37]. Table (1).

\[ IR = \frac{K_c \times Et_o \times A \times C_F}{10^3 \times Et_a} + LR \]

Where:
- \( IR \) = Irrigation water requirements, m³ ha⁻¹ day⁻¹
- \( Et_o \) = Potential evapo-transpiration, mm day⁻¹
- \( KC \) = Crop factor of wheat,
- \( A \) = Area irrigated, (m²)
- \( Ea \) = Application efficiency, %, where 90%
- \( LR \) = Leaching requirements.

The crop factor of wheat was used to calculate Etn, values, according to [35].

Measurements and calculations:
Energy analysis:

Total energy inputs into irrigation:

The total energy inputs into irrigation were determined by an annual basis and by both area and volume of applied water. Basis, The total seasonal energy is the sum of the seasonal fixed installation energy and the seasonal operation energy [38].

- The seasonal fixed installation energy is the energy required to install the irrigation system for a useful life of at least the length of any evaluation period divided by the number years of the period. In this study, the evaluation period was twenty years.
- Energy associated with transporting of different components to the site was not considered in this study, because of unreliable data records.

The total irrigation energy calculations procedure:

The total seasonal irrigation energy is the sum of the seasonal installation; operations (pumping plus maintenance) and human labor energies were evaluated as follows:

Installation energy (IE):
The installation energy includes:
The annual fixed energy to manufacture a limited number of products used in irrigation system was calculated by the method of [39].

\[ AFE = \frac{(ERM + ERC \times NTR)}{(ESL)} \]

Where:
- \( AFE \) = Annual fixed energy, (MJ. kg⁻¹ yr⁻¹),
- \( ERM \) = The energy input to manufacture products from raw materials, (MJ. kg⁻¹),
- \( ERC \) = The energy input to manufacture products from recycled materials (MJ. kg⁻¹),
- \( NTR \) = Number of times a product is replaced over the expected life of the system, and
- \( ESL \) = Expected system life, (years).

(b) The energy required manufacturing equipment or machinery.

(ME) which used in excavation and land forming was computed by the following relationship, [40].
Where:

\[ ME = \left[ kW \times 14.38 \times \frac{MJ}{kW} + \text{Equip.Wt.} \times 71.2 \times \frac{MJ}{\text{ton}} \right] \times \frac{\text{hours per year}}{\text{expected life, h}} \]

**Expected life (hours) = Expected life (years) \times Activity (hours/year) × Factor**

- Human labor energy inputs associated with the operation and control of the water in this study were those of manual labor with water control structures installed represents the anegligible energy input of less than 0.42 MJ. ha\(^{-1}\) yr\(^{-1}\). [38].

**Energy yield:**
The annual yields of crops were calculated according to [45 and 22].

**Relative consumed energy, RCE.**
RCE, (MJ.kg\(^{-1}\)) = total energy input (MJ. ha\(^{-1}\)) ÷ wheat yield (kg. ha\(^{-1}\)).

**Energy efficiency of crop irrigation (energy ratio), (%)**,
EECI

\[ \text{Energy Ratio} = \frac{\text{total energy outputs (MJ. ha}\(^{-1}\))}{\text{total energy inputs (MJ. ha}\(^{-1}\))} \]

The digestible energy of wheat is 16.4 MJ/kg according to [46].

**Energy productivity** = wheat yield (kg. ha\(^{-1}\)) ÷ total input energy (MJ. ha\(^{-1}\)).

**Net Energy Gain (MJ. ha\(^{-1}\)) = Total Energy Output (MJ. ha\(^{-1}\)) - Total Energy Input (MJ. ha\(^{-1}\))**

Energy requirements and energy-applied efficiency (EAE) were determined for various drip irrigation systems according to [39]. by following a formula:

- Power consumption use for pumping water (B\(_p\)) was calculated, as follows:

\[ BP = \frac{Q \times \text{TDH} \times \text{Yw}}{E_i \times E_p \times 1000} \]

**Pumping energy requirements (E\(_p\)) (kW.h)** were calculated as follows:

\[ E_p = B_p \times H \]

**Pumping energy applied efficiency (EAE)** was calculated as follows:

\[ EAE = \frac{\text{Total fresh yield (kg)}}{\text{Energy requirements (kW.h)}} \]
3. Results

To start with the irrigation pumping power consumption, which the main factor of operating energy, the highest pumping power is (FS, PS, SD and BD) irrigation systems, respectively. Otherwise, the highest energy requirement is (SD, W_3), (SD, W_2), (SD, W_1), (FS, W_3), (PS, W_3) and the other treatments are semi close. The highest applied installing energy is (BD, FS, SD and PS) irrigation systems respectively, as we have seen the last energy parameters lead to the operating and annual total energy. As we will see later, it’s crystal clear that the highest applied operating energy is (PS, W_3), (BD, W_3), (BD, W_2), (PS, W_2) and (SD, W_3) respectively. The highest ATEI is (BD, W_3), (BD, W_2), (BD, W_1), (FS, W_3), (FS, W_2), (PS, W_1) likewise SD then PS irrigation systems. The type of irrigation system used
obviously has an impact on the amount of energy consumed, even within pressurized systems, as the energy required for pumping depends on the total dynamic head, flow rate and system efficiency [47].

Indirect irrigation energy inputs are associated with the energy embodied in irrigation infrastructure and its operation. [47 and 48], the approximately 23% of direct energy use in crop production was used for on-farm pumping.

Subsequently, the highest ATEO and NEG is (FS, W_3), (PS, W_3), (FS, W_2), (PS, W_2), and the other treatments are semi close. But we should also consider, the big difference between the ATEO and ATEI wherever, the highest ATEI is (BD, W_3), (BD, W_2), (BD, W_1), (FS, W_3), (FS, W_2), (SD, W_1), and (FS, W_1) reaching to the lowest ATEI which is (PS, W_1).

The highest EAE is (BD, W_1), (BD, W_2), (BD, W_3), (SD, W_1), (SD, W_3), (PS, W_2), while the other treatments are semi close and are not far away about the last value. The highest value of both of AIEI and REC is (BD, W_1), (SD, W_1), (FS, W_1), (PS, W_1), (BD, W_2), and (SD, W_2). By the same token, FS then PS irrigation systems. Conversely, the behavior of both of EECEI and EP increases beginning of BD, SD, FS is reaching to PS irrigation systems.

According to the statically analysis, it’s Evidently, there’s a significant impact of both of applied water amounts and irrigation systems means on the energy parameters, besides, there’s a crystal clear significant influence of the applied water amounts, the pressurized irrigation systems and the interaction of them on all of the energy parameters. Pursuing this further the interaction impact is clear, especially in IE, ATEI, AIEI, REC at LSD = 0.05. Table.2. Fig.1, 2, 3 and 4.

4. Discussion and conclusion
The significant difference in pumping power of sprinkler irrigation system and drip irrigation system is due to the higher operating head, which is necessary to sprinkler water jet, and the pumping power of FS is higher than the PS irrigation system as a result to the number of operating sprinklers at the same time, as we have seen, the number of operating sprinklers in one hectare is 70 sprinklers at the same time at FS irrigation systems. In comparison, the number of operating sprinklers in one hectare is 24 sprinklers at the same time in the PS irrigation systems and this what make the difference of applied pumping power, [47 and 49].

In addition to, the total operating head of FS is higher than the PS irrigation systems. Having considered the last PS systems, it is also reasonable to look at the more needing of human labor energy for portable sprinkler irrigation systems. The last interpretation is supported by [50 and 51]. Table.3. For installing energy, it can be noted that the higher installing energy is BD, FS, SD and PS irrigation systems. As a consequence of annual fixed energy which related to the weight of material of irrigation system which installing in one hectare. As we will see, the weights of both of PVC and PE of BD, SD, FS and PS is 195, 195, 1278 and 876 kg of PVC per one hectare, and 250, 250, 5.5 and 1.92 kg of PE per one hectare. By the same token, the highest manufacture energy of FS, PS, BD and SD, and irrigation systems is 10.6, 7.2, 4.6 and 3.92 MJ. ha^{-1}, respectively, and as known it’s related to the excavation and backfill cubes of soil to install the irrigation systems beside the ratio of work capacity. [47 and 48]. Moreover, how many hours on one job per hectare. It can be seen from the above As a consequence, to the more of operating hours of the irrigation process in addition to the number of labor, which do the irrigation process which increasing the human labor energy per hectare. The heights human labor energy per hectare is (PS, W_1), (BD, W_1), (SD, W_1), and (FS, W_1) respectively, and for applied water amounts the highest the human labor energy per hectare is W_1, W_2 and W_3 respectively [51].

It is quite predictable that, the lowest value of both of AIEI and RCE is PS, FS, SD and BD respectively, also W_3, W_2 and W_1 according to the applied amounts of water which need more applied energy to pumping. Correspondingly, the highest value of both of the EP, ATEO and NEG is FS, PS,

Table 2: Energy feasibility analysis of pressurized irrigation systems and water amounts.

<table>
<thead>
<tr>
<th>IS</th>
<th>BD</th>
<th>SD</th>
<th>FS</th>
<th>PS</th>
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<tbody>
<tr>
<td>WA</td>
<td>W₁</td>
<td>W₂</td>
<td>W₃</td>
<td>W₁</td>
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<tr>
<td>Bp</td>
<td>2.4</td>
<td>2.4</td>
<td>4.3</td>
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<td>IE</td>
<td>8306</td>
<td>7466</td>
<td>7848</td>
<td>5172</td>
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<tr>
<td>OE</td>
<td>376</td>
<td>564</td>
<td>751</td>
<td>329</td>
</tr>
<tr>
<td>ATEI</td>
<td>8682</td>
<td>8870</td>
<td>9057</td>
<td>7795</td>
</tr>
<tr>
<td>AWE</td>
<td>2383</td>
<td>3574</td>
<td>4766</td>
<td>2247</td>
</tr>
<tr>
<td>AIEI</td>
<td>3.6</td>
<td>2.5</td>
<td>1.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Er</td>
<td>229</td>
<td>343</td>
<td>458</td>
<td>1714</td>
</tr>
<tr>
<td>EAE</td>
<td>20</td>
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<tr>
<td>Yield</td>
<td>4488</td>
<td>4769</td>
<td>4968</td>
<td>4622</td>
</tr>
<tr>
<td>RCE</td>
<td>1.93</td>
<td>1.86</td>
<td>1.82</td>
<td>1.69</td>
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<td>ATEO</td>
<td>73603</td>
<td>78208</td>
<td>81475</td>
<td>75807</td>
</tr>
<tr>
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<td>8.82</td>
<td>9.00</td>
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<td>EP</td>
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<td>0.54</td>
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<tr>
<td>NEG</td>
<td>64921</td>
<td>69339</td>
<td>72418</td>
<td>68012</td>
</tr>
</tbody>
</table>

Figure 4: The installing energy inputs (IE), operating energy (OE), annual total energy inputs (ATEI), annual total energy outputs (ATEO), and net energy gain (NEG). vs irrigation systems and applied water treatments.

SD and BD due to the highest grain yield of wheat of sprinkler systems.
With respect to the drip irrigation systems. Undoubtedly, these results are reflected in the sprinkler irrigation system flexibility of wheat or intensive agriculture in comparison to the drip irrigation systems. According to [52].

16
Table 3: The influence of pressurized irrigation systems and water amounts of the various energy parameters.

<table>
<thead>
<tr>
<th>IS</th>
<th>WA</th>
<th>IE</th>
<th>OE</th>
<th>ATEI</th>
<th>AWU</th>
<th>AIEI</th>
<th>Er</th>
<th>EAE</th>
<th>RCE</th>
<th>ATEO</th>
<th>EECl</th>
<th>EP</th>
<th>NEG</th>
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<tr>
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<td></td>
<td>7848</td>
<td>494.8b</td>
<td>332.5a</td>
<td>664.5c</td>
<td>295b</td>
<td>494b</td>
<td>564b</td>
<td>8769.8b</td>
<td>8140.5a</td>
<td>7960b</td>
<td>7979c</td>
<td>90c</td>
</tr>
<tr>
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<td>W1</td>
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<td>8682a</td>
<td>2383a</td>
<td>3.6a</td>
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Finally, it can be noted that the means NEG of (FS, W₁), (PS, W₁), (FS, W₂) and (PS, W₂) are higher than the means of the other treatments by 47 % approximately, the highest EECI is (PS, W₁), (FS, W₂), (FS, W₃) and (FS, W₄) respectively, while the other treatments are semi close according to the highest overlap irrigated area of sprinkler systems in comparison to drip irrigation, which need more and more of land surface drip tubes to cover the intensive cultivated area by wheat. In conclusion, the sprinkler irrigation systems have a higher net-back energy with respect to drip irrigation system for wheat cultivating, whatever the sprinkle irrigation systems need more total operating head. But we should also consider the many operating hours of irrigation process, the plant intensive and the covering efficiency of applied water under drip irrigation in comparison to any type sprinkler irrigation systems. According to [47 and 54].

Acknowledgment

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References


