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# Nitrate-N Leaching Losses into Field Tile Drains as Affected by Irrigation Regime and N-Fertilizer Doses in Clay Soil under Maize Plant

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## ABSTRACT

A field experiment was conducted at Sakha Res. Station, Kafr El-Sheihk Governorate during summer seasons (2017and 2018), to evaluate the effect of irrigation regime (i.e: traditional irrigation and cutoff irrigation when it reaches to 85% of furrow length) and applied N-fertilizer doses (one, two and three doses) on nitrate leaching losses into field tile drains in clay soil as well as productivity of irrigation water, yields and N-uptake of maize plant. The obtained results indicated that: Cutoff irrigation received the lowest amount of irrigation water and drain discharge rates. Cumulative amounts of drainage water were lower with cutoff irrigation than that observed under traditional irrigation. N-fertilizer application in two and three doses especially, with cutoff irrigation resulted in moderate increased of soil $NO_3^-$ content after every dose and slightly decreased after the followed irrigations while, one dose application resulted in the highest values of $NO_3^-$ content in the soil and rapidly decreased after the followed irrigations. N-fertilizers application in two or three doses resulted in decrease of nitrate concentration and losses in drainage water than the addition of one dose especially, under cutoff irrigation. The estimated losses of $NO_3^-$ or $N\text{-}NO^-_3$ in drainage water were increased when addition of N-fertilizer in one dose than two and three doses by 12.42 and 16.51% in the first season of study and 13.33 and 16.54 % in the second season, respectively under cutoff irrigation. The corresponding percentages were 19.02 and 22.04% in the first season and 19.12 and 22.88 % in the second season, respectively under traditional irrigation. N-fertilizer application in three and two does led to an increase in maize grains yield by about 14.84 and 10.59 % in the first season and 14.84 and 11.26 % in the second seasons, respectively as compared to one dose. Cutoff irrigation tends to increase maize grains yield by 2.44% in the first season and 2.13 % in the second season than traditional irrigation. The combination between irrigation and N-fertilizer doses data showed that, both irrigation treatments with addition of N-fertilizer in three doses resulted in relatively higher yield of maize (3470 kgfed.$^{-1}$) followed by two doses (3318 kgfed.$^{-1}$, ) while, the addition of N-fertilizer in one dose with both irrigation treatments resulted in relatively low yields (2955 kgfed.$^{-1}$). The higher values of N-uptake and productivity of irrigation water for maize yields were found with cutoff irrigation with three doses in both seasons of study and the lower values were obtained with traditional irrigation with one dose.

**Keywords:** Clay soils, Drainage, Irrigation regime, irrigation productivity, N-fertilizer, Nitrate leaching, maize yield

## INTRODUCTION

Subsurface drainage is important for agricultural production, but nitrate-N concentrations in drain effluent often exceed the 10 mg/L,which is the maximum contaminant level set by the Environmental Protection Agency for drinking water. Nitrate contamination of tile drainage water with intensive agricultural production systems has become a serious environmental and economic concern. Drain effluent may increase the nitrate-N concentration of the outlet water body, increasing the health hazard if the water body is used as a drinking water source (Bjorneberg *et al.,* 1996, Kladivko *et al*., 2004 and 2010). Nitrate transport, however, occurs throughout the season, and the major mass losses occur when the majority of the water flow occurs (Ibrahim *et al*. 2003, Antar 2007, Ramadan *et al*.2009, Maija *et al*. 2012 and El-Hawary 2012).

Farmers growing different crops in the Mediterranean areas traditionally apply high rates of both water and nitrogen fertilizers. It is difficult to maintain the balance of available nitrogen required satisfying crop needs and the same time minimizing leaching losses, even though fertilizers combined with soil mineralization can provide large amounts of inorganic nitrogen. The use of an excessive amount of nitrogen fertilizers increase the partially leach nitrate. Leaching occurs if an excess of water flow through drainage system. The leaching losses of nitrate-N from the root zone can be affected by the concentrations of $NO_3$-N in the soil profile at the time of percolation of water from the root zone. The time between supply of the available form of nitrogen in the soil and plant uptake of N can affect the leaching of $NO_3$-N (Bakhsh *et al*., 2002 and Ramadan *et al*.2009). The considerable variation in $NO_3^-$concentration in drainage water may be ascribed to several factors including soil properties, amount of irrigation water, temperature of the air and evaporation rates, drainage system, forms and rate of applied fertilizers, uptake by growing plants and adsorption and fixation of $NH^+_4$ on the 2: 1 type clay minerals ((Nasseem, 1991, Dinnes *et al*., 2002, Bakhsh *et al*., 2002 and Ramadan *et al*.2009). Also, Gheysari *et al*., (2009) indicated that the movement of nitrate out of the root zone depends on the soil hydraulic properties, the amount of irrigation, nitrogen applied, the nitrogen form and time application. Several researchers have monitored tile drain flows to study nutrients losses from different agricultural management practices (Drury *et al*., 1996; Bakhsh *et al*., 2002; Ibrahim *et al*., 2003; Antar 2007; Ramadan *et al*., 2009; Kladivko *et al*., 2010; Maija *et al*. 2012 and El-Hawary 2012). Sexton *et al*. (1996) found that N losses by leaching were 30 and 78 kg /ha/year with rates of fertilizer N of 100 and 180 kg ha$^{-1}$year$^{-1}$, respectively. Milburn and Richard (1994) and Bjorneberg *et al*. (1996) reported that 50%to 85% of the annual drain flow and 45% to 85% of the annual $NO^-_3$-N losses occurred when crops were not actively growing. Bakhsh *et al*. (2002) and Bjorneberg *et al*. (1998) showed a high correlation ($R^2$=0.89) between annual subsurface drainage flow volume and the annual $NO_3$-N leaching losses with subsurface drainage water.

Maize crop is one of the food crops that have several uses, whether as a food for man or as animal feed, due to its high nutrition value. Also, maize enters in the process of manufacturing some important products such as corn oil, fructose and starch.

Controlled of irrigation and fertilizers studies can therefore be useful in reducing $NO_3$-N leaching losses and consequentially improving surface and groundwater quality. The objectives of the present work were to evaluate the effect of irrigation (without cutoff irrigation and cutoff irrigation at 85% from furrow length) and applied of N-fertilizer (one, two and three doses as urea) on nitrate leaching losses into field tile drains in clay soils as well as yields and uptake of maize plant.

## MATERIALS AND METHODS

### 1- Field experiment and location:

A field experiment was conducted at the Experimental Farm of Sakha Agric. Res. Station Kafr El-Sheihk Governorate during two summer growing seasons (2017and 2018), to evaluate the effect of applying two irrigation regimes (without cutoff irrigation and cutoff irrigation when it reaches to 85% of furrow length) and applied N-fertilizer doses (one, two and three doses) on nitrate leaching losses into field tile drains in clay soils as well as yield and N-uptake of maize plant. The location is situated at 31°07′ 33″ N latitude and 30°57′ 53″ E longitude. The tile drains were spaced at 20 m between drains, 1.2 m depth and 100-m length with a slope of 0.1%. The field was plowed with moldboard plow to a depth of 20 cm. The soil has a clayey texture, The initial of some soil properties for the experimental field are presented in Table (1).

**Table 1. Some soil chemical and physical properties of the experimental field.**

| Soil depth (cm) | Particle size distribution% | | | Texture grade | Bulk density $gcm^{-3}$ | EC ($dSm^{-1}$) | CEC Meq/ 100g soil | PH | OM (%) | Nitrate (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sand | Silt | Clay | | | | | | | |
| 0—15 | 16.35 | 30.32 | 53.33 | Clay | 1.12 | 2.36 | 43.87 | 8.11 | 2.12 | 29 |
| 15—30 | 17.52 | 31.58 | 50.90 | Clay | 1.21 | 2.77 | 39.95 | 8.09 | 1.24 | 21 |
| 30—60 | 15.78 | 33.41 | 50.81 | Clay | 1.26 | 2.81 | 37.18 | 8.13 | 0.78 | 14 |

**EC-soil salinity, OM-Organic matter,**

### 2- Experimental treatments and field measurements

The experiment was conducted in two ways randomizes block design as follows:

1- Cutoff irrigation at 85 % from furrow length with N-fertilizer one dose
2- Cutoff irrigation at 85 % from furrow length with N-fertilizer two doses.
3- Cutoff irrigation at 85 % from furrow length with N-fertilizer three doses
4- Traditional irrigation without cutoff with N-fertilizer one dose
5- Traditional irrigation without cutoff with N-fertilizer two doses
6- Traditional irrigation without cutoff with N-fertilizer three doses

Seeds of maize (*Zea maize*), Single Pioneer Hybrid No. 10, were planted on June 12, 2017 and June 15, 2018. All plots received 50 kg/fed Ca-superphosphate (15.5% $P_2O_5$) during tillage operation, and 120 kg N/fed.(Urea 46.5% N) was applied in one dose (before the first irrigation), two doses (before the first and second irrigation) and three doses (before first, second and third irrigation). The different agricultural practices were done as recommended through the two growing seasons.

Drain discharge rates were manually measured two times per day when drain flow occurred, using bucket and stop watch method (ILRI, 1974 ) . Moreover the amounts of drainage water $m^3fed^{-1}$ are estimated. Water samples from tile drains were collected at different times of the day then, composite daily drainage water samples were taken for analysis. The drainage water samples were analyzed for $NO^-_3$. Also disturbed soil samples were taken to a depth of 0.6 m, before cultivation, after the first and second irrigations and at the end of growing seasons. Soil and water samples were analyzed for $NO^-_3$ using Kjeldahl method according to (Cottenie *et al*., 1982). The maize was harvested at the end of the season then maize grain and straw yields were determined. Grain and straw samples of maize were taken and dried at 70$^o$C, grounded with a mill and its Nitrogen content (as $NO^-_3$) was determined using Kjeldahl digestion (Cottenie *et al*., 1982). N-uptake (kg $fed^{-1}$) was calculated by multiplying dry yield (kg $fed^{-1}$) by N % (N content in percentage either for grain and straw).

### 3- Applied irrigation water:

Irrigation water was measured by using a rectangular sharp crested weir. The discharge was calculated using the following equation as described by (Masoud, 1969).

$$Q = CL (H)^{1.5}$$

**Where:**

**Q = Discharge ($m^3s^{-1}$)**
**L = Length of the crest (m).**
**H = Head above the weir (m).**
**C= Empirical coefficient determined from discharge measurement.**

### 4 -Productivity of irrigation water (PIW, $kgm^{-3}$)

Productivity of irrigation water is generally defined as crop yield per cubic meter of water and it is calculated according to Ali *et al*., (2007) as follows:

$$PIW = Gy/WA$$

**Where:**

**Gy= Grain and straw yields, kg $fed.^{-1}$, WA= Water applied, $m^3$ $fed.^{-1}$**

Data for grains and straw yields of maize were recorded and were subjected to statistical analysis by ANOVA technique according to Sendecor and Cochran (1980).Treatments were compared by Duncan's multiple range test (Duncan, 1955).

## RESULTS AND DISCUSSION

### 1- Amounts of applied irrigation water ($m^3fed.^{-1}$):

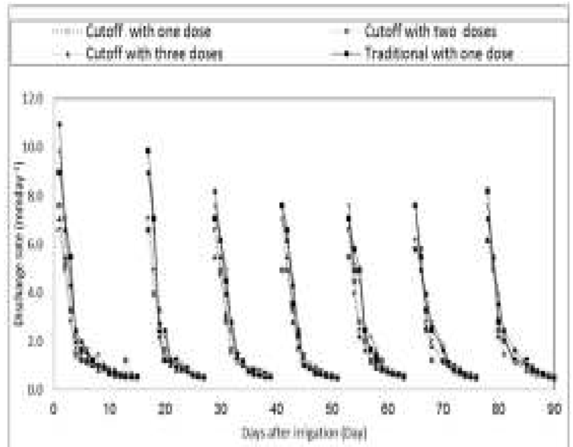
Data presented in Table (2) indicated that, planting irrigation received the highest amounts of irrigation water compared to other irrigations. Also, the amounts of planting irrigation were nearly the same for all treatments. Data also, indicated that, cutoff irrigation at 85 % from furrow length received the lowest amount of irrigation water compared to traditional irrigation without cutoff. This is due to, increasing irrigation period under traditional irrigation without cutoff. Irrigation water amount nearly the same in both seasons. The values of total applied irrigation water varied from 2572 to 2592 $m^3fed.^{-1}$ for cutoff irrigation treatments and from 3050 to 3068$m^3fed.^{-1}$ for traditional irrigation treatments in both season seasons. Also, data showed that doses of nitrogen fertilizer had no effect on amount of irrigation water for both seasons.

**Table 2.Amount of irrigation water applied ($m^3$fed) through six irrigation cycle for different treatments.**

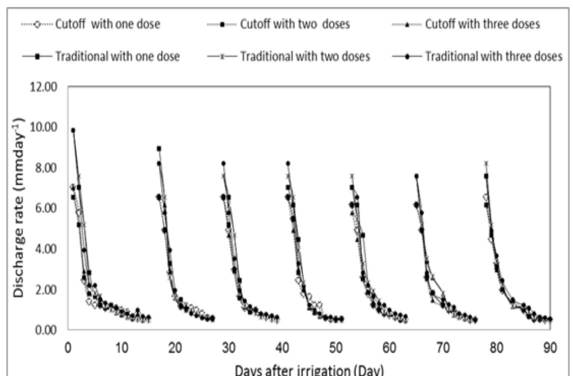
| Treatments | Amounts of applied irrigation water ( $m^3fed^{-1}$) for different irrigation no. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Planting irr. | 1 | 2 | 3 | 4 | 5 | 6 | Total |
| First season | | | | | | | | |
| Cutoff with one dose | 592 | 356 | 328 | 318 | 318 | 337 | 337 | 2585 |
| Cutoff with two doses | 590 | 356 | 335 | 324 | 318 | 336 | 314 | 2572 |
| Cutoff with three doses | 590 | 354 | 331 | 331 | 331 | 306 | 331 | 2573 |
| Traditional with one dose | 581 | 425 | 413 | 401 | 413 | 402 | 413 | 3050 |
| Traditional with two doses | 587 | 425 | 413 | 413 | 413 | 402 | 413 | 3067 |
| Traditional with three doses | 581 | 423 | 411 | 413 | 411 | 414 | 411 | 3064 |
| Second season | | | | | | | | |
| Cutoff with one dose | 586 | 356 | 335 | 328 | 337 | 328 | 324 | 2592 |
| Cutoff with two doses | 586 | 356 | 318 | 337 | 324 | 324 | 335 | 2579 |
| Cutoff with three doses | 584 | 342 | 331 | 331 | 328 | 328 | 335 | 2579 |
| Traditional with one dose | 579 | 420 | 413 | 416 | 413 | 414 | 413 | 3068 |
| Traditional with two doses | 584 | 425 | 413 | 413 | 413 | 402 | 413 | 3065 |
| Traditional with three doses | 587 | 416 | 413 | 413 | 411 | 414 | 413 | 3067 |

### 2- Drain discharge rate (mm $day^{-1}$) and drainage water amounts ($m^3$ $fed^{-1}$)

Data presented in Figs (1 and 2) shows that, the drain discharge was decreased with time especially in the first few days after all irrigation cycles. Drain discharge rates varied from 6.56 to 10.93 mm $day^{-1}$ after one day from irrigations and from 0.49 to 0.67 mm $day^{-1}$ before the next irrigation in both seasons, these results could be explained as Antar (2007) and Ramadan *et al*.(2009) indicated that in clay soil, the majority of discharge water is from water movement through soil cracks and macro pores. The water flow decreases sharply when the clay swells after a few days of irrigation. Data also showed that, the drain discharge rates (mm $day^{-1}$) were higher with traditional irrigation (varied from 0.49 to 10.93 mm $day^{-1}$) than with cutoff irrigation (varied from 0.49 to 7.57 mm $day^{-1}$) in both seasons. Data in Table (3) showed that the cumulative drainage water amounts ($m^3fed.^{-1}$) through planting irrigation nearly the same values for all treatments and were higher compared to irrigation ones. Also, these amounts of drainage water with traditional irrigation were higher than with cutoff irrigation for all irrigation cycles in both seasons. Total cumulative drainage water amounts throughout the irrigation cycles of maize growing season varied from 646 to 659 $m^3fed.^{-1}$ with an average of 653 $m^3fed.^{-1}$ for cutoff irrigation treatments while, from 782 to 791 $m^3fed.^{-1}$ with an average of 787 $m^3fed.^{-1}$ for traditional irrigation in both seasons. This is due to high amount of irrigation water with traditional irrigation compared to cutoff irrigation (Table 2). N-fertilizer doses do not effect on total cumulative drain discharge throughout the irrigation cycles of maize growing season in both seasons.




Fig(1). Drain discharge rate (mm day-1) after irrigation with treatments of study under maize plant through first season




Fig(2). Drain discharge rate (mm day-1) after irrigation with treatments of study under maize plant through second season

**Table 3. Cumulative amounts of drainage water ($m^3fed.^{-1}$) for five irrigation cycles under different treatments**

| Treatments | amounts of drainage water ($m^3fed.^{-1}$) for different irrigations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Planting irri. | First irri. | Second irri. | Third irri. | Fourth irri. | Fifth irri. | sixth irri. | Total |
| First season | | | | | | | | |
| Cutoff with one dose | 109.9 | 91.8 | 88.8 | 90.8 | 86.9 | 89.5 | 88.8 | 646 |
| Cutoff with two doses | 111.9 | 88.9 | 91.7 | 89.8 | 89.6 | 88.4 | 89.2 | 650 |
| Cutoff with three doses | 110.2 | 91.3 | 91.7 | 93.0 | 88.8 | 89.8 | 85.6 | 650 |
| Traditional with one dose | 141.4 | 111.4 | 109.1 | 104.5 | 111.4 | 103.8 | 100.7 | 782 |
| Traditional with two doses | 143.4 | 109.5 | 111.6 | 106.0 | 112.5 | 103.2 | 102.5 | 789 |
| Traditional with three doses | 144.4 | 111.5 | 112.7 | 106.3 | 109.0 | 104.0 | 102.5 | 791 |
| Second season | | | | | | | | |
| Cutoff with one dose | 111.7 | 93.5 | 90.7 | 94.8 | 87.9 | 87.7 | 90.1 | 656 |
| Cutoff with two doses | 110.8 | 92.5 | 91.0 | 91.8 | 93.1 | 88.1 | 88.3 | 756 |
| Cutoff with three doses | 112.2 | 96.6 | 88.3 | 91.2 | 87.4 | 93.9 | 89.4 | 659 |
| Traditional with one dose | 146.8 | 110.1 | 113.1 | 105.1 | 110.1 | 103.2 | 99.8 | 788 |
| Traditional with two doses | 147.5 | 104.8 | 109.7 | 107.5 | 107.4 | 104.5 | 103.6 | 785 |
| Traditional with three doses | 147.4 | 106.9 | 109.3 | 105.2 | 109.1 | 103.6 | 105.3 | 787 |

**3- Nitrate in soil**

Data in Table (4) show that $NO_3^-$ content of the soil was decreased markedly with the soil depth in both growing seasons. This may be due to the relatively high content of organic matter (OM) which decreased gradually with the depth and due to the addition of mineral N-fertilizers on the soil surface. Data also showed that, $NO_3^-$ contents of the soil before fertilizer application were low and varied from 15 to 29 ppm and increased after fertilizer application in both seasons. Data also showed that, the contents of $NO_3^-$ were reduced at the end of the seasons due to rapid N-uptake by plants after irrigation directly where the soil water tension is very low. Similar results were obtained by Ibrahim *et al*., (2003) and Antar, (2007 and 2013).

Data also showed that, $NO_3^-$ content of the soil after N-fertilizer application, in both seasons were higher to some degree with cutoff irrigation at 85 % from furrow length (varied from 26 to 77 ppm) than with traditional irrigation (varied from 21 to 69 ppm). This may be explained on the basis of cutoff irrigation which causes a decrease in drainage water (Table, 3) and consequently, increase in the amounts of nutrient in soil solution.

Whereas, cutoff irrigation at 85 % from furrow length improves irrigation efficiency and were reduces the potential for nutrient loss through better irrigation and runoff control.

Data (Table, 4) also showed that, the addition of N-fertilizer as one dose (after first irrigation) resulted in the highest values (ranged from 31 to 77 ppm) of $NO_3^-$ content in the soil and rapidly decreased after followed irrigations. While, the addition of N-fertilizer as two and three doses (after first and second irrigations with two doses and first, second and third irrigations for three doses) resulted in moderate increased (ranged from 25 to 55 ppm) of soil $NO_3^-$ content after every dose and slightly decreased after followed irrigations. On the opposite, at the end of seasons the higher values of $NO_3^-$ content in soil were observed with addition of N-fertilizer as three doses followed by two doses while, the lowest values were observed with one dose. The overall mean values of soil $NO_3^-$ content at the end of seasons were 19.0, 23.2 and 29.5 ppm for N-fertilizer of one, two and three doses, respectively under cut off irrigation. The corresponding values were 17.0, 20.4 and 25.8 ppm, respectively with traditional irrigation.

**Table 4. $NO_3^-$ concentration (ppm) at different soil depths before cultivation, after first, second and third irrigations and at harvesting for all treatments through both seasons.**

| Treatments | Soil depth (cm) | First season: Before cultivation | After 1st I | After 2nd I | After 3rd I | At harvest | Second season: Before cultivation | After 1st I | After 2nd I | After 3rd I | At harvest |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cutoff with one dose | 0-15 | 29 | 77 | 55 | 44 | 23 | 24 | 76 | 56 | 45 | 22 |
| | 15-30 | 20 | 55 | 48 | 35 | 19 | 19 | 56 | 48 | 36 | 18 |
| | 30-60 | 15 | 34 | 30 | 26 | 16 | 16 | 35 | 31 | 27 | 16 |
| Average | | 21.3 | 55.3 | 44.3 | 35.0 | 19.3 | 19.7 | 55.7 | 45.0 | 36.0 | 18.7 |
| Cutoff with two doses | 0-15 | 28 | 52 | 55 | 45 | 30 | 23 | 53 | 55 | 44 | 29 |
| | 15-30 | 19 | 47 | 49 | 40 | 21 | 20 | 46 | 50 | 40 | 22 |
| | 30-60 | 16 | 39 | 41 | 36 | 19 | 16 | 40 | 40 | 37 | 18 |
| Average | | 21.0 | 46.0 | 48.3 | 40.3 | 23.3 | 19.7 | 46.3 | 48.3 | 40.3 | 23.0 |
| Cutoff with three doses | 0-15 | 28 | 45 | 50 | 55 | 33 | 24 | 44 | 50 | 54 | 30 |
| | 15-30 | 19 | 32 | 44 | 47 | 32 | 19 | 33 | 43 | 46 | 29 |
| | 30-60 | 15 | 29 | 36 | 39 | 27 | 17 | 29 | 37 | 38 | 26 |
| Average | | 20.7 | 35.3 | 43.3 | 47.0 | 30.7 | 20.0 | 35.3 | 43.3 | 46.0 | 28.3 |
| Traditional with one dose | 0-15 | 29 | 69 | 50 | 40 | 20 | 24 | 67 | 49 | 40 | 19 |
| | 15-30 | 19 | 50 | 45 | 31 | 17 | 20 | 49 | 46 | 30 | 16 |
| | 30-60 | 16 | 31 | 27 | 22 | 15 | 16 | 30 | 28 | 21 | 15 |
| Average | | 21.3 | 50.0 | 40.7 | 31.0 | 17.3 | 20.0 | 48.7 | 41.0 | 30.3 | 16.7 |
| Traditional with two doses | 0-15 | 28 | 49 | 51 | 41 | 27 | 24 | 47 | 52 | 40 | 26 |
| | 15-30 | 18 | 44 | 43 | 39 | 19 | 20 | 42 | 44 | 38 | 19 |
| | 30-60 | 16 | 34 | 37 | 32 | 16 | 15 | 33 | 36 | 31 | 15 |
| Average | | 20.7 | 42.3 | 43.7 | 37.3 | 20.7 | 19.7 | 40.7 | 44.0 | 36.3 | 20.0 |
| Traditional with three doses | 0-15 | 28 | 41 | 46 | 49 | 31 | 25 | 40 | 46 | 48 | 30 |
| | 15-30 | 20 | 30 | 42 | 42 | 27 | 18 | 31 | 40 | 43 | 26 |
| | 30-60 | 16 | 26 | 30 | 34 | 21 | 16 | 25 | 31 | 35 | 20 |
| | | 21.3 | 32.3 | 39.3 | 41.7 | 26.3 | 19.7 | 32.0 | 39.0 | 42.0 | 25.3 |

**I = irrigation**

**4- Nitrate in drainage water:**

Concentrations of nitrate in drainage water during the two growing seasons (Figs 3 and 4) were ranged from 13 to 98 ppm. These concentrations before fertilizer application (Through planting irrigation) varied from 13 to 20 ppm. $NO_3^-$ concentration in drainage water was increased after fertilizer application (after first irrigation with one dose, first and second irrigations with two doses and first, second and third irrigations for three doses of N-fertilizer) and reduced again through the latest irrigations. These results revealed clearly that the $NO_3^-$ concentrations in drainage water were paralleled to the $NO_3^-$ content of the soil through both seasons. The increase in $NO_3^-$ concentrations after fertilizer application can be explained on the base of the addition of N-fertilizer before the first, the second and the third irrigations. Also, the decrease losses of $NO_3^-$ under the latest irrigations with all fertilizers treatments, may be attributed either to the decrease of N concentration in the soil solution and/or to the increasing demand of maize plant of N during this growth stage. Similar results were obtained by Ramadan *et al*. (2004 and 2009), Maija *et al*. (2012) and Antar, (2007 and 2013).

Data illustrated in Figures (3 and 4) also indicated that the high concentrations of nitrate in drainage water were recorded under addition of N-fertilizer as one dose especially, with traditional irrigation. One the other hand, N-fertilizer application in two and three doses resulted in decrease of nitrate concentration in drainage water especially, under cut off irrigation. Generally, nitrate concentrations in drainage water under cutoff irrigation were recorded somewhat lower values as compared to traditional irrigation. The average values of $NO_3^-$ concentrations throughout the maize growing season (Table, 4) were 37.0, 32.3 and 30.7 ppm in the first season and 36.6, 31.7 and 30.4ppm in the second season for N-fertilizer one, two and three doses, respectively under cut off irrigation. The corresponding values were 42.4, 34.1 and 32.7 ppm in the first season and were 42.3, 34.4 and 32.7ppm in the second season, respectively with traditional irrigation. In this concern, Kladivko *et al*. (1991) stated that nitrate concentrations in tile drainage water were usually >10 ppm. Similar results were obtained by Ramadan and El-Leithi, (1999) and Ibrahim *et al*. (2003).

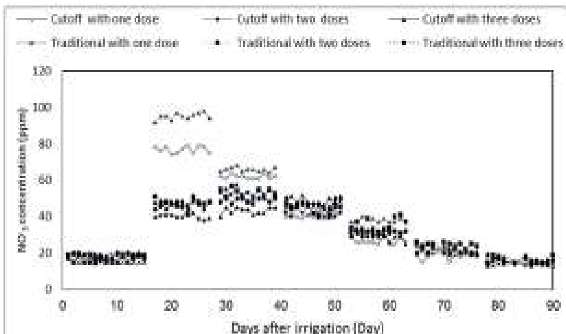
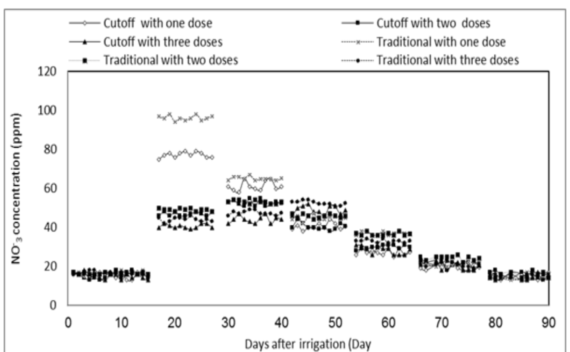



Fig (3). $NO_3^-$ concentration (ppm) in drainage water for irrigation cycles with treatments of study under maize plant through the first season




Fig(4). $NO_3^-$ concentration (ppm) in drainage water for irrigation cycles with treatments of study under maize plant through the second season

**5- Total losses of nitrogen via drainage water:**

Data in Table (5) show the total estimated amount of nitrogen losses as influenced by N-fertilizer doses under cutoff irrigation at 85 % from furrow length and traditional irrigation without cutoff. The addition of N-fertilizers as two and three doses are more pronounced on reducing nitrogen losses especially, under cutoff irrigation. Whereas, the highest values of nitrogen losses were found with addition of N-fertilizer as one dose especially, under traditional irrigation. The average values of NO3- losses were 23.92, 20.95 and 19.97 kg $fed^{-1}$ in the first season and were 24.02, 20.81 and 20.04 kg $fed^{-1}$ in the second season for one, two and three doses of N-fertilizer, respectively under cutoff irrigation. The corresponding values under traditional irrigation were 33.16, 26.85 and 25.85kg $fed^{-1}$ in the first season and 33.37, 26.99 and 25.73 kg $fed^{-1}$ in the second season, respectively. Also the estimated losses of N-$NO^-_3$ in drainage water were increased when addition of N-fertilizer as one dose compared to two and three doses, respectively by 12.42 and 16.51% in the first season and 13.33 and 16.54 % in the second season under cutoff irrigation. The corresponding percentages were 19.02 and 22.04% in the first season and 19.12 and 22.88 % in the second season, respectively under traditional irrigation. The addition of N-fertilizer as two or three doses caused decrease of $NO_3^-$-N losses than the addition of one dose. The leaching losses of nitrate-N from the root zone can be affected by the concentrations of $NO_3$-N in the soil profile at the time of percolation of water from the root zone. The time between supply of the available form of nitrogen to the soil and plant uptake of N can affect the leaching of NO3-N (Bakhsh *et al*., 2002, Ramadan *et al*.2004 and Antaer 2013). In this concern, Sexton *et al*. (1996) found that N losses by leaching were 30 and 78 kg /ha/year with rates of fertilizer N of 100 and 180 kg $ha^{-1}year^{-1}$, respectively.

Data also (Table 5) show the nitrogen losses in drainage water under cutoff irrigation were recorded somewhat lower values as compared to traditional irrigation. The average values of $NO^-_3$ losses in drainage water throughout maize growing season varied from 19.97 to 24.02 kg $fed.^{-1}$ for cutoff irrigation while, from 25.73 to 33.37 $kgfed.^{-1}$ for traditional irrigation in both seasons. This could be due to the control of water distribution with negligible water losses under cutoff irrigation. Also, these decrements in losses of nitrogen under cutoff irrigation could be attributed to that under traditional irrigation, the chance for more leaching downward for both water and its load of fertilizers could be happened. In this concern, Bjorneberg *et al*. (1998) and Bakhsh *et al*. (2002) showed a high correlation ($R^2$=0.89) between annual subsurface drainage flow volume and the annual $NO_3^-$-N leaching losses with subsurface drainage water.

**Table 5. Nitrogen losses into drainage water through six irrigation cycle under different treatments.**

| Season | Treatments | Drainage water amounts( $m^3fed^{-1}$) | NO3 ppm | $NO^-_3$ kg | N-$NO^-_3$ kg |
|---|---|---|---|---|---|
| First season | Cutoff with one dose | 646.45 | 37.01 | 23.92 | 5.402 |
| | Cutoff with two dose | 649.51 | 32.26 | 20.95 | 4.731 |
| | Cutoff with three dose | 650.41 | 30.71 | 19.97 | 4.510 |
| | Traditional with one dose | 782.33 | 42.38 | 33.16 | 7.487 |
| | Traditional with two dose | 788.69 | 34.04 | 26.85 | 6.063 |
| | Traditional with three dose | 790.54 | 32.70 | 25.85 | 5.837 |
| Second season | Cutoff with one dose | 656.44 | 36.59 | 24.02 | 5.423 |
| | Cutoff with two dose | 655.74 | 31.74 | 20.81 | 4.700 |
| | Cutoff with three dose | 659.17 | 30.41 | 20.04 | 4.526 |
| | Traditional with one dose | 788.12 | 42.34 | 33.37 | 7.535 |
| | Traditional with two dose | 785.04 | 34.38 | 26.99 | 6.094 |
| | Traditional with three dose | 786.68 | 32.71 | 25.73 | 5.811 |

### 6- Maize yield and N-uptake:

Data presented in Table (6) showed that there were significant differences in maize grains yield between fertilizer doses treatments as well as irrigation treatments. Results showed that, cutoff irrigation at 85 % from furrow length achieved favorable effects in the maize yields. Whereas, maize grains yield were decreased under traditional irrigation than cutoff irrigation by 2.44 and 2.13 % for the first and the second seasons, respectively. These decrements in production of maize yield could be attributed to that under traditional irrigation which received high irrigation water; the chance for more leaching downward for both water and its load of fertilizers could be happened. On the other hand, under cutoff irrigation which accompanied with less water content, more energy is forced to extract more water with its content of fertilizers, which in turn resulted in decreasing the withdrawn of fertilizers. Similar results were obtained by El-Hamdi and Knany (2000).

Results also, showed that, the addition of N-fertilizer as three doses was superior to two doses as well as the addition of N-fertilizer as two doses was better than the addition as one dose in enhancing maize yields. Whereas, the addition of N-fertilizer as three and two does were increased of maize grains yield by about 14.84 and 10.59 % in the first season and 14.84 and 11.26 % in the second seasons, respectively as compared to the addition of N-fertilizer as one dose. Data also, sowed that, slightly effects were realized in maize straw yield for all treatments.

The combination between irrigation and N-fertilizer doses data showed that, cutoff irrigation at 85 % from furrow length or traditional irrigation with addition of N-fertilizer as three doses resulted in high yields (3470 kgfed.$^{-1}$, overall mean) of maize followed by N-fertilizer as two doses(3318 kgfed.$^{-1}$, overall mean) with both irrigation treatments and both seasons. While, the addition of N-fertilizer as one dose with both irrigation treatments resulted in low yields (2955 kgfed.$^{-1}$, overall mean) of maize.

**Table 6. Grains and straw yields (kg fed$^{-1}$) of maize plant for different treatments in the first and second seasons.**

| Treatments | yield (Kg fed$^{-1}$) | | | |
|---|---|---|---|---|
| | First season | | Second season | |
| | Grains | Straw | Grains | Straw |
| Cutoff with one dose | 2990e | 2510 | 2980e | 2520 |
| Cutoff with two doses | 3350bc | 2570 | 3370bc | 2530 |
| Cutoff with three doses | 3510a | 2560 | 3510a | 2520 |
| Traditional with one dose | 2920e | 2515 | 2930e | 2510 |
| Traditional with two doses | 3260c | 2570 | 3290c | 2550 |
| Traditional with three doses | 3430ab | 2540 | 3430ab | 2530 |
| F test- interaction | * | ns | * | Ns |
| LSD 0.05% | 97.76 | | 96.23 | |
| Mean-cutoff | 3283a | 2547 | 3287a | 2523 |
| Mean traditional | 3203b | 2542 | 3217b | 2530 |
| F test- irrigation | ** | ns | ** | Ns |
| LSD 0.05% | 32.49 | | 26.92 | |
| Mean-one dose | 2955c | 2513b | 2955c | 2515 |
| Mean-two doses | 3305b | 2570a | 3330b | 2540 |
| Mean-three doses | 3470a | 2550ab | 3470a | 2525 |
| F test- N-fertilizer | ** | * | ** | Ns |
| LSD 0.05% | 39.79 | 39.0 | 32.97 | |

Data in Table (7) showed that, N-uptake by maize were parallel to the yields results in both seasons. Whereas, treatments application caused significant increases of N-uptake of maize grains yield. Results showed that, cutoff irrigation at 85 % from furrow length achieved favorable effects in N-uptake of maize grains yield. N-uptake by maize grains yield were decreased under traditional irrigation than cutoff irrigation by 2.68 and 2.80kg fed$^{-1}$ for the first and the second seasons, respectively. The reduction of N-uptake by maize could be attributed to that under cutoff irrigation which accompanied with less water content, more energy is forced to extract more water with its content of fertilizers, which in turn resulted in decreasing the withdrawn of fertilizers. Similar results were obtained by El-Hamdi and Knany (2000).

Data Table (7) showed that, the addition of N-fertilizer in two or three doses was more pronounced on increasing N-uptake by maize grain yield as compared to one dose application. The addition of N-fertilizer as three and two doses were increased of N-uptake by maize grain yield by 16.48 and 9.58 kg fed$^{-1}$ in the first season and 14.45 and 8.62 kg fed$^{-1}$ in the second seasons, respectively as compared to the addition of N-fertilizer as one dose. Data also, showed that, slightly effects were realized in increasing N-uptake by straw yield of maize with addition of N-fertilizer as three or two doses.

Data showed that, the high values of N-uptake by grains of maize were observed with the combination between N-fertilizer as three doses under both irrigations treatments, followed by N-fertilizer as two doses and the low values were found with N-fertilizer as one dose under both irrigations treatments in both seasons. The overall mean values (two seasons) of N-uptake by maize grain yield were 72.84, 66.53 and 56.87 kg fed-1 for cutoff with three doses, cutoff with two doses and cutoff with one dose and 69.80, 63.37 and 54.84 kg fed.-1, for traditional irrigation with three doses, traditional with two doses and traditional with two doses respectively. In generally, the high values of N-uptake by maize plant with N-fertilizer as three or two doses under both irrigations especially, cutoff irrigation may be due to the reduction of N losses with this treatments comparing with others and consequently increasing available N in the soil. Similar results were obtained by Antar, (2013).

### 7 -Productivity of irrigation water (PIW, kg m$^{-3}$)

Data are presented in Table (8) showed that the values of PIW for maize grain and straw yields were greatly varied for different treatments in both seasons. Results in Table (8) revealed that, the low values of PIW for grain yield (0.95 and 0.96 kg m$^{-3}$ for the first and second seasons, respectively) were found with traditional with one dose, and the high values (13.0 kg m$^{-3}$ for both season) were found with cutoff with three doses in both seasons. With respect to PIW for maize straw yield, data showed that values of PIW were ranged from 0.97 to 1.0 kg m$^{-3}$ with cutoff irrigation at 85 % from furrow length, while the corresponding values of PIW ranged from 0.82 to 0.84 kg m$^{-3}$ with traditional irrigation without cutoff.

Data also (Table 8) showed that, productivity of irrigation water for maize grain and straw yields, were higher with cutoff irrigation at 85 % from furrow length than with traditional irrigation. This is due to the less amount of irrigation water with cutoff irrigation at 85 % from furrow length compared to traditional irrigation without cutoff.

**Table 7. N-uptake (kg $fed^{-1}$) by grain and straw of maize plant for the different treatments in the first and second seasons.**

| Treatments | N-uptake (kg $fed^{-1}$) | | | |
|---|---|---|---|---|
| | First season | | Second season | |
| | Grains | Straw | Grains | Straw |
| Cutoff with one dose | 56.81 c | 26.36 | 56.92 c | 24.7 |
| Cutoff with two doses | 66.67 b | 28.27 | 66.39 ab | 27.58 |
| Cutoff with three doses | 73.71 a | 29.7 | 71.96 a | 28.22 |
| Traditional with one dose | 54.6 c | 25.4 | 55.08 c | 24.85 |
| Traditional with two doses | 63.9 b | 27.76 | 62.84 b | 27.54 |
| Traditional with three doses | 70.66 a | 28.7 | 68.94 a | 28.34 |
| F test- interaction | * | ns | * | Ns |
| LSD 0.05% | 3.21 | | 3.62 | |
| Mean-cutoff | 65.73a | 28.11a | 65.09a | 26.83a |
| Mean traditional | 63.05b | 27.29b | 62.29b | 26.91a |
| F test- irrigation | ** | ** | ** | ns |
| LSD 0.05% | 0.641 | 0.34 | 0.527 | |
| Mean-one dose | 55.71c | 25.88c | 56.00c | 24.78c |
| Mean-two doses | 65.29b | 28.02b | 64.62b | 27.56b |
| Mean-three doses | 72.19a | 29.20a | 70.45a | 28.28a |
| F test- N-fertilizer | ** | ** | ** | ** |
| LSD 0.05% | 0.785 | 0.428 | 0.646 | 0.659 |

**Table 8. Water productivity ($kgm^{-3}$) for grains and straw yields of maize with different treatments.**

| Treatments | Water productivity ($kgm^{-3}$) | | | |
|---|---|---|---|---|
| | First season | | Second season | |
| | Grains | Straw | Grains | Straw |
| Cutoff with one dose | 1.16 | 0.97 | 1.15 | 0.97 |
| Cutoff with two doses | 1.30 | 1.00 | 1.31 | 0.98 |
| Cutoff with three doses | 1.36 | 0.99 | 1.36 | 0.98 |
| Traditional with one dose | 0.96 | 0.82 | 0.95 | 0.82 |
| Traditional with two doses | 1.06 | 0.84 | 1.07 | 0.83 |
| Traditional with three doses | 1.12 | 0.83 | 1.12 | 0.83 |

## CONCLUSION

Nitrate-nitrogen concentrations of subsurface drain effluent always exceed the maximum contaminant level of 10 mg/L (U.S. Environmental Protection Agency, 1991). Cutoff irrigation reduces the potential for nutrient loss through better irrigation and runoff control. The addition of N-fertilizer in one dose lead to high losses of nitrate-nitrogen into drainage water with negligible increase in maize yield.

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## فقد النترات بالغسيل إلى المصارف الحقلية المغطاة وتأثره ببعض اساليب الري والتسميد النيتروجيني في الأرض الطينية المنزرعه بمحصول الذرة

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أجريت تجربتين حقليتين في مزرعة محطة البحوث الزراعية بسخا بمحافظة كفر الشيخ خلال موسمي الصيف (2017 و2018) بهدف دراسة تـأثير الري (إيقاف الري عندما يصل الى 85% من طول الخط والري التقليدي لنهاية الخط) واضافة السماد النيتروجيني (يوريا 46.5%N) ( علي دفعة واحدة، دفعتان، ثلاث دفعات) على غسيل و فقد النترات إلى المصارف الحقلية المغطاة في الأرض الطينية وأيضا انتاجية محصول الذرة والنيتروجين الممتص والإنتاجية المائية لمحصول الذرة. وتشير النتائج إلي أن:- إيقاف الري عند 85% من طول الخط ادي الى نقص كمية مياه الري مقارنة بالري التقليدي. وانخفض معدل تصريف المصارف للماء وإجمالي كمية المياه المنصرفة نتيجة إيقاف الري مقارنة بالري التقليدي. وإضافة السماد النيتروجيني على دفعات نتج عنها زيادة متوسطة في محتوى التربة من النترات بعد اضافة كل دفعة ثم تناقص ذلك المحتوى ببطئ بعد الريات التالية خصوصاً مع إيقاف الري بينما الاضافة على دفعة واحدة نتج عنها زيادة كبيرة في محتوى التربة من النترات ثم تناقص ذلك المحتوى سريعاً بعد الريات التالية خصوصاً مع الري التقليدي.إضافة السماد النيتروجيني على دفعات نتج عنة نقص تركيز وفقد النترات في ماء الصرف خصوصاً مع إقاف الري مقارنة بالاضافة على دفعة واحدة والري التقليدي. حيث زاد فقد النترات أو النيتروجين النتراتي في ماء الصرف عند اضافة السماد النتروجيني على دفعة واحدة مقارنة بالاضافة على دفعتين وثلاث دفعات بمقدار 12.42، 16.51 % في الموسم الاول 13.33، 16.54 % في الموسم الثاني على التوالي مع إقاف الري. وكانت النسب المقابلة 19.02، 22.04 % في الموسم الاول وكان 19.12، 22.88% في الموسم الثاني على التوالي مع الري التقليدي. إضافة السماد النيتروجيني على ثلاث دفعات و دفعتين أدي إلى زيادة إنتاج حبوب الذرة بمقدار 14.84، 10.59 % في الموسم الاول وبمقدار 14.84، 11.26% في الموسم الثاني على التوالي مقارنة بالاضافة على دفعة واحدة. وايضاً توقف الري عند 85% من طول الخط ادي لزيادة انتاج الذرة من الحبوب بمقدار 2.44، 2.13% في الموسم الاول والثاني على التوالي مقارنة بالري التقليدي. وعن التفاعل بين الري وجرعات التسميد وجد ان كلا معاملتي الري مع اضافة السماد النتروجيني على ثلاث دفعات نتج عنها اعلى انتاج من حبوب الذرة (3470كجم للفدان) يليها الاضافة على دفعتين(3318كجم للفدان) ، بينما الاضافة على دفعه واحدة مع كلا معاملتي الري نتج عنها اقل انتاج من حبوب الذرة (2955كجم للفدان). وايضاً أعلى القيم للنيتروجين الممتص بواسطة حبوب الذرة وأعلى القيم لإنتاجية وحدة المياه تحققت مع إقاف الري عند 85 % من طول الخط واضافة السماد النيتروجني على ثلاث دفعات واقل القيم تحققت مع الري التقليدي مع اضافة السماد على دفعة واحدة.