Effect of Irrigation Methods and Nitrogen Fertilizers on Barley Crop

Derbala A.[1, 2], A. Hashad[3]

[1]King Faisal University, Water Studies Center, P.O. Box 400 Al-Hofuf, 31982, Al-Hassa, Kingdom of Saudi Arabia

[2]Department of Agricultural Engineering, Faculty of Agriculture, Tanta University, Egypt

[3]Department of Soil and Water, Minister of Agriculture, Egypt, Phone No: 002-040-3305951

Abstract: *This work was carried out to study the effects of different sprinklers layouts, different irrigation levels, and different doses of fertilizers on barley production under clay soil conditions. Toachieve the objectives of this study, the sprinklers layouts were square and triangular in addition to the flood irrigation. Also, two irrigation levels (100% and 50%) crop evapotranspiration "ETc" and two nitrogen fertilizers doses were used. The results showed that the amounts of applied water were 5077 $m^3.ha^{-1}$ for flood treatment while for sprinkler treatment, were 4201 $m^3.ha^{-1}$ and 3068 $m^3.ha^{-1}$ at 100% ETc and 50% ETc, respectively. The highest values of distribution uniformity, coefficient of uniformity, and application efficiency of low quarter were achieved by the square layout. Grain yield increased from 4.55 $Mg.ha^{-1}$ with flood to 5.70 $Mg.ha^{-1}$ under sprinkler irrigation with square layout at 100% ETc and 100% fertilizer. Moreover, straw yield increased from 5.36 $Mg.ha^{-1}$ with flood to 9.65 $Mg.ha^{-1}$ under sprinkler irrigation with square layout at 100% ETc and 100% fertilizer. Water use efficiency increased from 0.90 $kg.m^{-3}$ with flood to 1.64 $kg.m^{-3}$ under sprinkling method with triangular layout at 50% ETc and 100% fertilizer. Energy use efficiency increased from 13.66 $kg.kW^{-1}.h^{-1}$ with flood to 18.20 $kg.kW^{-1}.h^{-1}$ under sprinkler irrigation with triangular layout at 50% ETc and 100% fertilizer. In conclusion, sprinklers square layout at 100% ETc with 100% fertilizer gave the best results.*

Keywords: Sprinkler layouts, Irrigation, Fertilizers, Clay soil, Energy

1. Introduction

Sprinkler irrigation system has been used worldwide due to its flexibility and adaptability for various soils, crops, and topographical conditions. Barley rank is the fourth after wheat, maize and rice. It is consumed as a staple food for animals as well as for human consumption. [1]studied the effects of irrigation intervals (daily, every two days and every three days), quantities of irrigation water (100% ETc and 120% ETc), and fertilization methods (traditional or broadcasting and fertigation) on peanut production. He found that maximum seed yield and water use efficiency was obtained with the treatment of irrigation every day with 100% ETc and traditional fertilization method. [2]selected sprinkler and surface drip irrigation methods to irrigate maize. They used two irrigation intervals (daily and every two days), two applied water based on 100% and 80% ETc, and two soil conditioners (polymer and manure) were selected as the studied treatment. They showed that the 100% ETc irrigation treatment increased both grain and ear yield by 28% and 35%, respectively compared to 80% ETc irrigation treatment. [3]investigated the effect of different seasonal amounts of applied water on the growth and water use efficiency of ten barley varieties under sprinkler irrigation. They showed that barley grain yield increased by increasing the seasonal amounts of the applied water. [4]investigated the effect of sprinkler irrigation, surface trickle, and subsurface trickle irrigation with different water regimes on both potato yield and water use efficiency. They showed that the potato yield and the water use efficiency increased with decreased soil moisture depletion. [5]studied three levels of water application deficit under semi-portable sprinkler irrigation system on cowpea yield. He showed that the water application was 1892.52, 1514.02 and 1135.51 $m^3.fed^{-1}$ for 100%, 80% and 60% of soil moisture content at

field capacity, respectively. The highest seed yield was observed with 100% ETc, while the lowest yield was recorded with 60% of soil moisture content at field capacity. The highest water use efficiency was 0.68 $kg.m^{-3}$ at 80% soil moisture content at field capacity. However the lowest one was 0.59 $kg.m^{-3}$ at 100% and 60% soil moisture content at field capacity. [6]evaluated the influence of three irrigation systems and different water management techniques on jatropha production. They found that the seeds yield increased as the applied water increased. The maximum value of water use efficiency (WUE) was 0.18 $kg.m^{-3}$ at 80% from ETc and 2 days interval for bubbler irrigation system. Also, the minimum value was 0.04 $kg.m^{-3}$ at 60% from ETc and 4 days interval for trickle irrigation system. The aim of this work was to investigate the effects of different sprinklers layouts, different irrigation levels, and different doses of nitrogen fertilizers on the yield of barley under clay soil conditions.

2. Materials and Methods

The experimental work was carried out at Al-Gemmeiza Agricultural Research Station, Gharbia Governorate, Egypt during 2010 winter growing season. This was to study the effects of different sprinklerslayouts, different irrigation levels, and different doses of fertilizers on barley *(hordeumsp)* production under clay soil conditions. The area of the experiment was 1.26 ha and prior to the experimental work, soil samples were collected from different randomized locations. These soil samples were undertaken at the depths of 0-15, 15-30, 30-45, and 45-60 cm. Some physical properties of the experimental site are shown in Table 1. However, the soil was classified as clay soil which was determined according to [7] and [8].

Table 1: Some physical properties of soil experimental site

Depth, (cm)	Particle size layout (%)			Texture	Bulk Density, (g.cm^{-3})	Field Capacity, (%)	Available Water, (%)
	Sand	Silt	Clay				
0-15	24.00	26.30	49.70	clay	1.16	43.36	19.11
15-30	24.15	27.30	48.55	clay	1.20	39.93	18.04
30-45	24.20	28.25	47.55	clay	1.23	36.62	16.77
45-60	25.00	28.45	46.55	clay	1.25	34.85	15.88

Super phosphate (15.5% P_2O_5) was applied at the rate of 238 kg.ha^{-1} before seeding. Seed-drill planting machine was used in the planting process at the rate of 119 kg.ha^{-1}. To insure complete seed germination, all treatments were irrigated by flooding in the first irrigation event. In cases of flood irrigation, urea (46% nitrogen) was applied by manual method at the rates of 238 kg.ha^{-1} in equal doses. The first dose was applied before the second irrigation and the second dose was applied before the third irrigation. In cases of sprinkler irrigation, urea (46% nitrogen) was applied by manual method at the rate of 238 kg.ha^{-1} for treatments of 100% fertilizer recommended dose and 179 kg.ha^{-1} for treatments of 75% fertilizer recommended dose in 12 equal doses. However, the frequency of fertilization was done four days before irrigation and the irrigation intervals were four days also.

2.1 Component of the Sprinkler Irrigation System

Fixed sprinkler irrigation system was used which can be described as follows: A centrifugal pump was operated using power take-off with a tractor of 29.41 kW power. The operating pressure was 150 kPa. Main lines were located on the ground surface which carries water from the open canal to the sub-main lines. Main lines were made from aluminum pipes-which is 100 mm in diameter, 6 m in length for each one, and 90 m as a total length. The water which flows from the main lines to the sub-main lines was controlled using three valves. Sub-main lines located on the ground surface carry water from the main lines to the laterals. Sub-main lines were made from galvanized steel pipes which is 89 mm in diameter, 6 m in length for each one, and 72 m as the total length. Laterals located on the ground surface carry water from the sub-main lines to the sprinklers. Laterals were made from galvanized steel pipes which is 70 mm in diameter, 6 m in length for each one, and 150 m as the total length. Seventy two risers carry water from the laterals to the sprinklers, which was 3/4 inch in diameter and 60 cm in height. Seventy two rotating type sprinklers were used; thus, Perrot ZB 22 have one nozzle of 5.2 mm in diameter. The sprinkler discharge rate was 1.18 m^3.h^{-1} at 150 kPa operating pressure. The sprinklers installed at a spacing of 12×12 m have a wetted diameter of 24 m, and overlapping was 100%. Precipitation equals 8.2 mm.h^{-1}, while the plant height was 80 cm.

2.2 Experimental Design

The field experiment included two sprinklers layouts (square and triangular), two irrigation levels (100% ETc and 50% ETc), and two fertilization doses (100% and 75% from recommended). To control the amount of irrigation to be 50% and 100% ETc, an automatic valve was used to connect

the riser with the lateral line. Therefore, the different treatments may be classified as follows:

S_1 = square layout at 100% ETc with 100% fertilizer, S_2 = square layout at 100% ETc with 75% fertilizer, S_3 = square layout at 50% ETc with 100% fertilizer, S_4 = square layout at 50% ETc with 75% fertilizer, T_1 = triangular layout at 100% ETc with 100% fertilizer, T_2 = triangular layout at 100% ETc with 75% fertilizer, T_3 = triangular layout at 50% ETc with 100% fertilizer, T_4 = triangular layout at 50% ETc with 75% fertilizer, and C = flood irrigation.

2.3 The Applied Water Under Flood Irrigation

Discharge rate of water in flood irrigation was calculated using a 4 inch plastic spile according to **[9]** as follows:

$$Q = 0.61 \times 10^{-3} \times A \times (2gH)^{1/2} \quad (1)$$

Where: Q = flow rate in L.s^{-1}, H = water head above the center of spile in cm, A = orifice cross-section area of the spile in cm^2, and g = gravitational acceleration (981 cm.s^{-2}).

2.4 The Applied Water Under Sprinkler Irrigation

The flow rate of sprinkler was measured at operating pressure by connecting a flexible hose to the sprinkler nozzle, and by collecting a known volume of water in a container over a specified period of one mint. However, the flow rate was calculated by **[10]** using the equation below:

$$Q = \frac{V}{T} \quad (2)$$

Where: Q = the flow rate of sprinkler in m^3.h^{-1}, V = the collecting water volume in m^3 and T = time of collecting water in h.

2.5 Distribution Uniformity

The distribution uniformity, coefficient of uniformity, and application efficiency of low quarter were calculated using the water quantity which was recorded from 16 catch cans. The catch cans were placed in a uniform pattern in the wetted area on each side of an operating lateral between each four sprinklers. Hence, cans were placed at 3 m distance between each other at every two laterals. The test duration time was forty minutes. The distribution uniformity "DU" was calculated according to **[11]** as follows:

$$DU = \left[\frac{Z_{lq}}{Z_{av}} \right] \times 100 \quad (3)$$

Where: DU = the distribution uniformity in %, Z_{lq} = the average depth of water collected from catch cans in the low quarter of data in mm, and Z_{av} = the average depth of water collected from catch cans in the entire field in mm.

2.6 Coefficient of Uniformity

The coefficient of uniformity "Cu" was calculated according to **[12]** as follows:

$$Cu = 100\left|1 - \frac{\sum (xi - x\grave{})}{nx\grave{}}\right| \qquad (4)$$

Where: Cu = the coefficient of uniformity expressed in %; xi = the individual collected water application depth from catch cans in mm; $x\grave{}$ = the average of all xi in mm; and n = the total number of catch cans used in the evaluation.

2.7 Application Efficiency of Low Quarter

The application efficiency of low quarter (AELQ) was calculated by [13] formula as follows:

$$AELQ = \left[\frac{Z_{r,lq}}{D}\right] \times 100 \qquad (5)$$

Where: $AELQ$ = the application efficiency of low quarter in %, $Z_{r,lq}$ = the average low quarter depth of collected water in mm, and D = the average depth of water applied in mm.

2.8 Water Use Efficiency

The water use efficiency was determined according to [14]as follows:

$$WUE = \frac{Y}{Q} \qquad (6)$$

Where: WUE = water use efficiency in kg.m^{-3}, Y = grain yield in kg.ha^{-1}, and Q = applied water in m^3.ha^{-1}.

2.9 Energy Use Efficiency

The energy use efficiency was determined using the following equation:

$$EUE = \frac{Y}{E_r} \qquad (7)$$

Where: EUE = energy use efficiency in kg.kW^{-1}.h^{-1}, Y = grain yield in kg.ha^{-1}, and E_r = energy consumption in kW.h.ha^{-1}.

3. Results and Discussions

3.1 The Amount of Applied Water

The amounts of applied water for flood irrigation and sprinklers (100% ETc and 50% ETc) are shown in Figure 1. The amounts of applied water were 5077, 4201, and 3068 m^3.ha^{-1} for flood irrigation, and sprinklers (100% ETc and 50% ETc), respectively. These results showed that the maximum applied water of 5077 m^3.ha^{-1}was recorded with flood irrigation, while the minimum applied water of 3068 m^3.ha^{-1} was recorded with 50% ETc of sprinkling method. However, it is interesting to mention that the water savings were 17% and 40% for 100% and 50% ETc, respectively in comparison with the control treatment.
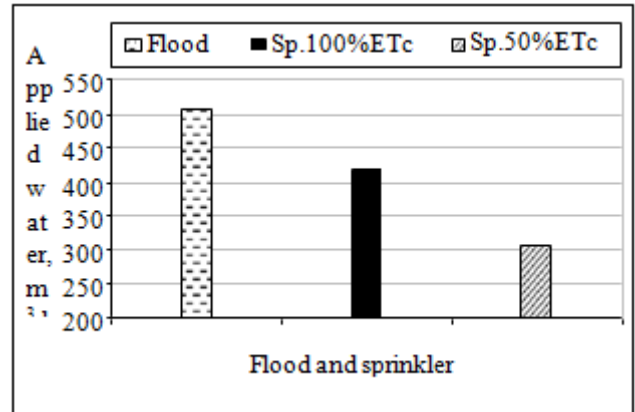

Figure 1: The amount of applied water under different irrigation regimes

3.2 Effect of Sprinklers Layouts on Distribution Uniformity, Coefficient of Uniformity and Application Efficiency of Low Quarter

The results in Table 2 indicate the values of distribution uniformity for square and triangular layouts. It values were 77.24% and 73.47% for square and triangular layouts, respectively. The values of coefficient of uniformity were 78.28% and 78.22% for square and triangular layouts, respectively. The values of application efficiency of low quarter were 73.15% and 70.53% for square and triangular layouts, respectively. The results explained that the highest values of distribution uniformity, coefficient of uniformity, and application efficiency of low quarter were achieved by square layout. However, the lowest one was achieved by triangular layout.

Table 2: Effect of sprinklers layouts on distribution uniformity, coefficient of uniformity, and application efficiency of low quarter

Sprinklers layouts	Distribution uniformity, (%)	Coefficient of uniformity, (%)	Application efficiency of low quarter, (%)
Square	77.24	78.28	73.15
Triangular	73.47	78.22	70.53

3.3 Effect of Watering and Fertilizer Levels on Biomass, Grain Yield and Straw Yield Under both Square and Triangular Layouts

The results in Table 3 indicates the effect of watering and fertilizer levels on biomass, grain yield, and straw yield using square layout and triangular layout. The highest value of biomass (15.35 Mg.ha^{-1}) was obtained by treatment S_1. It was a minimum value (12.14 Mg.ha^{-1}) by treatment S_4. However, the lowest value (9.91 Mg.ha^{-1}) was obtained under flood irrigation. The maximum value of grain yield (5.70 Mg.ha^{-1}) was obtained by treatment S_1. It was a minimum value (4.82 Mg.ha^{-1}) by treatment S_4. However, the lowest value (4.55 Mg.ha^{-1}) was obtained under flood irrigation. The highest value of straw yield (9.65 Mg.ha^{-1}) was obtained by treatment S_1. It was a minimum value (7.33 Mg.ha^{-1}) by treatment S_4. However, the lowest value (5.36 Mg.ha^{-1}) was obtained by flood irrigation. These results agree with the study of [3]. The results in Table 3 presented also that, the highest value of biomass (13.08 Mg.ha^{-1}) was

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obtained by treatment T_1 using triangular layout. It was a minimum value (10.82 Mg.ha^{-1}) by treatment T_4. However, the lowest value (9.91 Mg.ha^{-1}) was obtained by flood irrigation. The maximum value of grain yield (5.03 Mg.ha^{-1}) was obtained by both treatments T_1 and T_3. It was a minimum value (4.79 Mg.ha^{-1}) by treatment T_4. However, the lowest value (4.55 Mg.ha^{-1}) was obtained by flood irrigation. The highest value of straw yield (8.05 Mg.ha^{-1}) was obtained by treatment T_1. It was a minimum value (6.04 Mg.ha^{-1}) by T_4. However, the lowest value (5.36 Mg.ha^{-1}) was obtained by flood irrigation.

Table 3: Effect of watering and fertilizer levels on biomass, grain yield, and straw yield under both square and triangular layouts

Treatments	Biomass, (Mg.ha^{-1})	Grain, (Mg.ha^{-1})	Straw, (Mg.ha^{-1})
S_1	15.35	5.70	9.65
S_2	13.12	5.00	7.80
S_3	12.98	4.90	7.95
S_4	12.14	4.82	7.33
C	9.91	4.55	5.36
T_1	13.08	5.03	8.05
T_2	12.90	4.95	7.96
T_3	12.60	5.03	7.80
T_4	10.82	4.79	6.04
C	9.91	4.55	5.36

3.4 Effect of Watering and Fertilizer Levels on Water Use Efficiency Using both Square and Triangular Layouts

Figure 2 illustrate that, the highest value of water use efficiency "WUE" (1.58 kg.m^{-3}) was obtained by treatment S_3 in the case of square layout. It was 1.18 kg.m^{-3} by treatment S_2. In the case of triangular layout, the highest value of WUE (1.64 kg.m^{-3}) was obtained by treatment T_3. It was 1.16 kg.m^{-3} by treatment T_2. However, the lowest value of WUE (0.90 kg.m^{-3}) was obtained by flood irrigation.

3.5 Energy Consumption

The results in Figure 3 indicated that, the values of energy consumption were 412, 333, and 276 kW.h.ha^{-1} for sprinkler at 100% ETc, flood irrigation, and sprinkler at 50% ETc, respectively. These results showed that the maximum value of the energy consumption was 412 kW.h.ha^{-1} by using sprinklers at 100% ETc. However, the lowest value of the energy consumption was 276 kW.h.ha^{-1} using sprinkler at 50% ETc.

3.6 Effect of Watering and Fertilizer Levels on Energy Use Efficiency Using both Square and Triangular Layouts

Figure 4 illustrates the values of energy use efficiency "EUE" using different irrigation regimes. In the case of square layout, the highest value of EUE (17.52 kg.kW^{-1}.h^{-1}) was obtained by treatment S_3. However, the lowest value (12.04 kg.kW^{-1}.h^{-1}) was obtained by treatment S_2. In case of triangular layout, the highest value of EUE (18.20 kg.kW^{-1}.h^{-1}) was obtained by treatment T_3. However, the lowest value (11.88 kg.kW^{-1}.h^{-1}) was obtained by treatment T_2. On the other hand, the value of EUE was 13.66 kg.kW^{-1}.h^{-1} using flood irrigation. From the results, the treatments of the square layout produced good results compared to the triangular layout. Treatments of 100% ETc produced best results compared to 50% ETc. Also, treatments of 100% fertilizer recommended dose produced best results compared to 75% fertilizer recommended dose.
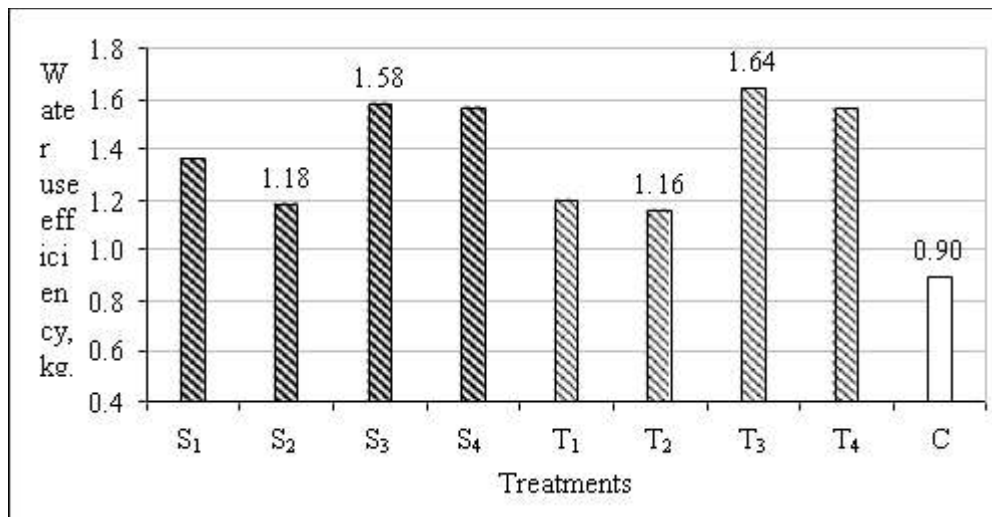

Figure 2: Effect of watering and fertilizer levels on water use efficiency using square and triangular layouts
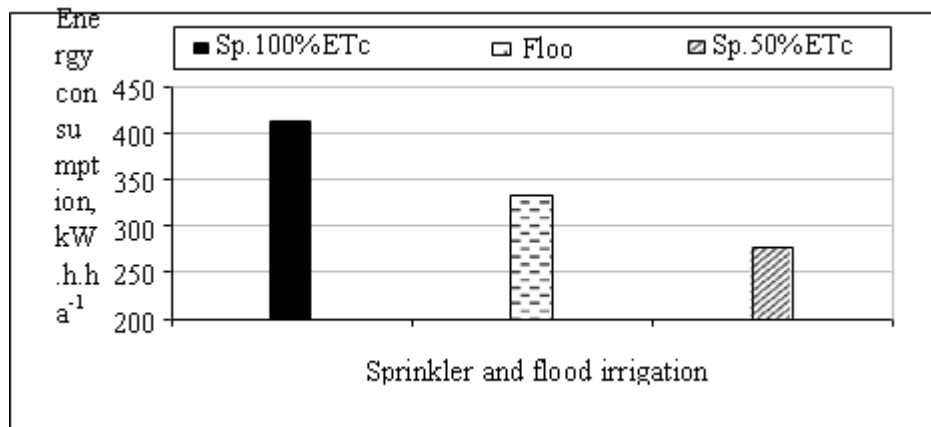
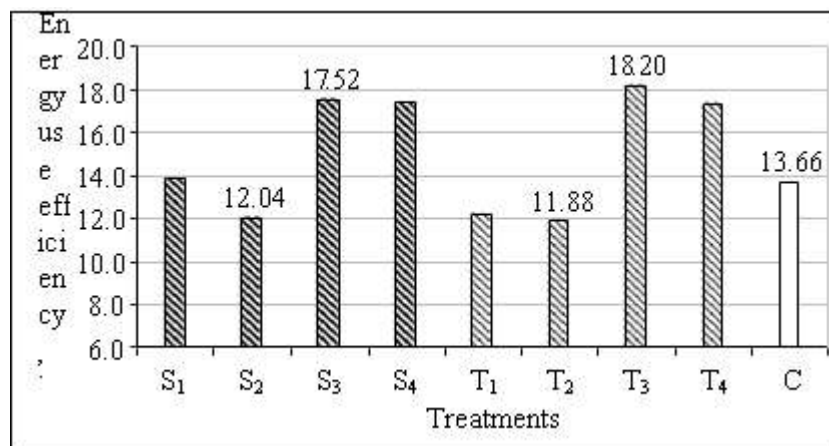**Figure 3:** The energy consumption using different irrigation regimes

Figure 4: The energy use efficiency using different irrigation regimes

4. Conclusions

From the above mentioned investigation, conclusions can be drawn from the following:
Sprinkler irrigation with 100% ETc and 50% ETc saved water by 17% and 40%, respectively compared with flood irrigation. The highest values of water distribution uniformity, coefficient of uniformity, and application efficiency of low quarter were achieved by square layout. The highest value of WUE (1.64 kg.m^{-3}) was obtained by treatment T_3. It was 1.16 kg.m^{-3} by treatment T_2. However, the lowest value of WUE (0.90 kg.m^{-3}) was obtained using flood irrigation. In conclusion, sprinklers square layout at 100% ETc with 100% fertilizer gave the best results.

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Author Profile

Asaad Derbala obtained his B.Sc. and M.Sc. degrees in Agricultural Engineering from Tanta University, Egypt in 1990 and 1996, respectively. From 1999 to 2003, he was a full-time Ph.D. student in the Institute of Production Engineering and Building Research, Federal Research Centre of Agricultural (FAL), Braunschweig, Germany. This was in cooperation with the Institute of Agricultural Engineering, Justus-Liebig-University, Giessen, Germany where he finished his Ph.D. in Irrigation Engineering. From October 2003 to September 2009, he was an assistant professor in the Agricultural Engineering Department, Faculty of Agriculture, Tanta University, Egypt. From October 2009 to May 2014 he was an associate professor of Agricultural Engineering and Head of Agricultural Engineering Department, Faculty of Agriculture, Tanta University, Egypt. Thus since June 2014 he is associate professor of Irrigation and Drainage Engineering at Water Studies Center, King Faisal University, KSA.

AbdelmoneamHashadobtained his B.Sc. degree in Agricultural Engineering from Alexandria University, Egypt in 2006. He obtained his M.Sc. degree in Agricultural Engineering from Tanta University, Egypt in 2012. From 2008 until now, he working as an assistant researcher in Dept. of soil and water,Minister of Agriculture, Egypt. In 2013 he was registered as a Ph.D. student in Agricultural Engineering Department, Tanta University, Egypt until now.