# MANUFACTURING CONTROL VALVE AND FLOWMETER TO MEASURE FLOW RATE AND DEVELOPMENT OF SURFACE IRRIGATION USING SURGE IRRIGATION IN CLAYEY SOIL

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## ABSTRACT

*The experiment was conducted to develop and evaluate surge irrigation under different slopes and discharges against continuous irrigation under traditional levelling in terms of irrigation and water use efficiencies to produce wheat crop in clay soil under short field conditions. It was carried out at the experimental farm, Faculty of Agriculture, Kafrelsheikh University, during the winter season 2013/2014.The furrows with blocked ends were 50 m long and 1.1 m center – center spacing furrows and the wheat was planted on beds with 0.8 m width(7 rows of wheat per bed with 0.10 m spacing between rows).The treatments for surge irrigation consisted of factorial combination of three slopes $S_1$= 0.0%, $S_2$= 0.1% and $S_3$= 0.2%, three discharges $Q_1$= 0.4 l/s, $Q_2$ = 0.55 l/s and $Q_3$ = 0.75 l/s and two – cycle ratios ($T_1$ = 1/2 and $T_2$ = 2/3), in addition, treatments of continuous flow for the same discharges under traditional levelling. To monitor the advance time, five points were established along the furrows at 0, 12.5, 25, 37.5 and 50 m from the inlet. Soil moisture content was measured with gravimetric methods at 0 - 0.15, 0.15 – 0.30, 0.30 – 0.45 and 0.45 – 0.60 m depths at the beginning, middle and end of the furrows. The discharge was measured using control valve and flowmeter which manufactured to measure and control the applied irrigation water to each treatment. Results indicated that surge irrigation under three different slopes 0.0, 0.1 and 0.2% reduces amount of irrigation water applied, increases advance time, irrigation uniformity, water application efficiency, grain yields and water use efficiency compared with continuous flow irrigation under traditional levelling. The best treatment is the discharge of 0.55 l/s with 1/2 cycle ratio under three different slopes.*



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*It saved and decreased amount of water irrigation applied by 27, 33.4 and 37.4 % and increased the yield by 15.1, 17.7 and 12.7 % under slope of 0.0, 0.1 and 0.2 % respectively compared with continuous flow irrigation under traditional levelling for the same discharge. It had the maximum water use efficiency values of 1.39, 1.56 and 1.59 kg/m$^3$ for surge flow irrigation under slopes of 0.0, 0.1 and 0.2%, respectively.*

## INTRODUCTION

Surface irrigation methods are extensively used throughout the world. However, unfortunately these methods often have lower application efficiencies and distribution uniformities. High runoff and deep percolation losses are cited as the main problems. Therefore, minimizing deep percolation and runoff while meeting irrigation requirements of crops can increase irrigation performance. For these reasons, several management techniques have been developed to reduce water losses during the irrigation event. Some of these are the cutback stream method, the runoff recovery system, and the intermittent application of water ***(Stringham and Keller 1979; Walker and Skogerboe 1987 and Valipour 2013).***

Surge irrigation, also known as intermittent irrigation or surge flow ***(Stringham and Keller, 1979),*** has emerged over the last 30 years as one of the most efficient strategies for use of irrigation water. Surge flow irrigation is the intermittent application of water to furrows in a series of relatively short on and off time periods. It is one of the famous methods in irrigation management and has been studied in many articles, which some of them will be described in the following.

***Kanber et al. (2001)*** compared surge and continuous furrow methods for cotton in the Harran plain. Surge flow reduced the water intake of a surface soil loosened by tillage by 13-23% as compared to continuous flow, thus manifesting an incomparable advantaged to the level furrow systems. ***Jensen and Shock (2001)*** considered surge irrigation or at last a modified surge program on the first irrigation as a strategy for furrow irrigation. ***Rodríguez et al. (2004)*** compared surge irrigation and conventional furrow irrigation for covered black tobacco cultivation in a Ferralsol soil. The surge flow furrow irrigation with variable time cycles increased the application efficiency by more than six fold, and the water volume was reduced by more than 80% compared to continuous irrigation. The largest rises in distribution uniformity and reductions in percolation losses were obtained with a furrow length of 200 m and a discharge of 1 liter per second, respectively. ***Mostafazadeh-Fard et al. (2006)*** developed and evaluated an automatic surge irrigation system in furrow irrigation. The results showed that the system was able to accurately and automatically irrigate the furrows by surge method based on information were given to the system. For the same discharge and volume of water applied to the furrows the water advance along the furrows were faster for surge flow as compared to the continuous flow. ***Sial et al. (2006)*** studied performance of surge irrigation under borders. Keeping in view different parameters like volume of water, distribution uniformity, application efficiency، deep percolation losses, and yield of wheat, the surge mode of irrigation was convincingly better compared with conventional/continuous irrigation even under the border irrigation. ***Horst et al. (2007)*** assessed impacts of surge-flow irrigation on water saving and productivity of cotton. The best irrigation water productivity (0.61 $kg/m^3$) was achieved with surge-flow on alternate furrows, which reduced irrigation water use by 44% and led to high application efficiency, near 85%. Results demonstrated the possibility for applying deficit irrigation in this region. ***Popova and Periera (2008)*** scheduled surge irrigation for furrow-irrigated maize under climate uncertainties in the Thrace plain of Bulgaria. The results indicate that vulnerability to climate change is higher for non-irrigated crops and that coping with possible rainfall decreased requires adopting less sensitive crop varieties including when deficit irrigation would be applied for water saving. ***Valipour (2013)*** studied different types of inflow regimes include continuous flow, cutback, fixed surge, and variable surge, and showed that surge irrigation methods was able to increasing irrigation efficiency to the amount of 28.37% and reducing inflow to the amount of 16.6 $m^3$ water saving.

Although studies conducted in Egypt ***(Ismail et al. 2004; Mahmood et al. 2003; Amer 1998 and Zaghloul 1988)*** under cropped condition have indicated that surge irrigation improves irrigation performance and irrigation water use efficiency, it is imperative to test its validity under different soil and crop conditions. The specific objective of this study was to develop and evaluate surge flow irrigation under different slopes and discharges in heavy clay soil under short field conditions and compare it with continuous flow under traditional levelling, and also to define the best cycle ratio, discharge and slope for optimizing the water use efficiency.

## MATERIALS AND METHODS

### 1 - Experimental Site:

The field experiments were conducted at the experimental farm, Faculty of Agriculture, Kafrelsheikh University, Kafrelsheikh Governorate, Egypt during the winter season 2013/2014. Wheat (Misr1 variety) was planted on the 1st of December, 2013 on beds at the rate of 45 kg/fed by using bed planter. Bed planting in 1.10 m (center - to -center of furrows). The width of the beds was 0.80 m (7 rows of wheat per bed with 0.10 m spacing and 50 m length) at alternated by 0.30 m furrows. The wheat crop was harvested after 160 days of the planting date. The experimental site was ploughed four times by using chisel plough (9 shares). MIKROLASER ML 4 self – levelling rotary laser was used to level the soil at three different slopes namely 0.0, 0.1and 0.2%.The meteorological data were obtained from Sakha Weather Station, Kafrelsheikh Governorate, Egypt during the growing season for wheat crop as shown in Table 1.

**Table1: Monthly mean values of some meteorological data during wheat growing season 2013/2014.**

| **Reference evapotranspiration** ETo **according to Penman – Monteith** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Country:** EGYPT | | | | **Meteo Station:** Sakha | | | | |
| **Altitude:** 20 meter | | | | **Coordinates:** 31.11 N.L 30.95 E.L | | | | |
| **Month** | **Max.Temp.** K (°C) | **Min.Temp.** K (°C) | **Humidity** % | **Wind speed** km/day | **Sunshine hours** h/day | **Solar radiation** $Mj/m^2/day$ | **Total rainfall** (mm) | $ET_0$ (mm/day) |
| **Dec.** | 294.5 (21.5) | 281.2 (8.2) | 84 | 95 | 5.9 | 10.4 | 77.1 | 1.54 |
| **Jan.** | 292.3 (19.3) | 279.0 (6.0) | 84 | 112 | 6.2 | 11.4 | 11.7 | 1.54 |
| **Feb.** | 293.5 (20.5) | 279.2 (6.2) | 82 | 121 | 6.9 | 14.2 | 16.5 | 2.03 |
| **Mar.** | 296.0 (23.0) | 280.8 (7.8) | 73 | 147 | 7.8 | 18.1 | 26.2 | 3.04 |
| **Apr.** | 300.0 (27.0) | 283.3 (10.3) | 62 | 130 | 8.7 | 21.6 | 20.2 | 4.15 |
| **May** | 304.1 (31.1) | 287.1 (14.1) | 54 | 130 | 9.6 | 24.1 | 00.0 | 5.23 |

The soil type of the experimental site is clayey with field capacity, permanent wilting point, and bulk density of 40.61%, 21.81%, and 1.2 g/cm$^3$, respectively.

**2 - Experimental design and field layout:**

The experiment area was about 3550 m$^2$ (50 * 71m).The water was applied through PVC gated pipe for giving equal discharge to the experimental furrows via a centrifugal pump. The length of the PVC gated pipe was almost 71m, and its diameter was 63 mm. A pair of T shape valves with a diameter 16 mm was located at the beginning of each furrow to control the surge irrigation by adding the required discharge to furrow. The present study was used to improve the surface irrigation using surge irrigation and included on the following factors (Fig.1):

**a) Furrow slope (S):** Three different soil slopes were used namely 0.0 ($S_1$), 0.1 ($S_2$) and 0.2% ($S_3$).

**b) Discharge (Q):** Three different discharges (Flow rate) were used namely 0.4($Q_1$), 0.55 ($Q_2$) and 0.75 l/s ($Q_3$).

**c) Cycle ratio (T)**: Two cycle ratios have been chosen, 1/2 ($T_1$) and 2/3($T_2$) for 24 minutes cycle time.

The traditional irrigation was used as a control treatment.

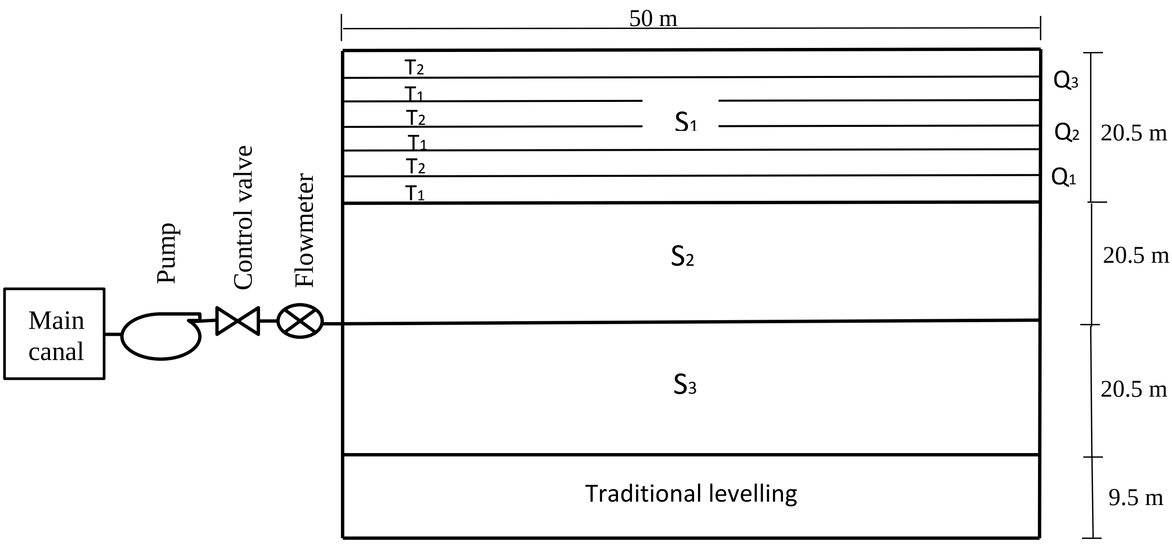


**Fig.1: Layout of the experimental plots for surge and continuous irrigation.**

**3 - Water consumptive use:**

It was calculated according to the climate data as presented in Table1 using the following formula (***Doorenbos and Pruitt, 1977***):-

$$\text{ETcrop} = \text{ETo} * \text{Kc} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where:

ETcrop = Crop water consumptive use, (mm/day),

$ET_o$=Reference evapotranspiration, (mm /day), and

$K_c$ = Crop coefficient, (dimensionless).

A crop coefficient values ($K_c$) for wheat crop was used according to **Allen *et al*.,1998** at different growth stages. Reference evapotranspiration of wheat crop was calculated using FAO CROPWAT program depending on the average of climatic data according to Penman –Monteith methods, and tablet in Table 2.

**Table 2: Calculated water consumptive use for wheat crop.**

| **Growth stages** | **ETo** (mm/day) | $K_c$ | **ETcrop** (mm/day) | **ETcrop** (mm/stage) |
|---|---|---|---|---|
| **Initial** | | | | |
| 01/12/2013 - 21/12/2013 | 1.54 | 0.7 | 1.08 | 22.64 |
| **Mid – season** | | | | |
| 22/12/2013 - 31/12/2013 | 1.54 | 1.15 | 1.77 | 17.71 |
| 01/01/2014 - 31/01/2014 | 1.54 | 1.15 | 1.77 | 54.90 |
| 01/02/2014 - 28/01/2014 | 2.03 | 1.15 | 2.33 | 65.37 |
| 01/03/2014 - 31/03/2014 | 3.04 | 1.15 | 3.5 | 108.38 |
| 01/04/2014 - 18/04/2014 | 4.15 | 1.15 | 4.77 | 85.91 |
| **End / Late** | | | | |
| 19/04/2014 - 30/04/2014 | 4.15 | 0.4 | 1.66 | 19.92 |
| 01/05/2014 - 09/05/2014 | 5.23 | 0.4 | 2.09 | 18.83 |
| **ETcrop** (mm/season) | - | - | - | 393.66 |
| **Total rainfall** = 151.70 mm /season | | | | |
| **Total ETo after adding rainfall** = 241.96 mm / season | | | | |

**4 - Discharge measuring:**

Control valve and flowmeter was manufactured using the local materials (Fig.2) which installed on irrigation main line at the pump outlet to measure and control the water flow rate. The control valve and flowmeter consists of the following components as shown in Fig.3 and Table3.

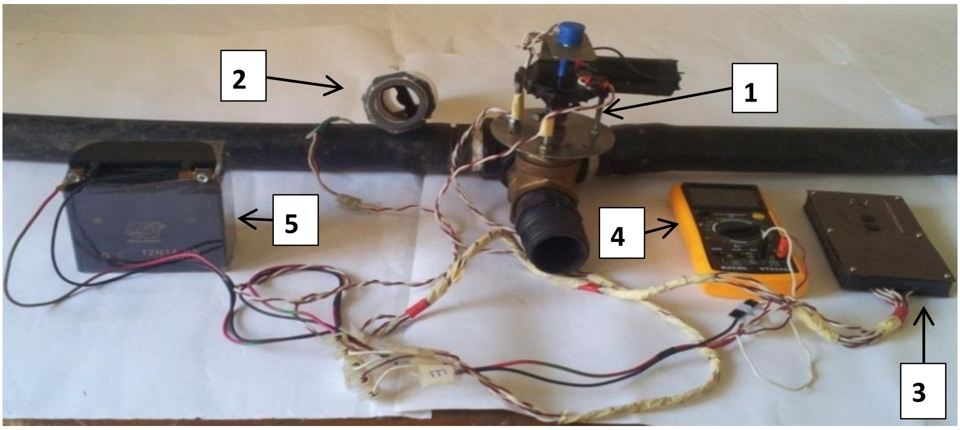


**Fig.2: Photograph of control valve and flowmeter for controlling and measuring the water flow rate.**

**Table 3: Components of control valve and flowmeter and its functions.**

| No. | Component | | Function |
|---|---|---|---|
| 1 | Control valve | DC servo motor with gear box | DC servo motor is used to control motion and it connected to gearbox which utilized to increase output torque and change the rotational speed (RPM) of a motor. Every revolution of the motor shaft is equal one revolution for the stem of the gate valve. |
| | | Rotary potentiometer | It converts the mechanical movement of motor to voltage, because it uses as a transducer. It outputs a voltage telling the control unit where the motor is and how fast it is moving. |
| 2 | Water flowmeter | Flowmeter pipe | The length of the PVC pipe is almost 25 cm, and its inner diameter is 63 mm. It represents the body of flowmeter. |
| | | Flowmeter fan | It was installed in the middle of the flowmeter pipe from inside and consists of two blades. Magnet was installed on each blade in order to maintain a balance during the rotation of the fan. |
| | | Reed switch | It was installed in the middle of the flowmeter pipe from outside. Every revolution for the flowmeter fan gives two pulses and it happens when reed switch is located in magnetic field of the magnet. |
| 3 | Control unit | | The control unit is responsible for controlling the opening and closing the control valve, in addition to measuring the water flow rate which passing through the flowmeter. |
| 4 | Display unit | | Digital multimeter was used as a display unit to read the output voltage from the control unit as a calibrated discharge. |
| 5 | Battery | | Battery 12V, 14 A.h was used as a source of electrical power and connected to the control unit. |

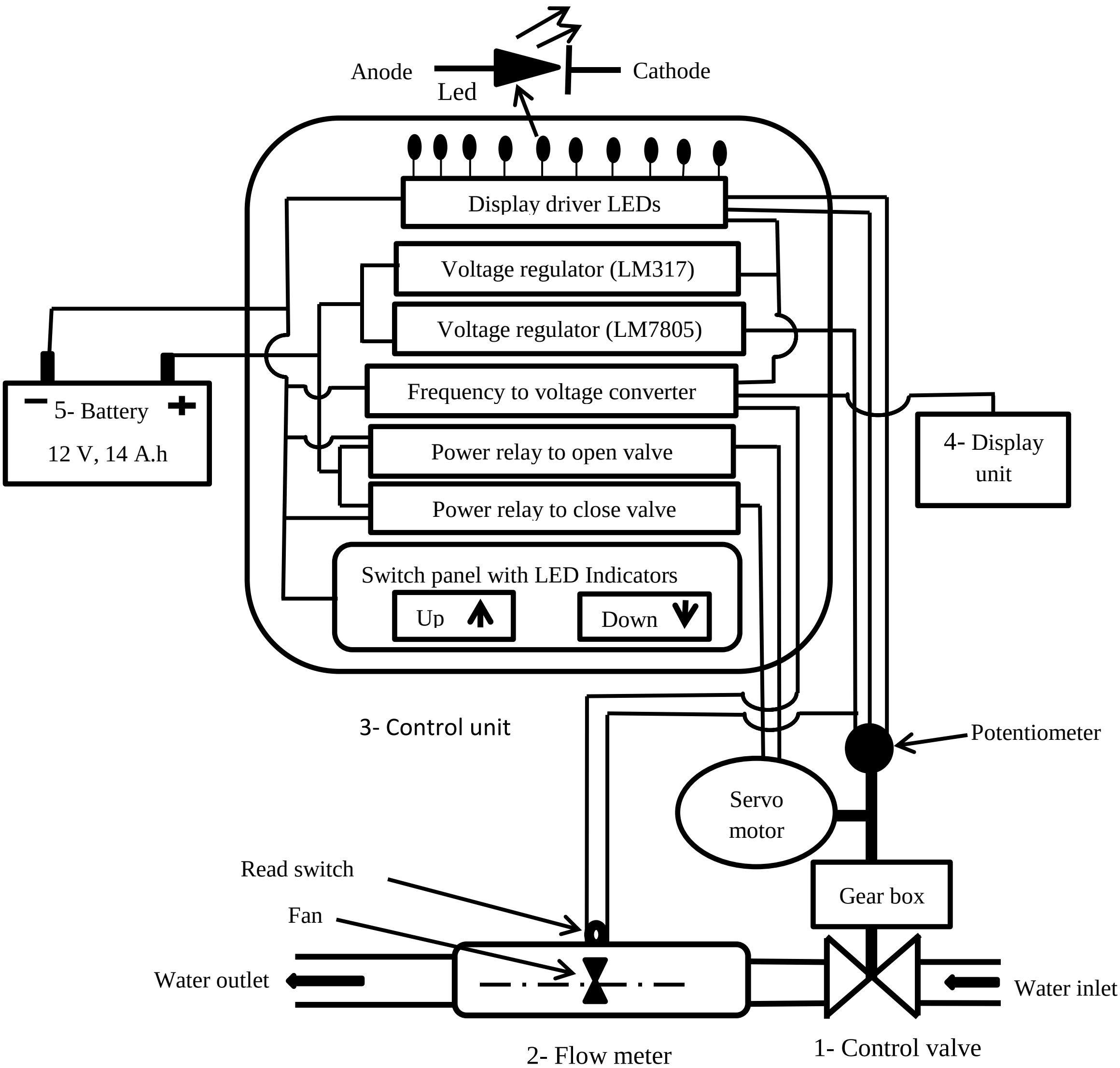


**Fig. 3: Schematic diagram of experimental set up, control valve and flowmeter for controlling and measuring the water flow rate.**

**5- Soil moisture:**

Three locations were chosen to measure the soil moisture content namely at the beginning, middle and end of the furrows. In each location four points were measured along the depth; 0 - 0.15 , 0.15 - 0.30 , 0.30 - 0.45 and 0.45 - 0.6 m .The samples were collected before and after 48 h of irrigation by Auger and immediately transferred in tightly closed cans of

Aluminum to laboratory to estimate the soil moisture content using the Gravimetric method.

**6- Advance time:**

The length of the furrows used for the experiments was 50 m and their width was 0.30 m. The furrows had a blocked end. To monitor the advance time, five monitoring points were established along the furrow namely at 0 , 12.5 , 25 , 37.5 and 50 m from the inlet. The distance between two consecutive points was 12.5 m.

**7 - Determination of performance indicators.**

The following performance indices were used to evaluate the surge and continuous irrigation:

(a) **Application efficiency** was calculated according to ***Kruse (1978)*** as:

$$E_a = \frac{D_{ad}}{D_{ap}} * 100 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (2)$$

Where:

$E_a$ = The application efficiency (%),

$D_{ad}$ = Depth of water added to the root zone (mm), and

$D_{ap}$ = Depth of water applied to the furrow (mm).

(b) **Distribution uniformity** was calculated according to ***Kifle et al., 2007*** as:

$$DU = \frac{D_{min}}{D_{av}} * 100 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots.. \quad (3)$$

Where:

DU = The distribution uniformity (%),

$D_{min}$ = The minimum infiltrated depth (mm), and

$D_{av}$ = The mean infiltrated over the furrow length (mm).

(c) **Irrigation water use efficiency** was calculated according to ***McIndoe (2000)*** *as:*

$$IWUE = \frac{Y}{D_{ap}} * 100 \quad \dots\dots\dots\dots.\dots.\dots\dots \quad (4)$$

Where:

IWUE = The irrigation water use efficiency (kg/$m^3$),

Y = Crop yield (kg/ha), and

$D_{ap}$ = Irrigation water applied ($m^3$/ha).

**8 - Statistical analysis:**

The analysis was performed on the grain yield for all irrigation treatments using MSTATC statistical software. The data of the experiment were analyzed in factorial randomized complete block design (RCBD), and the mean difference was estimated using the least significant difference (LSD) comparison.

## RESULTS AND DISCUSSION

**1 - Advance time:**

The average value of advance time at different soil slopes, inflow rates and cycle ratio was shown in Fig.4. The results showed that, soil slopes had a highly significant effect on advance time where the average values of advance time were 59.2, 53 and 48.2 min , for 0, 0.1, 0.2% soil slopes, respectively. Cycle ratio 2/3 gave the lowest values of advance time comparing with 1/2 cycle ratio. Results indicated also that, the advance time decreased by increasing in flow rate. The obtained results were in agreement with those obtained by ***Ismail et al. 2004 and Horst et al. 2007.***

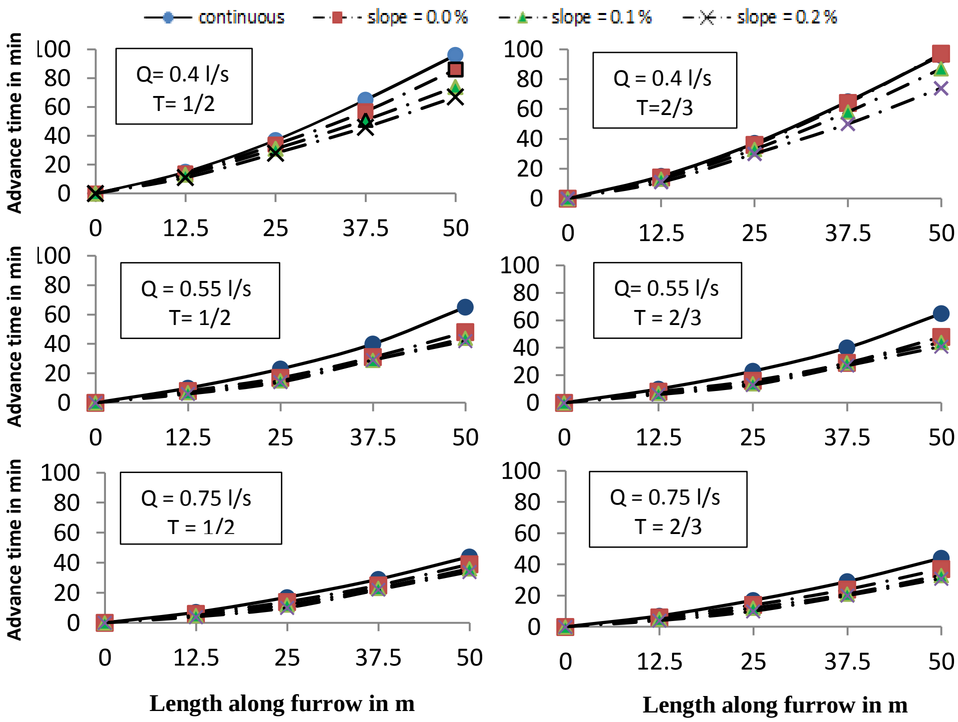


**Fig.4: Advance time for continuous under traditional levelling and surge irrigation at different slopes, inflow rates and cycle ratios**

**2- Moisture content distribution:**

The results illustrated in Fig.5 indicated that surge irrigation treatments distributed the water uniformity along the furrow compared to continuous irrigation under traditional levelling. The obtained results showed that the discharge of 0.4 l/s with 2/3 cycle ratio and the discharge of 0.55 l/s with1/2 cycle ratio gave a high distribution uniformity under slope of 0.0, 0.1 and 0.2 %, but a discharge of 0.55 l/s with 1/2 cycle ratio is better than the other one.

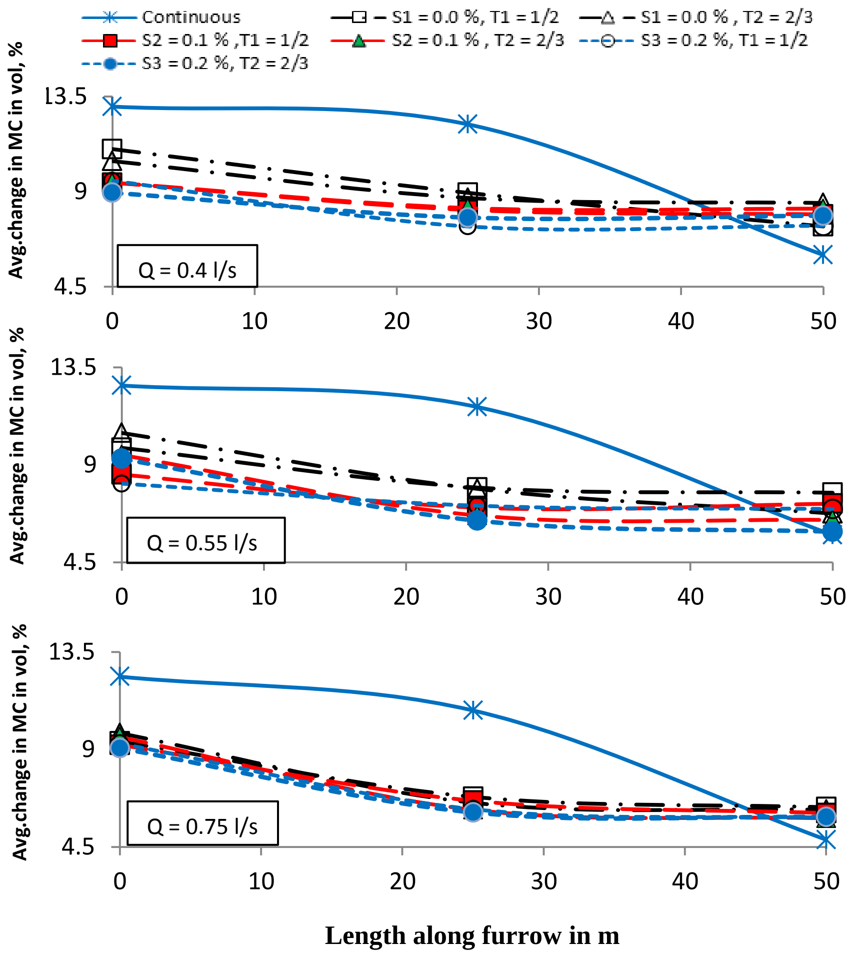


**Fig.5: Average of change in soil moisture content for continuous flow under traditional levelling and surge flow irrigation under different slopes.**

**3 - Applied irrigation water:**

The obtained results in Fig.6 indicated that all surge irrigation treatments under different slopes of 0.0, 0.1 and 0.2% used less amounts of total applied water than the continuous irrigation under traditional levelling. The total amounts of applied irrigation water for continuous flow under traditional levelling were 3190.3, 3012.2 and 2827.4 $m^3$/fed. for the discharges of 0.4, 0.55 and 0.75 l/s, respectively. The corresponding values for surge flow irrigation technique varied from 1774.1 to 2998.5 $m^3$/ fed.

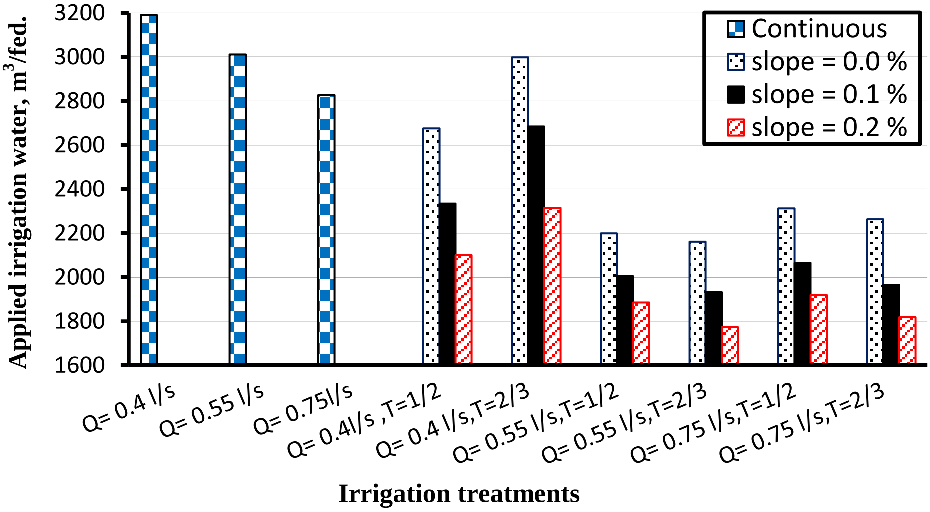


**Fig.6: Amount of applied irrigation water for treatments of surge flow irrigation at different slopes compared with continuous flow under traditional levelling.**

**4 – Water saving:**

The results illustrated in Fig.7 indicated that surge flow irrigation under slope of 0.0, 0.1 and 0.2% reduced the quantity of applied water from 6 to 41.1% compared with continuous irrigation under traditional levelling according the slope, discharge and cycle ratio. The obtained results indicated also that, the best treatments in the saving of water were that using the discharge of 0.55 l/s with 1/2 and 2/3 cycle ratio.

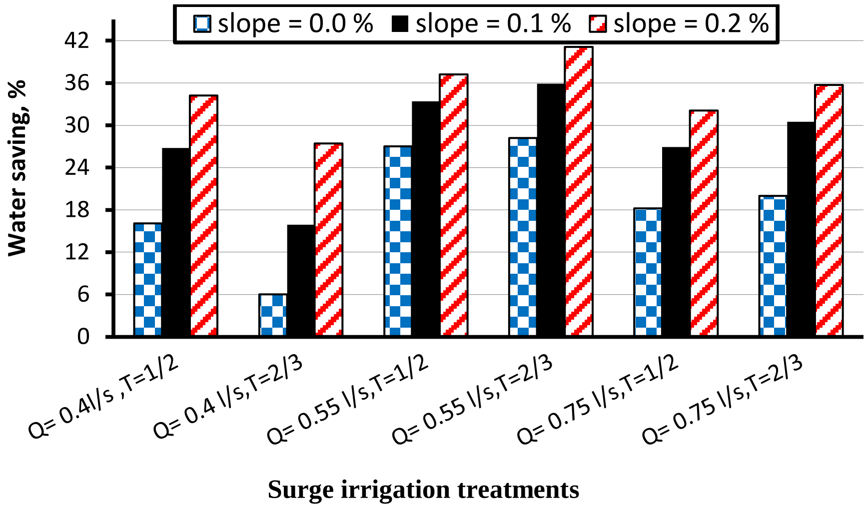


**Fig.7: Water saving for treatments of surge flow irrigation at different slopes in relation to continuous flow under traditional levelling.**

## 5 - Application efficiency (Ea):

Application efficiency was determined using Eq.2.The obtained results showed that, the surge flow treatments under three different slopes 0.0, 0.1 and 0.2% had appreciable increase in water application efficiency compared with continuous flow irrigation under traditional levelling for the same discharges as shown in Table 4 .This may be due to a good irrigation distribution for surge flow than continuous ones. The results also showed that the average values of irrigation application efficiency for a discharge of 0.55 l/s gave higher values than discharges of 0.4 and 0.75 l/s under the three different slopes for all treatments. WAE values for the discharge of 0.55 l/s with 2/3 cycle ratio were 82, 82 and 85 % under slope of 0.0, 0.1 and 0.2 %, respectively. Also, WAE values for a discharge of 0.55 l/s with 1/2 cycle ratio, were 81, 80 and 82 % under slope of 0.0, 0.1 and 0.2 %, respectively. This result is
in agreement with those obtained by ***Ismail et al. 2004 and Kifle et al. 2007.***

## 6 - Distribution efficiency (DU):

Distribution uniformity was computed using Eq.3.The obtained data revealed that all surge irrigation treatments under three different slopes

0.0, 0.1 and 0.2 % lead to increase the water distribution efficiency compared with continuous irrigation under traditional levelling for the same discharges. The average values of DU for continuous flow under traditional levelling were 75, 75 and 73% for the discharge of 0.4, 0.55 and 0.75 l/s, respectively. The corresponding values of the same discharges for surge irrigation under different slopes of 0.0, 0.1 and 0.2% varied between 91 to 97 % as shown in Table 4. This result is in agreement with those reported by ***Ismail (2006).***

**7 - Yield and water use efficiency:**

**7.1- Wheat yield:.**

The obtained data revealed that surge flow irrigation significantly affected grain yield. All surge flow treatments under slope of 0.0, 0.1 and 0.2 % gave higher yields than continuous irrigation under traditional levelling as shown in Table 5. The grain yield increased with the decrease of cycle ratio and by the increase of the off – time. Mean values of the grain yields for continuous irrigation under traditional levelling were 2758, 2665 and 2472 kg/fed. for the discharges of 0.4, 0.55 and 0.75 l/s, respectively. The corresponding values under surge irrigation treatments varied from 2643 to 3137 kg/fed. In other words, surge flow treatments under slope of 0.0, 0.1 and 0.2% increased the yield between 2.8 to 17.7% compared with continuous flow under traditional levelling. The discharge of 0.55 l/s with 1/2 cycle ratio recorded the highest yield of 3067, 3137 and 3004 kg/ fed. under slope of 0.0, 0.1 and 0.2 %, respectively. The trend of these results is similar to that found by ***Mahmood et al. (2003).***

**7.2- Wheat water use efficiency:**

The obtained data showed that surge flow treatments under three different slopes 0.0, 0.1 and 0.2% recorded the highest values of WUE compared with continuous flow irrigation under traditional levelling. Mean values of WUE for continuous irrigation under traditional levelling were 0.86, 0.88, and 0.87 kg/m$^3$ for the discharges of 0.4, 0.55 and 0.75 l/s, respectively. The corresponding values under surge irrigation treatments varied from 0.97 to 1.59 kg/m$^3$ as shown in Table 4. These results are in line with the results reported by ***Kifle et al. 2007 and Horst et al. 2007.***

**Table 4: Values of water application efficiency, distribution uniformity, water use efficiency and grain yield for continuous flow under traditional levelling and surge irrigation under different slopes, inflow rates and cycle ratios.**

| Slope | Treatment | Discharge l/s | Cycle ratio | Number of surges | Total amounts of applied irrigation water | Grain yield | Water use efficiency | Application efficiency (Ea %) | Distribution uniformity (DU %) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | m³/fed | kg /fed | kg/m³ | | |
| Traditional levelling | $Q_1$ | 0.4 | Cont. | | 3190.3 | 2758 | 0.86 | 68 | 75 |
| | $Q_2$ | 0.55 | Cont. | | 3012.2 | 2665 | 0.88 | 70 | 75 |
| | $Q_3$ | 0.75 | Cont. | | 2827.4 | 2472 | 0.87 | 69 | 73 |
| 0.0 % | $Q_1T_1$ | 0.4 | 1/2 | 7 | 2675.9 | 2953 | 1.10 | 71 | 93 |
| | $Q_1T_2$ | 0.4 | 2/3 | 6 | 2998.5 | 2921 | 0.97 | 64 | 96 |
| | $Q_2T_1$ | 0.55 | 1/2 | 4 | 2198.7 | 3067 | 1.39 | 81 | 96 |
| | $Q_2T_2$ | 0.55 | 2/3 | 3 | 2161.9 | 2811 | 1.30 | 82 | 91 |
| | $Q_3T_1$ | 0.75 | 1/2 | 3 | 2313.1 | 2790 | 1.21 | 68 | 95 |
| | $Q_3T_2$ | 0.75 | 2/3 | 2 | 2262.7 | 2716 | 1.20 | 70 | 91 |
| 0.1 % | $Q_1T_1$ | 0.4 | 1/2 | 6 | 2334.4 | 3114 | 1.33 | 76 | 95 |
| | $Q_1T_2$ | 0.4 | 2/3 | 6 | 2684 | 3086 | 1.15 | 67 | 96 |
| | $Q_2T_1$ | 0.55 | 1/2 | 4 | 2005.2 | 3137 | 1.56 | 80 | 96 |
| | $Q_2T_2$ | 0.55 | 2/3 | 3 | 1931.2 | 2847 | 1.47 | 82 | 92 |
| | $Q_3T_1$ | 0.75 | 1/2 | 2 | 2065.6 | 2801 | 1.36 | 74 | 95 |
| | $Q_3T_2$ | 0.75 | 2/3 | 2 | 1964.8 | 2713 | 1.38 | 77 | 92 |
| 0.2 % | $Q_1T_1$ | 0.4 | 1/2 | 6 | 2100 | 2987 | 1.42 | 81 | 95 |
| | $Q_1T_2$ | 0.4 | 2/3 | 5 | 2315.1 | 2893 | 1.25 | 74 | 96 |
| | $Q_2T_1$ | 0.55 | 1/2 | 4 | 1885 | 3004 | 1.59 | 82 | 97 |
| | $Q_2T_2$ | 0.55 | 2/3 | 3 | 1774.1 | 2679 | 1.51 | 85 | 91 |
| | $Q_3T_1$ | 0.75 | 1/2 | 2 | 1918.6 | 2712 | 1.41 | 78 | 95 |
| | $Q_3T_2$ | 0.75 | 2/3 | 2 | 1817.8 | 2643 | 1.45 | 81 | 91 |

**Table 5: The effect of slope, discharge and cycle ratio on yield (kg/fed.).**

| Irrigation method | Slope % | Cycle Ratio | Discharge (l/s) | | |
|---|---|---|---|---|---|
| | | | 0.4 | 0.55 | 0.75 |
| Surge irrigation | 0.0 | 1/2 | 2953[g] | 3067[d] | 2790[m] |
| | | 2/3 | 2921[h] | 2811[k] | 2716[p] |
| | 0.1 | 1/2 | 3114[b] | 3137[a] | 2801[l] |
| | | 2/3 | 3086[c] | 2847[j] | 2713[p] |
| | 0.2 | 1/2 | 2987[f] | 3004[e] | 2712[p] |
| | | 2/3 | 2893[i] | 2740[o] | 2643[r] |
| Continuous irrigation | | 1 | 2758[n] | 2665[q] | 2472[s] |
| L.S.D.(0.05) = 6.90 | | | | | |

Figures followed by similar letter are not significantly different.

## CONCLUSION

Results indicated that surge irrigation under three different slopes 0.0, 0.1 and 0.2 % reduces amount of irrigation water applied, increases advance time, irrigation uniformity, water application efficiency, grain yields and water use efficiency compared with continuous flow irrigation under traditional levelling. The best treatment is the discharge of 0.55 l/s with 1/2 cycle ratio under different slopes 0.0, 0.1 and 0.2 %. It saved and decreased amount of water irrigation applied by 27, 33.4 and 37.4 % and increased the yield by 15.1, 17.7 and 12.7 % under slope of 0.0 , 0.1 and 0.2 % respectively compared with continuous flow irrigation under traditional levelling for the same discharge. It had the maximum water use efficiency values of 1.39, 1.56 and 1.59 kg/m$^3$ for surge flow irrigation under slopes of 0.0, 0.1 and 0.2 %, respectively.

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**الملخص العربي**

## تصنيع صمام تحكم ومقياس تصرف لتطوير الري السطحي باستخدام الري النبضي في الأراضي الطينية.

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أجريت التجربة لتطوير وتقييم فاعلية الري النبضي تحت ميول مختلفة (صفر، ٠.١ و ٠.٢ %) مقارنة بالري المستمر تحت ظروف التسوية التقليدية من ناحية كفاءات الري واستخدام المياه وذلك لإنتاج محصول القمح في الأراضي الطينية ذات الخطوط القصيرة. أجريت التجربة في المزرعة البحثية – كلية الزراعة – جامعة كفر الشيخ خلال موسم الزراعة الشتوي ٢٠١٤/٢٠١٣. تم زراعة محصول القمح علي مصاطب عرض المصطبة ٠,٨ متر ( ٧ صفوف من القمح المسافة بينها ١٠ سم ) يتم ريها من خلال خطوط متبادلة مع المصاطب طولها ٥٠ متر وعرضها ٠,٣ متر ذات نهاية مغلقة .

وأشتملت معاملات الري النبضي علي ثلاث ميول (صفر، ٠.١ و ٠.٢ %)) ، وثلاث تصرفات ( التصرف الأول = ٠,٤٠ لتر/ ثانية ، التصرف الثاني = ٠,٥٥ لتر/ ثانية ، التصرف الثالث = ٠,٧٥ لتر/ ثانية )، نسبة دورة (٢/١ ، ٣/٢ )، بالإضافة الي معاملات الري المستمر لنفس معدلات التصرف تحت ظروف التسوية التقليدية. ولرصد تقدم المياه تم اختيار خمس نقاط علي طول الخط ( صفر ، ١٢,٥ ، ٢٥ ، ٣٧,٥ ، ٥٠ متر من مدخل المياه) . وتم قياس نسبة الرطوبة بالتربة بالطريقة الوزنية علي أعماق ( صفر- ٠,١٥ ، ٠,١٥ – ٠,٣٠ ، ٠,٣٠ – ٠,٤٥ ، ٠,٤٥ – ٠,٦٠ متر) وذلك لثلاث مواقع مختلفة ( بداية ، منتصف ، نهاية الخط). وتم تصنيع صمام تحكم ومقياس تصرف للتحكم في كمية المياه المطلوبة لكل معاملة.

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وأوضحت النتائج أن الري النبضي تحت ميول صفر ، ٠,١ ، ٠,٢ % يعمل علي تقليل كمية المياه المطلوبة للري، ويزيد سرعة تقدم المياه ، وانتظامية الري ، وكفاءة أضافة المياه ، وإنتاجية المحصول ، وكفاءة استخدام المياه. وأظهرت النتائج المتحصل عليها أن أفضل معاملة تم استخدامها وأعطت أفضل نتائج هي معدل تصرف ٠.٥٥ لتر /ثانية مع نسبة دورة ٢/١ تحت كل الميول المستخدمة . حيث وفرت كمية المياه المضافة للري بحوالي ٢٧ ، ٣٣,٤ ، ٣٧,٤ % . وأدت أيضاً إلي زيادة إنتاجية محصول القمح بحوالي ١٥,١ ، ١٧,١ ، ١٢,٧ % تحت ميول صفر، ٠,١ ، ٠,٢ % علي التوالي مقارنة بالري المستمر تحت ظروف التسوية التقليدية . كما أنها حققت أكبر قيم لكفاءة استخدام المياه علي النحو التالي ١,٣٩ ، ١,٥٦، ١,٥٩ كجم / م$^{٣}$ للري النبضي تحت ميول صفر، ٠,١ ، ٠,٢ % علي التوالي.