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EFFECT OF SURFACE IRRIGATION USING GATED PIPES SYSTEM ON NITROGEN DISTRIBUTION AND WHEAT PRODUCTIVITY IN SMALL HOLDINGS

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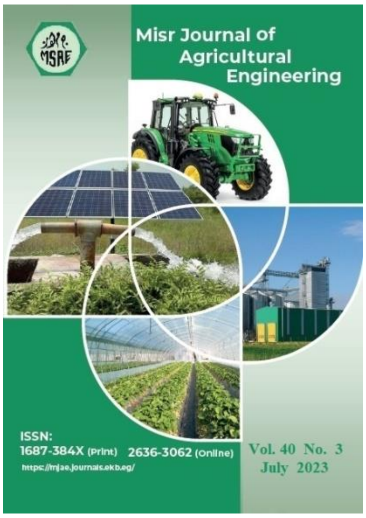

Keywords:
Surface Irrigation; Border Irrigation; Gated Pipes; Wheat Crop; Nitrogen Distribution.

ABSTRACT

A field study on wheat using border irrigation was carried out on a clay loam soil with 1.2 g cm^{-3} average soil bulk density in Shebin El-Kom area, Egypt. The main aim of this work is to study the irrigation water flow rate (10.71 and 5.35 m^3 h^{-1}) and fertilizer application regime (in complete irrigation time and half irrigation wave) under two different soil slopes (0.05 and 0.10 %) of the wheat field to improve border irrigation method in small holdings using gated pipes irrigation system. Wheat seeds (Gemeza 11) were planted on November 13 and received five irrigations during the growing season. In comparison to the 0.05% border slope, application efficiency (E_a) was significantly improved by applying a 0.10% border slope at the second and third irrigations. Storage efficiency (E_s) was properly achieved by applying all treatments at the second and third irrigation. The results showed that increasing border slope, decreasing inlet flow rate, and applying (N) when water advanced to the middle of the border increased grain yield, straw yield, TSS for grain, TSS for straw, and 1000-grain weight. Nitrogen application after offering half wave achieved high nitrogen (N) concentration in the wheat root zone. Applying border slopes of 0.10% relative to 0.05%, inflow rates of 5.35 m^3 h^{-1} relative to 10.71 m^3 h^{-1}, and (N) when water advanced to the middle of the border as opposed to applying (N) from the beginning of irrigation, increased wheat yield by 20.10, 1.58 and 3.59%, respectively.

1. INTRODUCTION

The oldest and most popular way to irrigate agriculture is surface irrigation. This irrigation system, also known as flood irrigation, functions by applying water at a precise point and allowing it to flow freely over the field surface, which applies and distributes the required amount of water to replenish the crop root zone **(USDA, 2012)**. In Egypt and around the world, surface irrigation systems are the most often used kind of crop irrigation **(Amer, 2009; El Awady et al., 2009; Koech et al., 2010)**. In general, surface irrigation efficiency is low in comparison to sprinkler and trickle irrigation systems **(Amer, 2009)**. Water from surface irrigation systems can be applied to the field in a number of different ways. Furrow, basin, and border irrigation systems make up their classification **(McClymont, 2007)**. In border irrigation, water flows between dikes that divide a sloping field into rectangular strips with free drainage at the end, the irrigated areas between dikes maybe 3–30 m wide, and water can be delivered to borders from open ditches with gates, breaches, or siphon tubes as well as from above- or below-ground pipelines **(DL Bjorneberg, 2013)**. The inefficiency of the surface irrigation system is the main problem, according to **Ali and Mohammed (2015)**. Surface irrigation systems are becoming more effective by utilizing gated pipes (GP), which take into account a new method for distributing irrigation water into furrows to conserve applied irrigation water. In comparison to the traditional irrigation system, which provided the most applied water (6423.81 m^3 ha^{-1}), the use of gated pipes (GP) increased grain and dry wheat yields by 5.7% and 3.4%, respectively, while reducing water application by 923.81 m^3 ha^{-1}. The use of gated irrigation pipes to transfer water from the ends of the field upstream to downstream improves the efficiency of the surface irrigation system. Gated pipes offer a good method for controlling the irrigation stream size (**El-Sayed, 1998**). **Smith et al., (1986)** reported that for the purpose of supplying irrigation water, a system of "gated pipes" uses gates that are spaced regularly apart over the pipeline.

Advance, storage, depletion, and recession are the four stages of the surface irrigation process **(Holzapfel et al., 1984; Walker and Scorebox, 1987; Alazba, 1999)**. The time elapsed between the advance and recession curves is the opportunity time for water to infiltrate at any point along the field **(Merriam and Keller, 1978; Holzapfel et al., 1984; Foroud et al., 1996; Rodriguez, 2003)**. Water seeps into the soil at a certain rate, which is known as the infiltration rate (**Amer, 2009**). Constant factors, like soil texture, have an impact on a soil's infiltration rate. Various variables, like the moisture content of the soil, also play a role. When the soil is dry, water infiltrates more quickly than when it is wet (higher infiltration rate) (**Brouwer et al., 1985**). Infiltration in borders is generally considered to be one dimensional: downward **(Hoffman et al., 2007)**. Numerous variables, including soil variability, flow channel shape, irrigation type (border or furrow), inflow rate, irrigation hydraulics, irrigation duration, and slope of the field, affect the shape of the infiltrated irrigation depth **(Vaziri and Wu, 1972; Holzapfel et al., 1984; Blair and Smerdon, 1988; Valiantzas et al., 2001; Mohammed, 2008)**. According to **Assefa et al. (2017)**, the interaction effects of furrow lengths and flow rates were significantly different in how they affected the effectiveness of application. Additionally, the interaction between furrow length and flow rate had a significant impact, with the greatest value being 89.32% for 200 m of length and 6 L s^{-1}. The interaction between furrow length and flow rate had a significant impact on storage efficiency, with the maximum value of 100% for the treatment combination of 200 m furrow length and 4 L s^{-1} and the lowest value of 99.06% for the effect of 100 m and 6 L s^{-1}.

Wheat *(Triticum aestivum L.)* is one of the most important cereal crops grown in the world which plays a key role in economic activity **(Hammad and Ali, 2014).** In Egypt, wheat is regarded as the first strategically important food crop. Throughout that time, it has maintained its status as the fundamental staple food in urban areas, a combination of maize and flour in rural areas for making bread, and an ingredient in numerous industries for biscuits, macaroni, and pies. Wheat straw is also a crucial form of feed. The most crucial national goals in Egypt are to increase wheat cultivation production per unit of land area in order to close the production-to-population consumption gap. The use of fertilizers and improved irrigation techniques could help achieve that **(Bakry et al., 2012)**. Egypt is the largest wheat importer worldwide **(Gazette, 2013)**. Regarding declining water availability and the area designated for wheat production, Egypt faces very difficult circumstances **(Boutros, 2022)**. Deficiency of water is typically regarded as one of the factors that limit crop productivity and has an impact on the physiological and biochemical functions of plants **(Osborne et al., 2002)**. Irrigated wheat plants at 40-45% soil moisture depletion significantly increased plant height, weight of grains, 1000-grain weight, No. of grains, grain and straw yield **(El-Sabbagh et al. (2002) and Moussa and Abdel-Maksoud (2004)**. When irrigation was used at a 50% soil moisture depletion, grain yield, and water use efficiency were both higher **(Mahmood and Ahmad, 2005)**. Water stress reduced all growth characteristics, total and relative water content, free water, transpiration rate, phenol oxidase activity, N, P, and K (percent), activators phytohormones, yield, and its characteristics **(Maria et al., 2008)**. Growth characters of wheat plants, peroxidase, phenol oxidase, enzyme activities and grain yield negatively effects with increasing soil moisture depletion levels **(Hammad and Ali, 2014)**. With an average of five irrigations, wheat is grown in Egypt from the middle of October until the end of November **(Karrou et al., 2012)**.

In soil-plant systems, nitrogen is a nutrient that is mobile. The efficiency of how effectively crops use nitrogen (N) can be improved through crop management practices. The creation of favorable environmental conditions for crops is one of these improved practices. This increases the uptake and utilization of nitrogen (N), which in turn increases yields. Important nitrogen (N) management strategies include selecting the right sources, employing effective application techniques, and timing applications for when crops can absorb the most N **(Fageria and Baligar, 2005)**. Plant growth is significantly influenced by the uptake of nitrogen by plants. As a result, nitrogen fertilization has proven to be a useful tool for increasing the yield of cultivated plants like cereals (**Gallais and Hirel, 2004**). The ideal fertilizer increases productivity of grain while enhancing the grain's starch and protein composition (**Abdul Rehman et al., 2011**). According to **Cetin and Akinci (2015)**, using nitrogen for yield production necessitates balancing it with other potential constraints, particularly water. Approximately 70–80% of the necessary (N) for cereal grain filling is obtained from vegetative organs prior to flowering **(Mainard and Jeuffroy, 2001).** There are three types of fertilizer to fertilize wheat **(Karrou et al., 2012; Hammad and Ali, 2014)**, as follows:

1- Calcium Phosphate Super (15.5% P_2O_5) - to be added at the sowing/planting stage at the rate of 15.5 kg P_2O_5 per feddan (100-150 kg per feddan).
2- Potassium fertilizer, which is very important for the grain - to be added at the sowing/planting at a rate of 50 kg per feddan.
3- Nitrogen fertilization - to be added at a rate of 75 kg N per feddan in two quantities equal at first irrigation and second irrigation.

Broadcasting urea is the standard method of applying nitrogen. Low fertilizer use efficiency is caused by the applied nitrogen's tendency to be washed away by irrigation water from higher levels of the surface of the soil to lower levels **(Jat et al., 2006)**. The groundwater and surface water pollution by nitrate occurs in this area as a result of excessive nitrogen application and unreasonable nitrogen and water management **(Zhu and Chen 2002)**. The two most important factors directly affecting the effectiveness of surface irrigation systems are the discharge of irrigation water and accurate land leveling. The accurate land leveling by laser improves the effectiveness of field irrigation, conserves irrigation water, boosts yield, and subsequently improves irrigation productivity **(Awad and Gomaa, 2004)**. According to **Jat et al., (2006)**, a slope of 0 to 0.2% is good for optimum water flow. The main goal of this work is to study the effect of inflow rates and the methods of fertilizer application under different levels of irrigating border slopes of the wheat crop to improve border irrigation method using gated pipes irrigation system. The distributions of irrigation water and nitrogen over the border length should also be studied.

2. MATERIALS AND METHODS

A field experiment was carried out at the Shebin El-Kom area, 17.9 m above sea level (30˚32/N, 31˚03/E). Clay loam was identified as the type of soil at the experimental site, with an average bulk density of 1.2 g/cm^3 at a depth of 0.6 m. According to **Black (1982)**, the soil's physical and mechanical analysis were analyzed. The results of the soil mechanical analysis, field capacity, permanent wilting point, bulk density, and organic matter measurements for each soil depth, which were taken up to a depth of 60 cm, are displayed in Table (1) below. Table (2) displays some chemical characteristics of the soil at the experimental site.

Table (1): The results of the soil mechanical analysis, field capacity, permanent wilting point, bulk density, and organic matter measurements for each soil depth

Soil depth (cm)	Particles size distribution (%)			Bulk density (gm cm^{-3})	*FC (gm gm^{-1})	**PWP (gm gm^{-1})	Organic matter percent (%)
	Sand	Silt	Clay				
0 – 20	25.0	30.2	44.80	1.18	0.33	0.18	2.6
20 – 40	17.8	31.1	51.07	1.21	0.37	0.18	1.8
40 – 60	15.7	27.4	56.90	1.22	0.35	0.17	1.4
Average	19.5	29.56	50.92	1.20	0.35	0.18	1.9

*(FC) is the field capacity of the experimental soil and **(PWP) is the wilting point of the soil.

Table (2): Some chemical characteristics of the soil at the experimental site

Depth (cm)	PH	EC (ds m^{-1})	Soluble cations, meq.l^{-1}				Soluble anions, meq.l^{-1}		
			Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^{-1}	HCo_3^{-2}	So_4^{-2}
0 - 20	8.60	0.290	3.20	0.07	0.30	0.10	1.10	1.50	1.10
20 - 40	8.70	0.300	3.40	0.06	0.20	0.20	1.10	1.60	1.10
40 - 60	8.70	0.330	3.70	0.02	0.10	0.20	1.20	1.70	1.10

Chisel plows were used to plow the experimental plot twice orthogonally, and then a laser leveling machine was used to level the soil ground. A first subplot with a 0.05 percent leveling was chosen, and a second subplot with a 0.1 percent leveling. Eight borders were used to each separate subplot. Each border was 60 m long and 5 m wide, with a belted area extending one meter in between each border. The randomized arrangement of the experimental treatments is depicted as shown in Fig. 1.

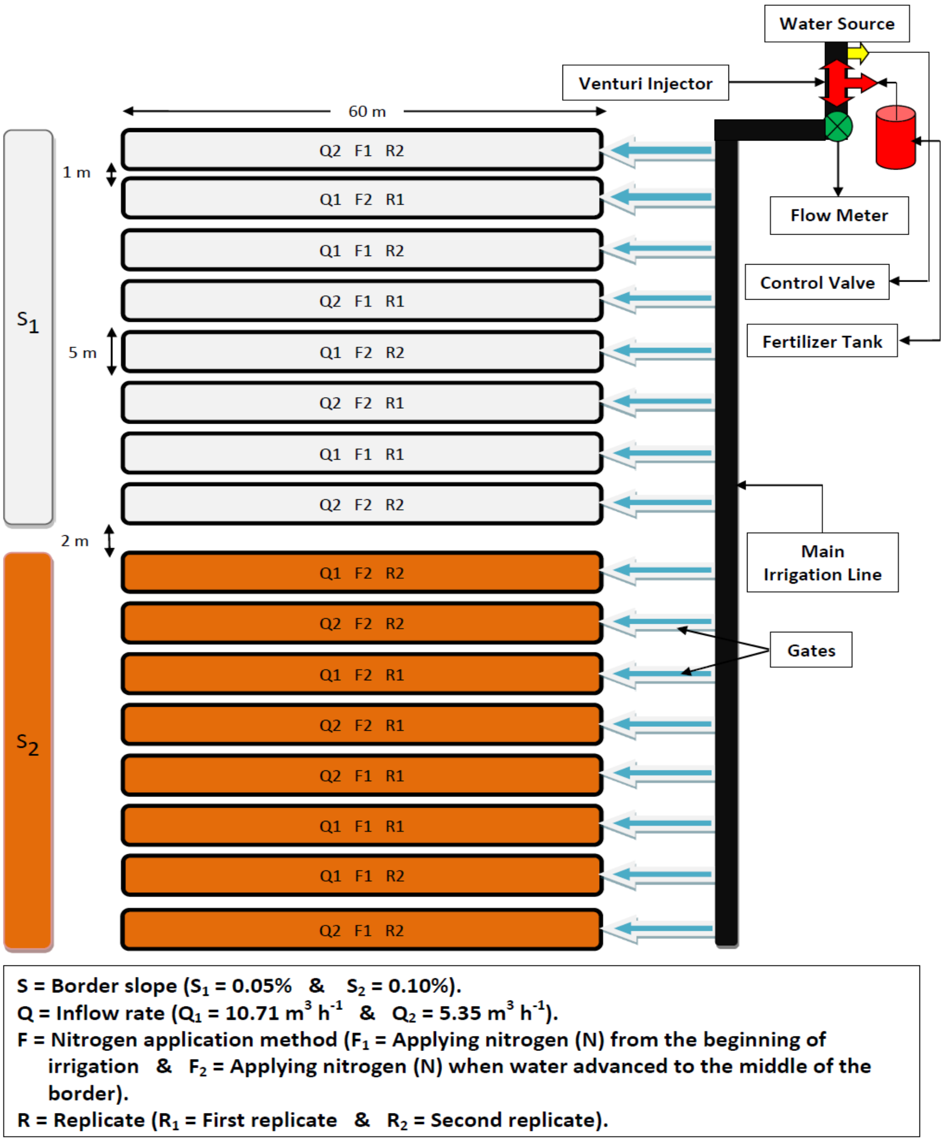

Fig. 1: The schematic diagram of the experimental treatments' layout

With a rate of 119 kg ha^{-1}, wheat seeds (Gemeza 11 variety) were planted using a seed drilling machine (with a 10 cm distance between the drilling tubes) on November 13 and terminated on April 23. Following a manual strewing procedure, super phosphate calcium and potassium fertilizers were spread over the experimental soil. The venturi injector was used to add the nitrogen fertilizers (Urea 46.5%) in two stages at a rate of 383 (kg ha^{-1}). The first dose (50 percent of the amount of the total fertilizer) and the second dose (50 percent of the amount of the total fertilizer) were applied with the first and second irrigations, respectively. An irrigation water venturi injector was installed in the gated pipes irrigation system to add fertilizer.

A modified surface irrigation system was used to water the experimental area, with a gated pipes system placed upstream of each border with a 70 cm distance between the gated. Gated pipes were connected together by their couplers. The last gated pipe had a plug attached to the end of it. For full and half openings, the gates of the gated pipes were manually adjusted. A discharge of 10.71 and 5.35 m^3 h^{-1} was produced by the gate's full and half openings, respectively. Catch cans were used to gauge the discharge in the field. In a pipeline, the flow rate of water varied from 1.5 to 2.4 m s^{-1} according to (**Hastings Co., 1986**). The experimental system's layout and parts are schematically depicted in Fig. 2.

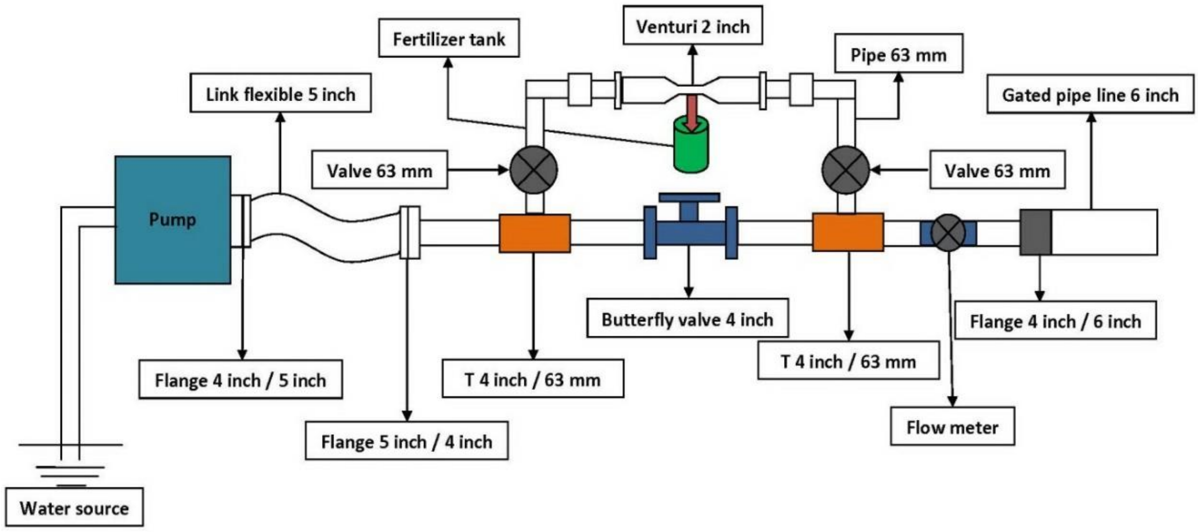

Fig. 2: Schematic diagram of the gated pipes irrigation system layout and its parts.

Five times during the growing season, the wheat crop was watered. It took 21 days after planting to apply the first irrigation, which is known as Mahaya irrigation. After planting, there were subsequent irrigations at 53, 83, 108, and 126 days, respectively. For all treatments, the irrigation stream was stopped after 50 meters of the border length. 161 days after planting, when the wheat spikes were yellow and the grains were fully developed, harvesting of the wheat crop began. At a rate of one square meter per each 10 m of the border length, wheat samples were taken and collected. The samples were then left to dry in the open air.

According to **Estefan et al., (2013)**, We only took soil samples the day before irrigation. Two days after irrigation, soil samples were also taken. Three samples were taken at 0-20, 20-40, and 40-60 cm of soil depth along the border length every 15 meters at each length point. With the 1st, 2nd, and 3rd irrigations, soil samples were taken and collected. Stainless steel auger was used to collect soil samples.

By gathering soil samples and placing them in a drying oven set at 105°C for 24 hours, the moisture content of the soil was determined. The nitrogen content ratio was found using soil samples that had been collected and dried by air. To digest the samples, soil samples were lightly crushed and sieved. Next, the nitrogen content ratio was calculated. The well-known Kjeldahl procedure is typically used to measure total soil nitrogen (primarily organic) after wet digestion (**Estefan et al., 2013**).

Based on the average of the soil volumetric water content of the root depth after and before irrigation (θ_F, and θ_i), the schedule depth of irrigation (d) which will be applied was calculated in mm per each irrigation as follows:

$$d = (\theta_F - \theta_i)D \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where (d) is scheduling irrigation depth in mm, (θ_F) is volumetric soil moisture content at field capacity $m^3\ m^{-3}$, (θ_i) volumetric soil moisture content before irrigation in $m^3\ m^{-3}$, and (D) is the wet depth of the soil root depth in mm.

According to **Amer, (2007**), the schedule parameter (α) was calculated using equation (2).

$$\alpha = \frac{1}{CV}\left(\frac{d}{\mu} - 1\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where (CV) is the variation coefficient and (μ) is the average value of the infiltrated irrigation depth by mm.

In non-uniformity condition, the water application efficiency (E_a) can be calculated using the following equation based on **Amer, (2010**):

$$E_a = 1 - \frac{(1.725 - \alpha)^2 CV}{6.9} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Based on **Amer, (2010)**, the water storage efficiency (E_S) was determined using the following equation:

$$E_s = 1 - \frac{(1.725 + \alpha)^2 CV}{6.9(1 + \alpha CV)} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

According to **Amer, (2009**), the coefficient of uniformity (UC) for the depth of the water infiltrated in soil was calculated using the following equation:

$$UC = 1 - 0.86CV \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

The water distribution uniformity (DU) was determined using the following equation based on **Amer, (2009**):

$$DU = 1 - 1.33CV \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The variation coefficient (CV) was calculated using the following function (**Amer, 2009**):

$$CV = \frac{1}{\overline{Z}}\sqrt{\frac{\left(Z - \overline{Z}\right)^2}{N - 1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where (CV) is the variation coefficient, (Z) is the depth of infiltrated water in mm, ($\overline{Z}$) is the average depth of infiltrated water in mm, and (N) is the total measured number.

3. RESULTS AND DISCUSSION

3.1. Irrigation depth over the border length and efficiency

Table (3) shows the measured and illustrated irrigation depth over the border length and the criteria of evaluation for the first and the mean of the second and third irrigations under two different levels of gate inflow rate and border soil slopes. The reported results illustrated that the advance time of water, the recession time of water and the water depth of irrigation were significantly affected by the border soil slope and the gate inflow rate. The advance time of irrigation water, the recession time of irrigation water and the depth of irrigation water were decreased by growing the border soil slope due to quick movements of irrigation water over the border length. These results are in agreements with **El-Khatib (2010) and Amer et al., (2017)**.

Table (3): The results of infiltrated irrigation water in the soil by mm, and calculated parameters of evaluation.

Irrigation	First Irrigation				Mean of Second and Third Irrigation			
Border slope, %	0.05		0.10		0.05		0.10	
Inflow rate, $m^3 h^{-1}$	10.71	5.35	10.71	5.35	10.71	5.35	10.71	5.35
Border length, m	Infiltrated irrigation depth (mm)							
0	40.88	59.88	38.03	52.08	61.46	68.20	53.22	64.20
5	44.52	61.02	39.74	52.65	65.06	70.12	55.31	64.76
10	50.57	61.22	42.88	52.90	67.47	70.93	57.33	65.60
15	53.53	61.08	43.90	53.55	69.02	72.32	58.70	66.02
20	54.16	60.87	45.00	53.65	70.50	73.89	59.24	64.64
25	55.35	61.17	47.97	53.67	71.58	74.44	59.30	64.72
30	55.81	60.12	49.37	54.60	72.18	73.19	61.12	63.40
35	56.27	59.33	50.61	54.05	73.31	72.58	62.52	63.08
40	57.32	58.96	52.94	53.25	74.23	72.32	66.73	62.07
45	57.49	58.38	53.96	52.42	75.34	71.76	68.40	62.15
50	57.37	56.64	54.37	51.25	76.30	70.89	70.47	61.45
55	57.63	56.14	54.76	51.20	76.89	69.05	70.60	61.84
60	57.78	52.85	55.79	49.85	76.56	66.44	70.09	63.01
*μ, mm	53.74	59.05	48.41	52.70	71.45	71.46	62.54	63.61
CV, %	9.59	4.08	11.92	2.43	6.26	2.57	9.32	2.25
DU, %	87.82	94.82	84.86	96.92	92.05	96.73	88.17	97.14
UC, %	91.75	96.49	89.75	97.91	94.62	97.79	91.99	98.06
E_a, %	99.64	98.95	99.86	94.43	83.34	76.37	93.69	94.12
E_S, %	89.24	97.39	80.57	82.94	99.25	90.96	97.66	99.78

***(μ) is the average depth of infiltrated water, (CV) is the variation coefficient, (DU) is the water distribution uniformity, (UC) is the coefficient of uniformity, (E_a) is the water application efficiency, and (E_s) is the water storage efficiency.**

The time of depletion phase was decreased with the increasing of the border soil slope due to decreasing the duration of the advance stage when the water was utilized. Due to the plants' increased resistance to water flow, the time of depletion phase lengthened as plant age increased. The time of water advance, the time of water recession and the depth of irrigation water were significantly affected and increased by decreasing the gate inflow rate due to quietly movement of irrigation water over irrigating field. These results are in agreements with the results reported by **Amer (2009) and Amer et al., (2017)**. Results showed that location of the minimum and the maximum infiltrated depth affected by 5.35 and 10.71 $m^3 h^{-1}$ inflow rates. The minimum depth of the infiltrated irrigation water ($Z_{\min}$) which done at the upstream end of the border and the maximum depth of the infiltrated irrigation water ($Z_{\max}$) that found at the downstream end of the irrigating border at the fate inflow rate of 10.71 $m^3 h^{-1}$ due to increasing the time of opportunity for infiltrate irrigation water at the irrigating border downstream end. The minimum depth of the infiltrated irrigation water ($Z_{\min}$) was found at the downstream end of the irrigating border and the maximum depth of the infiltrated irrigation water ($Z_{\max}$) was done at the upstream end of the irrigating border at the gate inflow rate of 5.35 m^3 h^{-1} due to increasing the time of opportunity for infiltrate irrigation water at the irrigating border upstream end. Both the distribution uniformity (DU) and the coefficient of uniformity (UC) as related to the variation coefficient (CV) were affected by altering both the border soil slope and the gate inflow rate, and acceptable values were attained for all treatments. The results of the gate inflow rate of 5.35 m^3 h^{-1} in comparison to 10.71 m^3 h^{-1} confirmed that, the variation coefficient (CV) was decreased; the uniformity of distribution (DU) and the coefficient of uniformity (UC) were increased by increasing of the irrigating border slope. The evaluation of border irrigation was improved by the decrease amount of gate inflow rate from 10.71 to 5.35 m^3 h^{-1}. According the results of (CV), (DU) and (UC) the best water distribution was obtained for 0.10% of irrigating border slope and the gate inflow rate of 5.35 m^3 h^{-1} treatments. Due to increased initial soil moisture content of the first irrigation in comparison to the mean of the second and third irrigation, all treatments improved water application efficiency (E_a) where the irrigation schedule depth (d) was 60 mm. The water application efficiency (E_a) was achieved high value with applying the irrigating border slope of 0.10% at the second and third irrigation in comparison of the irrigating border slope of 0.05%. Applying all treatments at the second and third irrigations was the proper way to achieve storage efficiency (Es).

3.2. The soil Nitrogen distribution over the irrigating border

Figures 3 and 4 illustrate the soil nitrogen (N) content % as applied in irrigation stream using two different ways. The uniformity of soil nitrogen (N) was affected by the irrigating border slope (S), as well as the gate inflow rate (Q) and the application method of nitrogen (F). The results of 0.05% border slope (S1) treatment confirmed that, the coefficient of variation (CV) for nitrogen content in the root zone over the border length was improved by applying (N) with the starting of irrigation (F1) as well as the nitrogen (N) content in the root zone was increased by applying the gate inflow rate of 10.71 m^3 h^{-1} (Q1). On the other hand, the nitrogen (N) content in the root zone was growing when applying the gate inflow rate of 5.35 m^3 h^{-1} (Q2) under the irrigating border slope of 0.10% (S2). The reported results illustrated that the location of the higher and lower value of soil nitrogen (N) content % in contrary with location of the minimum and the maximum infiltrated depth. With applying the gate inflow rate of 10.71 m^3 h^{-1} (Q1), the minimum value of soil nitrogen (N) content was found at the point of downstream end; the maximum soil nitrogen (N) content was found at the point of upstream end. On the other hand, applying 5.35 m^3 h^{-1} inflow rate (Q2), the minimum (N) content was occurred at the upstream end; the maximum (N) content was occurred at the downstream end. Increase the depth of infiltration led to decreased fertilizer concentration because of distributing in wide wetted area.

The reported results illustrated that soil nitrogen (N) content % increased by applying the nitrogen (N) when the water movement reached to the middle of the border length (F2) compared to applying nitrogen from the beginning of irrigation (F1) because the upper soil layer, where most plant roots were located, was where fertilizer was more effectively distributed. The acceptable uniform nitrogen (N) distribution over the irrigating border was achieved for (F2) at a given inflow rate and field slope because the majority of the (N) remained in the plant root zone with less nitrogen (N) leaching.

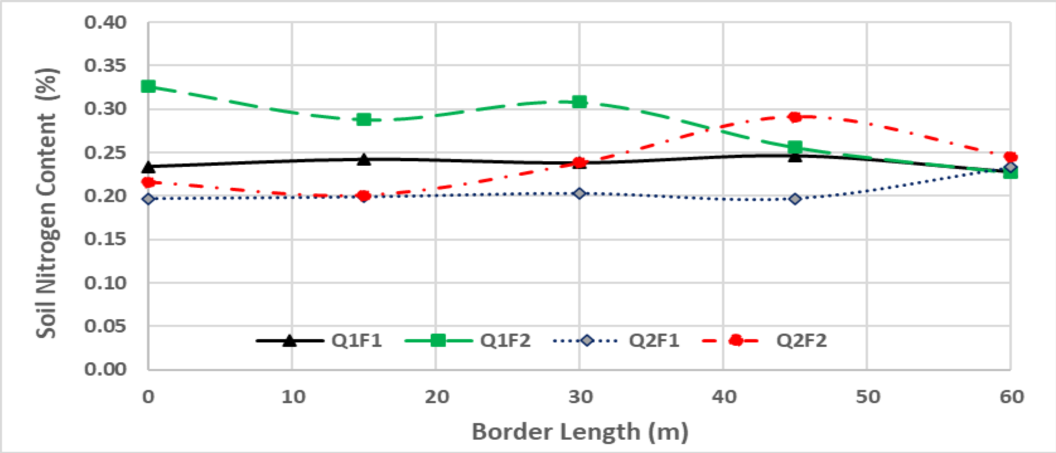

Fig. **3**: The distribution of the soil nitrogen content under border slope of 0.05%.

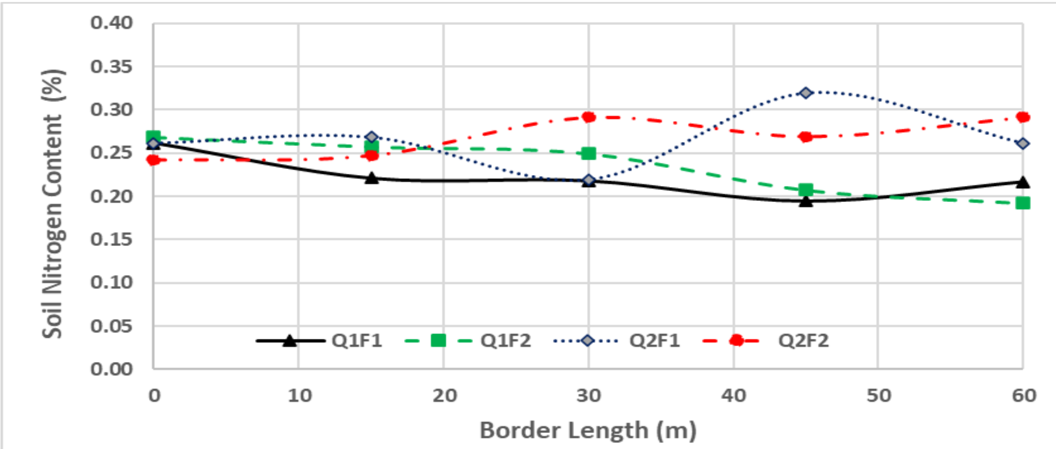

Fig. **4**: The distribution of the soil nitrogen content under border slope of 0.10%.

3.3. Wheat Grain and Straw Productivity

Figures 5 and 6 illustrate the Wheat grain yield (Mg ha^{-1}) under different two levels of the gate inflow rate (Q) and the method of fertilizer adding (F) with the irrigating border slope of 0.05 and 0.10%. Also, the wheat straw yield (Mg ha^{-1}) are shown in Figs. 7 and 8, respectively. The irrigating border slope (S), the gate inflow rate (Q), and the method of nitrogen application (N) all had a significant impact on the wheat grain and straw yield. According to the reported results, the distribution of soil nitrogen and water had a significant impact on wheat productivity.

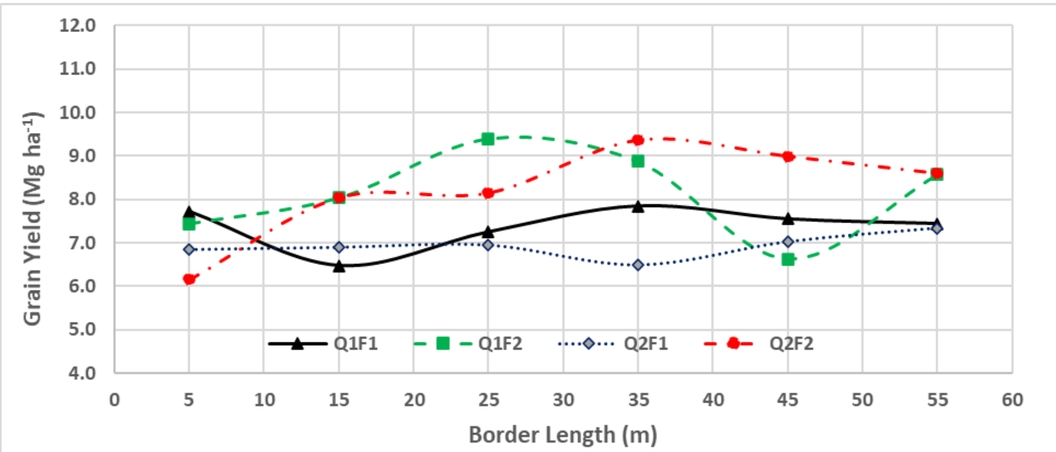

Fig. **5**: The wheat grain yield (Mg ha^{-1}) under border slope of 0.05%.

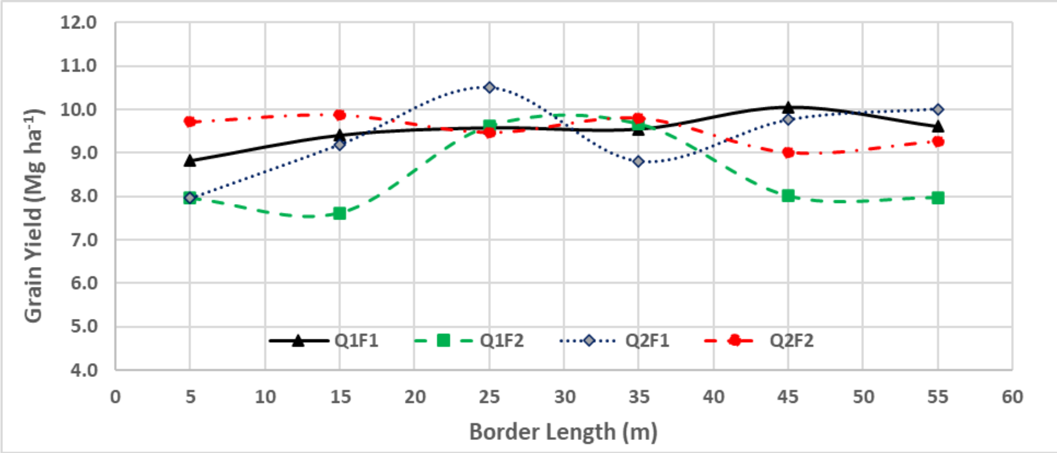

Fig. **6**: The wheat grain yield (Mg ha^{-1}) under border slope of 0.10%.

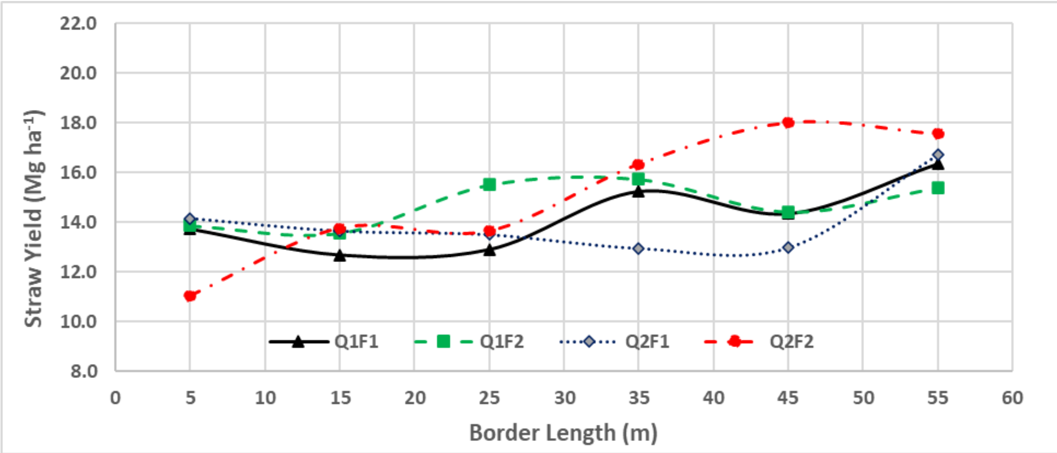

Fig. **7**: The wheat straw yield (Mg ha^{-1}) under border slope of 0.05%.

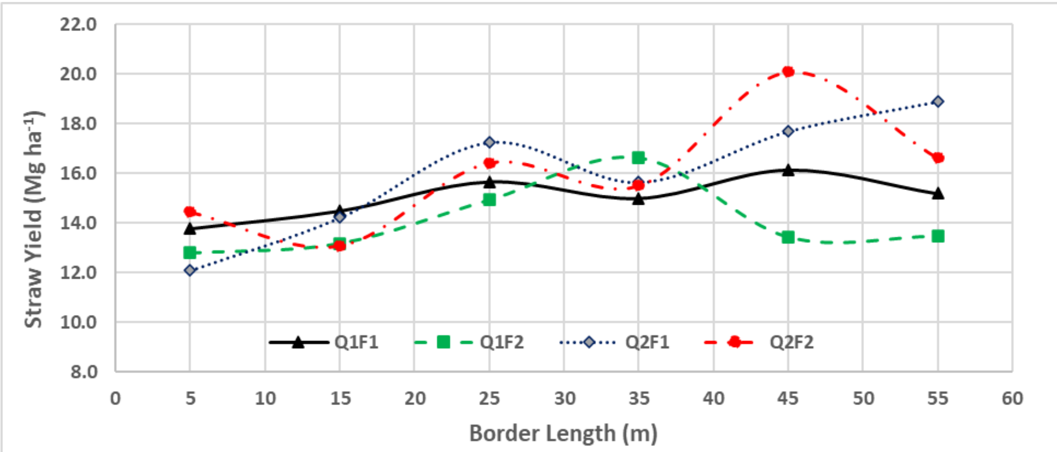

Fig. **8**: The wheat straw yield (Mg ha^{-1}) under border slope of 0.10%.

The results of total soluble solid (TSS) for grain and straw, and 1000-grain weight of wheat crop are shown in Table (4). Table (5) Illustrates the statistical analysis of Wheat grain yield, straw yield, total soluble solid (TSS) for grain, TSS for straw and the weight of 1000-grain. Results were significantly impacted by the irrigating border slope, except for TSS for straw, when the irrigating border slope was considered. Results showed that grain yield, straw yield, TSS for grain, TSS for straw and 1000-grain weight increased by increasing of border slope. These results are in agreements with **El-Khatib (2010) and Amer et al., (2017)**.

Table (4): Total soluble solid (TSS) for wheat grain and straw, and the weight of 1000-grain.

	Slope	0.05% Border Slope				0.1% Border Slope			
	Inflow rate	10.71 $m^3 h^{-1}$		5.35 $m^3 h^{-1}$		10.71 $m^3 h^{-1}$		5.35 $m^3 h^{-1}$	
	Fertilization Method	F1	F2	F1	F2	F1	F2	F1	F2
	Border Length (m)	Productivity (Mg/ha)							
TSS for Grain (Mg ha^{-1})	5	7.31	7.05	6.49	5.84	8.42	7.58	7.61	8.35
	15	6.13	7.58	6.51	7.64	8.89	7.19	8.75	7.45
	25	6.85	8.86	6.57	7.74	9.05	9.11	9.96	9.95
	35	7.44	8.34	6.14	8.79	9.08	9.09	8.35	9.22
	45	7.12	6.26	6.62	8.47	9.53	7.58	9.25	10.45
	55	7.07	8.04	6.86	8.11	9.13	7.57	9.45	8.73
	Average	6.99	7.69	6.53	7.76	9.02	8.02	8.89	9.03
	CV %	6.10	11.12	3.27	12.18	3.64	9.68	8.64	11.02
TSS for Straw (Mg ha^{-1})	5	12.68	12.85	13.26	10.06	12.53	11.98	11.14	13.24
	15	11.39	12.53	12.82	12.43	13.42	12.16	13.07	11.91
	25	11.94	14.47	12.56	12.61	14.10	13.76	15.91	15.03
	35	14.03	14.68	11.98	14.85	13.49	15.11	14.54	14.28
	45	13.16	13.48	12.15	16.59	14.84	11.97	16.12	18.45
	55	15.00	14.37	15.56	16.09	13.76	12.00	17.14	15.48
	Average	13.03	13.73	13.06	13.77	13.69	12.83	14.65	14.73
	CV %	9.33	6.05	9.16	16.62	5.11	9.36	13.86	13.82
		1000 grain weight (g)							
1000-grain weight (g)	5	59.88	57.53	52.05	63.73	61.10	59.03	64.88	62.70
	15	59.05	59.78	49.53	63.95	59.95	61.83	61.45	62.20
	25	56.30	59.28	50.83	63.03	59.35	62.38	55.78	56.35
	35	58.30	59.55	57.50	59.50	60.63	64.38	55.80	59.48
	45	54.95	58.15	55.48	56.95	57.48	61.30	57.60	54.95
	55	51.13	53.98	47.80	53.08	58.48	62.33	55.48	51.68
	Average	56.60	58.04	52.20	60.04	59.50	61.87	58.50	57.89
	CV %	5.22	3.42	6.41	6.67	2.08	2.57	6	6.83

Table (5): Mean square, F value, and probability for wheat grain yield, straw yield, TSS for grain, TSS for straw and weight of 1000-grain.

Item	Yield of wheat grain (Mg ha^{-1})	Yield of wheat Straw (Mg ha^{-1})	TSS for grain	TSS for straw	Weight of 1000-grain (g)
Mean square					
S	86.211	21.754	80.625	12.174	266.315
Q	0.611	19.736	0.579	18.698	122.822
F	3.145	1.101	2.638	0.791	274.979
S*Q	3.842	17.340	3.601	17.661	14.880
S*F	19.551	14.081	17.577	10.929	126.994
Q*F	6.443	5.581	6.146	2.452	26.308
S*Q*F	1.013	0.554	0.785	1.624	197.941
F value and probability					
S	101.90 *	9.267 *	106.74 *	5.886 *	64.930 *
Q	(0.722)	8.407 *	(0.766)	9.040 *	29.945 *
F	(3.717)	(0.469)	(3.492)	(0.382)	67.042 *
S*Q	4.541 *	7.386 *	4.767 *	8.539 *	(3.628)
S*F	23.108 *	5.998 *	23.269 *	5.284 *	30.962 *
Q*F	7.615 *	(2.377)	8.137 *	(1.185)	6.414 *
S*Q*F	(1.198)	(0.236)	(1.039)	(0.785)	48.260 *

(*) Significant at 5%, and (ns) is not significant.

(S) is the irrigating border slope, (Q) is the gate inflow rate, and (F) is the method of nitrogen application.

Improving water uniformity and application generally led to higher yields. The same results were reported by **Amer (2009) and Amer et al., (2017)**. The coefficient of variation (CV) for grain productivity along border was improved by increasing border slope. As a result of the rapid water movement over the irrigating border length, the results showed that the water consumption, the advance time of water, the recession time of water, and the depth of irrigation water were all decreased by increasing the irrigating border slope. Water productivity decreased by 4.10% and 4.61% at the gate inflow rates of 10.71 and 5.35 $m^3 h^{-1}$, respectively, as border slope increased from 0.05% to 0.10%. Based on the findings of this study, a border slope of 0.10% is advised for the cultivation of wheat. According to **Gomaa et al., (2019)**, these findings concur with their findings.

Results were significantly influenced by the gate inflow rate (Q), except for grain yield and TSS for grain. Results showed that grain yield, straw yield, TSS for grain and TSS for straw increased by decreasing inflow rate. Water use was decreased by 6.93 and 7.43% at the border slopes of 0.05 and 0.10%, respectively, as the gate inflow rate dropped from 10.71 to 5.35 $m^3 h^{-1}$. The reported results confirmed that the results of 0.05% border slope (S1) treatment showed that grain and straw productivity were increased by decreasing inflow rate with applying (N) when the water reached to the middle of the irrigating border (F2). Results of irrigating border slope of 0.10% (S2) treatment showed that, applying 10.71 $m^3 h^{-1}$ inflow rate (Q1) with first method of nitrogen application (F1) compared to the second methods of nitrogen application (F2), grain and straw productivity were increased, and the coefficient of variation (CV) for productivity along border was improved. On the other hand, applying the gate inflow rate of 5.35 $m^3 h^{-1}$ (Q2) with the second method of nitrogen application (F2) relative to the first method of nitrogen application (F1), the productivity of grain and straw were increased, and the variation coefficient (CV) for productivity along border was improved. According to the findings of this study, the gate inflow rate of 5.35 $m^3 h^{-1}$ is advised for wheat cultivation.

According to the study results, the results were not significantly impacted by the method of nitrogen application, except for 100-grain weight. Results showed that grain yield, straw yield, TSS for grain, TSS for straw and 1000-grain weight increased by applying the second method of nitrogen application (F2). According to the findings of this study, the second method of nitrogen application (when water reached to the middle of the irrigating border F2) is advised for wheat cultivation.

4. CONCLUSION

A field experiment was carried out at the Shebin El-Kom area, 17.9 m above sea level (30˚32/N, 31˚03/E). Clay loam was identified as the type of soil at the experimental site, with an average bulk density of 1.2 g/cm^3 at a depth of 0.6 m. The main goal of this work is to study two different gate inflow rates (Q) of 10.71 and 5.35 $m^3 h^{-1}$ and two methods of fertilizer application (F) under two different levels of irrigating border slopes (0.05 and 0.10 %) of the wheat crop to improve border irrigation method using gated pipes irrigation system. With a rate of 119 kg ha^{-1}, wheat seeds (Gemeza 11 variety) were planted using a seed drilling machine (with a 10 cm distance between the drilling tubes) on November 13 and terminated on April 23 and irrigated five times during the growing season. The outcomes of the study revealed the following conclusions:

1- The advance time of water, the recession time of water, and the depth of irrigation water all decreased as the irrigating border slope increased.

2- The advance time of water, the recession time of water, and the depth of irrigation water all decreased as the inflow rate dropped.

3- Distribution uniformity as well as distribution efficiency increased by increasing of border slope at 5.35 m^3 h^{-1} inflow rate; in contrary at 10.71 m^3 h^{-1} inflow rate.

4- Distribution uniformity (DU) and uniformity coefficient (UC) were increased by decreasing inflow rate.

5- Applying the nitrogen when water reached the middle of the irrigating border length (F2) increased the soil's nitrogen content in the plant root zone.

6- Grain yield, straw yield, TSS for grain, TSS for straw and 1000-grain weight significantly increased by increasing of border slope.

7- Grain yield, straw yield, TSS for grain and TSS for straw significantly increased by decreasing of inflow rate.

8- Grain yield, straw yield, TSS for grain, TSS for straw and 1000-grain weight increased by applying the nitrogen when the water reached to the middle of the irrigating border length (F2).

9- According to the findings of this study, 0.10% border slope (S2), 5.35 m^3 h^{-1} inflow rate (Q2) and applying nitrogen when the water reached to the middle of the irrigating border length (F2) are recommended for wheat cultivation.

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تأثير الري السطحي باستخدام نظام الأنابيب المبوبة على توزيع النتروجين وإنتاجية محصول القمح في الحيازات الصغيرة

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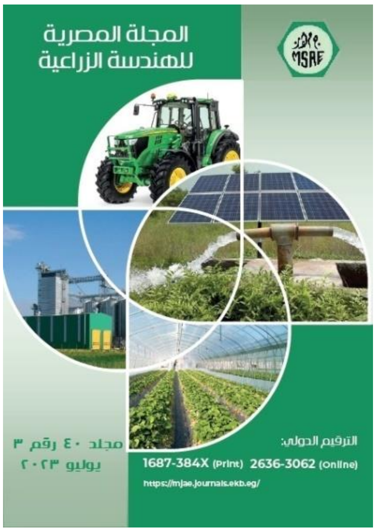

الكلمات المفتاحية:
الري السطحي؛ الأنابيب المبوبة؛ توزيع النتروجين؛ إنتاجية القمح.

الملخص العربي

تم إجراء التجربة بمزرعة كلية الزراعة جامعة المنوفية في تربة طينية طميية ذات كثافة ظاهرية ١,٢ جم/سم^{3}. الهدف من البحث هو تطبيق طريقة الري بالشرائح باستخدام نظام الأنابيب المبوبة بميلين لسطح التربة (٠,٠٥% - ٠,١٠%) وتصرفين للبوابة (١٠,٧١ – ٥,٣٥ م^{3}/ساعة) وطريقتين لإضافة السماد (إضافة السماد مع بداية نزول المياه للحقل – إضافة السماد بعد تقدم نصف الموجة). وتمت عملية زراعة القمح (Gemeza 11) باستخدام ألة الزراعة في سطور وبمعدل ١١٩ كجم/هكتار. وتم حصول محصول القمح على عدد خمس ريات اثناء موسم النمو. وكانت أهم النتائج:

١- بزيادة ميل الشريحة تزداد قيمة (CV) وتقل قيمة كل من (DU)، (UC) عند التصرف الأكبر وهو ١٠,٧١ م^{3}/ساعة بينما تقل قيمة (CV) وتزداد قيمة كل من (DU)، (UC) عند تصرف البوبة الأقل وهو ٥,٣٥ م^{3}/ساعة.
٢- متوسط المحتوى النيتروجينى بالتربة يزداد بتطبيق النيتروجين بعد وصول موجة المياه الى منتصف الشريحة.
٣- متوسط انتاجية كل من محصول الحبوب ومحصول القش والمواد الصلبة الذائبة للحبوب والمواد الصلبة الذائبة للقش ووزن ال ١٠٠٠ حبة يزداد بزيادة ميل الشريحة مع وجود فروق معنوية.
٤- متوسط انتاجية كل من محصول الحبوب ومحصول القش والمواد الصلبة الذائبة للحبوب والمواد الصلبة الذائبة للقش يزداد بانخفاض التصرف للبوبة مع وجود فروق معنوية.
٥- متوسط انتاجية كل من محصول الحبوب ومحصول القش والمواد الصلبة الذائبة للحبوب والمواد الصلبة الذائبة للقش ووزن ال ١٠٠٠ حبة يزداد بتطبيق السماد بعد تقدم نصف الموجة مع عدم وجود فروق معنوية.
٦- وبناءا على هذه النتائج توصى الدراسة بزراعة محصول القمح باستخدام ميل ٠,١٠% وتصرف ٥,٣٥ م^{3}/ساعة مع تطبيق السماد بعد وصول موجه المياه الى منتصف الشريحة.