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NITRATE TRANSPORT IN CLAY SOILS AND ITS LOSSES INTO FIELD DRAINS TILES FROM UREA APPLIED FOR SUGAR BEET

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ABSTRACT

Two field experiments were carried out at Fuwwa district, Kafr El-Sheikh Governorate (North Nile Delta), during the two growing seasons 2005/2006 and 2006/2007 to find out the impact of tile drainage system with two spacings of 30-m and 60-m on nitrate losses. N-fertilizer in the form of urea was added in two doses before the first and second irrigation.

Results indicated that, water table levels increased with time after irrigation. The drop was faster with 30 m spacing than 60 m one. Drain discharge were higher for 30 m spacing (0.09 – 9.15 mm/day) than 60 m one (0.34-7.48 mm/day). NO_3^- content of the soil was decreased with the increasing of soil depth. The highest contents of NO_3^- were found after fertilizer application, and ranged from 29.4 to 61.5 ppm. These contents were reduced at the end of seasons. After fertilizer application, NO_3^- content was lower to some degree in 30 m spacing than 60 m spacing. At the end of seasons, NO_3^- content was increased under 60 m spacing than 30 m by about 26.3% and 24.9% for the first and second seasons, respectively.

Nitrate concentration in drainage water during the two growing seasons was reduced with the time and it ranged from 11 to 18.5 ppm. The concentration of NO_3^- was higher under 30 m spacing than 60 m spacing. The average of NO_3^- concentrations for 30 m and 60 m spacings in the first season were 12.9 and 11.9 ppm, respectively. The estimated loss of NO_3^- was 16.7 kg/fed for 30 m drain spacing and 11.7 kg/fed for 60 m. Also, in the second season the estimated loss of NO_3^- was 16.8 kg/fed for 30 m drain spacing and 11.8 kg/fed for 60 m one. NO_3^- concentration in the groundwater ranged from 12.4 to 20.1 ppm and reduced at the end of seasons. The concentration of n in groundwater was higher with 30 m spacing than 60 m one.

Root, shoot and gross sugar yield of sugar beet was higher under 30 m spacing than 60 m one. N-uptake by root and shoot was paralleled to the yield results, whereas, N-uptake of root and shoot was higher with 30 m spacing than 60 m spacing, in both seasons. Nitrogen application efficiency (%) was higher in 30 m spacing than 60 m for both seasons. Research should be focused on designing practical strategies to minimize the preferential flow during the first few irrigations after fertilizers application and consequently nitrate loss. Continued research is also needed on ways to better predict and apply N to more closely match the needs of the crop during the growing season.

Keywords. Drain spacing, discharge rate, nitrate transport, N-uptake, sugar beet.

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. (Kladivko *et al.,* 1991, Bjorneberg *et al.,* 1996, Ibrahim et al. 2003 and Kladivko *et al*., 2004).

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*.2004). 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. The plant uptake of N may offer an alternative for reducing soil nitrate levels to reduce the leaching of nitrates and maintain crop productivity. 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.

Sugar beet (Beta vulgaris L) is the second important crop for sugar production in Egypt. The importance of this crop comes not only for its ability for growing in the new reclaimed lands, but also for giving high yield of sugar. So, there is a great need for several studies under Egyptian conditions to establish the best recommendations for raising the quantity and quality of sugar beet production. One way of increasing production of sugar beet is proper soil management such as drainage and increasing the efficiency of added nitrogen fertilizer. Korany and El-Said (1998) and El-Shahawy et al. (2001) concluded that improve root and shoot quality and sugar yield of sugar beet, may be due to improve soil structure and consequently the permeability and aeration. The analysis of drain flows provide information on the quality of water that moves between and below the drain. Drainage studies can therefore be useful in assessing the impact of agricultural management practices on surface and groundwater quality.

The objective of the present study was to evaluate the impact of subsurface drainage system with different drain spacing on: 1) Nitrate transport through clay soils into subsurface tile drains, 2) yield and N-uptake by sugar beet crop.

MATERIALS AND METHODS

Two field experiments were carried out at Fuwwa district, Kafr El-Sheikh Governorate (North Nile Delta), during the two growing seasons 2005/2006 and 2006/2007 to find out the impact of tile drainage system on nitrate losses. The tile lines were spaced to simulate a 30 m and 60 m spacing and 1.2 m depth with a slope of 0.1%. The field was plowed with moldboard plow to a depth of 20 cm. Seeds were sown on 5^{th} of sept. in 2005 and 8^{th} of sept. in 2006. The hills were thinned to one plant before the first irrigation. All plots received a total of 100 Kg Ca-superfhosphate/fed, and 50 Kg K-sulfate/fed, during cultivation. Nitrogen fertilizer in the form of urea was side dressed at a rate of 80 Kg N/fed, in two doses before the first irrigation and before the second irrigation.

Infiltration rate (IR) was determined using double cylinder infiltrometer as described by Garcia (1978).The soil hydraulic conductivity(K) was measured in the field by using the auger-hole method according to Van Beers (1970). Soil bulk density was determined according to Klute (1986) and other soil properties were analyzed before planting and are presented in Table (1).

Table (1): Some chemical and physical properties for the soil of the experimental field.

Drain	Soil depth	Particles size distribution			Texture	Bulk density	EC	O M	N	I R	K
Spacing	(cm)	Sand%	Silt%	Clay%	grade	g/cm³	(dS/m)	(%)	(ppm)	(cm/d)	(cm/d)
30-m	0--15	9.14	33.75	57.11	Clay	1.14	1.3	2.19	34	21	14
	15--30	9.55	33.14	57.31	Clay	1.18	1.3	1.81	30		
	30--60	8.98	38.49	52.53	Clay	1.26	1.5	0.84	28		
	60--90	9.21	39.05	51.74	Clay	1.26	1.5	0.84	25		
60-m	0--15	9.82	31.66	58.52	Clay	1.17	1.2	2.16	35	17	12
	15--30	9.45	33.24	57.31	Clay	1.19	1.4	1.87	33		
	30--60	9.11	36.54	54.35	Clay	1.25	1.6	0.77	26		
	60--90	9.25	36.14	54.61	Clay	1.25	1.6	0.77	26		

EC-soil salinity, OM-Organic matter, N-Available nitrogen, IR-infiltration rate, K-hydraulic conductivity

Through irrigations cycles, to monitor water table level and to collect groundwater samples, observation wells were installed midway between field drains. The discharge rates (Q) at drain outlets were measured as mm/day according to Dieleman and Trafford (1976). Several water samples were collected from tile effluent and groundwater at different times of the day and composite daily samples were taken for analysis. The water samples taken from tiles and groundwater were analyzed for NO^-_3 using Kjeldahl method (Cottenie et al., 1982). Disturbed soil samples were taken to a depth of 0.9 m, before fertilizer application, after the first, the second and the third irrigations and at the end of growing seasons. Soil samples were analyzed for NO^-_3 (according to Cottenie *et al*., 1982). The sugar beet was harvested on 2th March in 2006 (first season) and 5th March in 2007 (second season) to determine sugar beet root and shoot yields (ton/fed), and determined sucrose %. Gross sugar yield (ton/fed) was calculated by multiplying root yield (ton/fed) by sucrose %. Root and shoot samples were taken and dried at 70^{o}C, grounded with a mill and its total N content was determined using Kjeldahl digestion (Cottenie *et al.,* 1982). N-uptake (kg/fed) was calculated by multiplying dry yield (kg/fed) by N % (N content in percentage either for root and shoot). Nitrogen application efficiency (NAE) was calculated as follows:

$$\text{NAE} = \frac{\text{N-uptake}}{\text{N-native} + \text{N-applied}} \times 100$$

Where:

N-Native: **The base content of nitrogen in soil before cultivation**

N-applied: **Artificial application of nitrogen**

RESULTS AND DISCUSSION

Water table depth:

Results of water table depth for the investigated treatments were reflected on hydraulic head (Figs 1 and 2). The results indicated that the water table level increased rapidly with elapsing of the time after irrigation until it reached the highest values. The drop of water table level was faster with 30 m drain spacing than with 60 m drain spacing. The average values of water table depth with 30 m drain spacing plots, throughout the growing season, were 85.9 cm and 84.7 cm in the first and the second seasons, respectively. The corresponding values in 60 m drain spacing were 74.9 cm and 75.3 cm. This may be due to more effectiveness of drainage system under 30 m spacing.

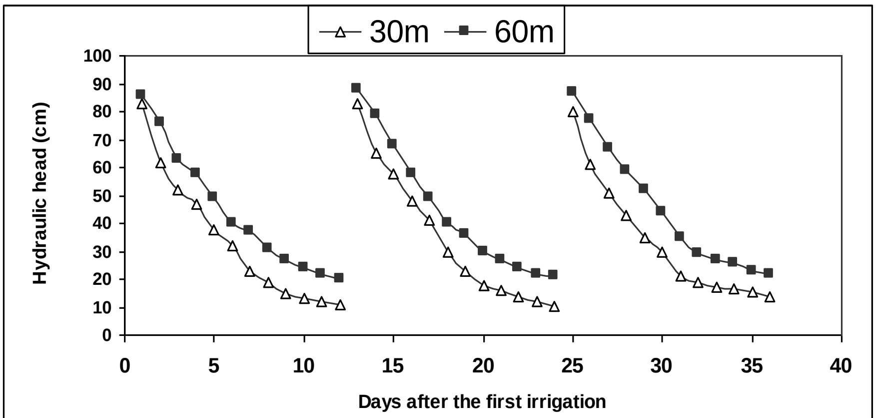

Fig (1) : Average hydraulic head (cm) after irrigation from the 30-m and 60-m spacings in the first season (Three-irrigations)

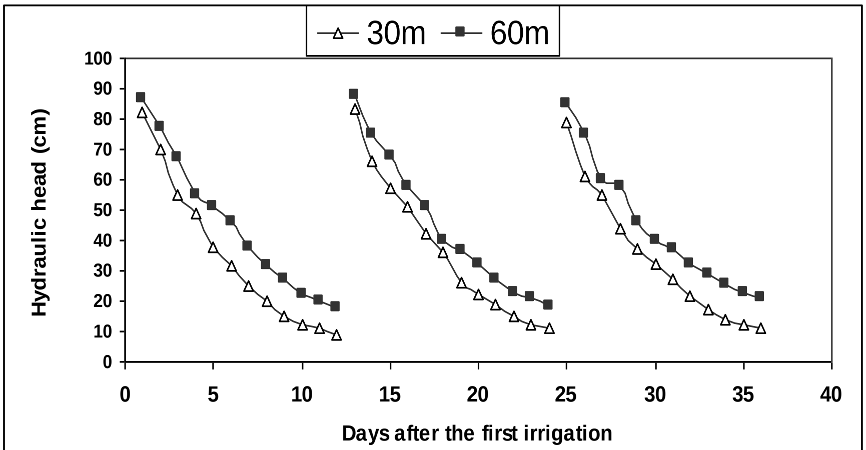

Fig (2) : Average hydraulic head (cm) after irrigation from the 30-m and 60-m spacings in the second season (Three-irrigations)

Drain discharge:

Data presented in Figures 3 and 4 show that, the drain discharge was decreased with time and reached after 12 days from irrigation to 0.09 -0.12 mm/day for 30 m spacing and 0.34- 0.42 mm/day for 60 m spacing in both seasons. Drain discharge in both seasons were higher for 30 m drain spacing (0.09 – 9.15 mm/day) than 60 m one (0.34-7.48 mm/day). Results indicated that total discharge obtained from 30 m spacing drains was higher than 60 m drain spacing. The cumulative drain discharge, throughout the growing seasons, were 1295.1 and 1288.1 m^3/fed with 30 m drain spacing and were 978.5 and 986.5 m^3/fed with 60 m drain spacing, for the first and the second seasons, respectively.

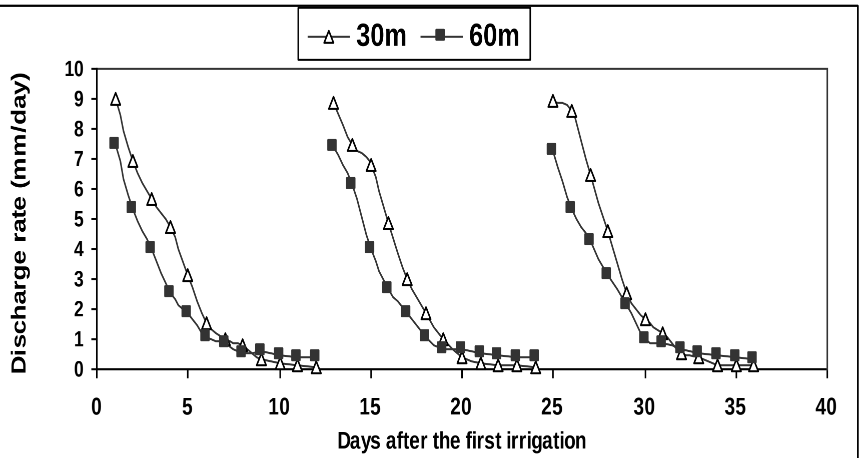

Fig (3) : Average drain discharge rate (mm/day) after irrigation from the 30-m and 60-m spacings in the first season (Three-irrigations)

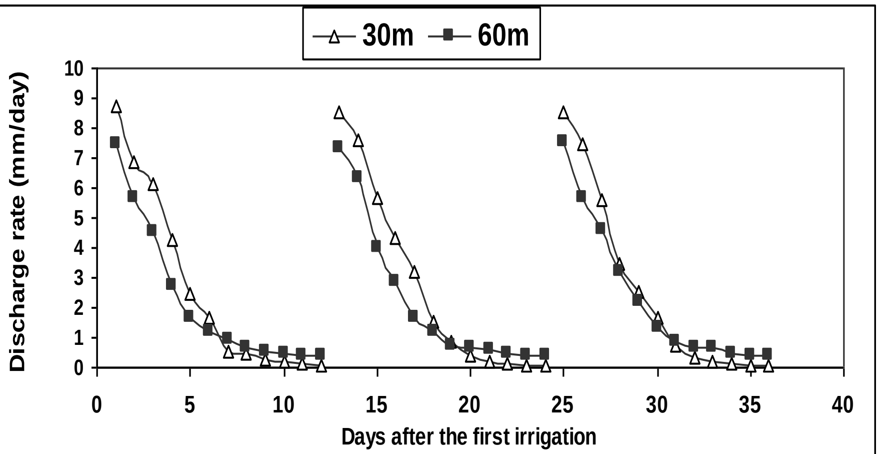

Fig (4) : Average drain discharge rate (mm/day) after irrigation from the 30-m and 60-m spacings in the second season (Three-irrigations)

Nitrate in soil:

Data presented in Table (2) 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 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. The highest contents of NO_3^- were found after fertilizer application (after the first and the second irrigations), where the values ranged from 29.4 to 61.5 ppm. The contents of NO_3^- were reduced at the end of seasons (14.6 to 30.5 ppm) due to rapid N-uptake by plants after irrigation directly where the soil water tension is very low. NO_3^- contents in the soil after fertilizer application in both seasons were lower to some degree under 30 m spacing (an average of 42.9 ppm) than 60 m spacing (an average of 45.8 ppm).At the end of seasons, the mean of NO_3^- content with 60 m spacing was higher than that with 30 m spacing by 26.3% and 24.9% for the first and second seasons, respectively. This may be explained on the basis of increasing drainage spacing which causes a decrease in drainage water and consequently, increase in the amounts of nutrient in soil solution. These results are in agreement with those obtained by Abd El-Khalek, (2000), Ibrahim *et al*., (2003) and Antar, (2005).

Table (2): Average NO_3^- concentration (ppm) at different soil depths for 30and 60m spacing and after first, second and third irrigations and at harvesting through both seasons of study.

Drain Spacing	Soil depth (cm)	First season				Second season			
		1st I	2nd I	3rd I	At harvesting	1st I	2nd I	3rd I	At harvesting
30-m	0-----15	49.6	58.6	48.6	24.5	48.7	59.3	46.7	24.4
	15-----30	45.2	55.4	43.9	24.6	46.2	56.9	44.6	22.4
	30---60	35.1	42.5	35.4	18.4	35.8	44.5	36.1	18.5
	60----90	32.2	33.6	32.8	15.6	31.2	34.2	33.4	14.6
60-m	0-----15	53.2	61.5	56.4	30.5	51.6	59.6	54.6	29.6
	15-----30	46.8	57.5	51.6	29.1	46.3	58.6	50.4	25.6
	30----60	31.2	46.8	44.6	25.3	32.5	44.5	42.6	23.3
	60----90	29.4	37.6	34.7	20.1	32.5	39.8	35.2	21.3

I = irrigation

Nitrate in drainage water:

Concentrations of nitrate in drainage water during the two growing seasons (Figs 5 and 6) were reduced with time and ranged from 11 to 18.5 ppm. These concentrations before fertilizer application were 3.5, 5.4 and 4.2, 6.1ppm in the first and the second seasons for 30 m, 60 m spacings, respectively. NO_3^- concentration in drainage water was increased after the first and the second irrigation and then reduced again after the third irrigation (Fig.7).The increase in NO_3-N leaching after the second irrigation more than the first irrigation can be explained on the base of the addition of N-fertilizer before the second irrigation. While, NO_3^- concentration in the drainage water was reduced in the end of season but its concentration under 60 m drain spacing was higher than 30 m ones (Fig.7).

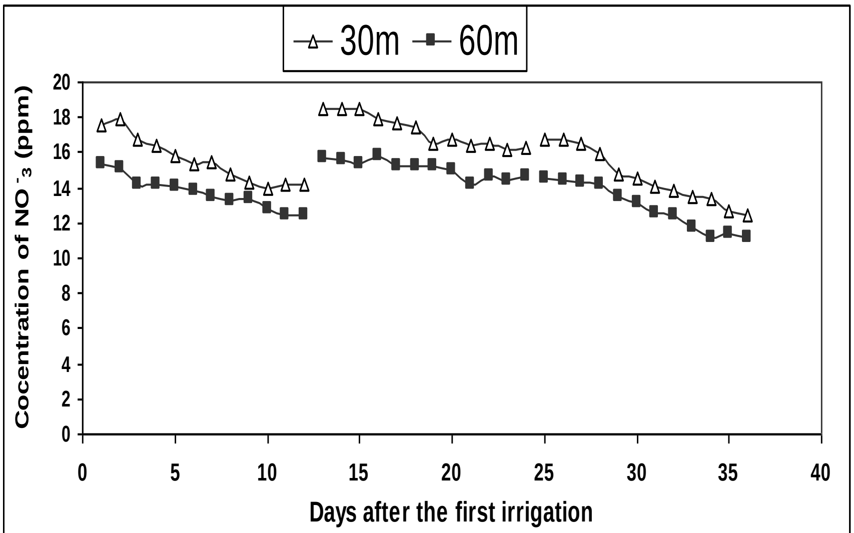

Fig (5) : Average concentration of NO^-_3 in drainage water from the 30-m and 60-m spacings in the first season (Three-irrigations).

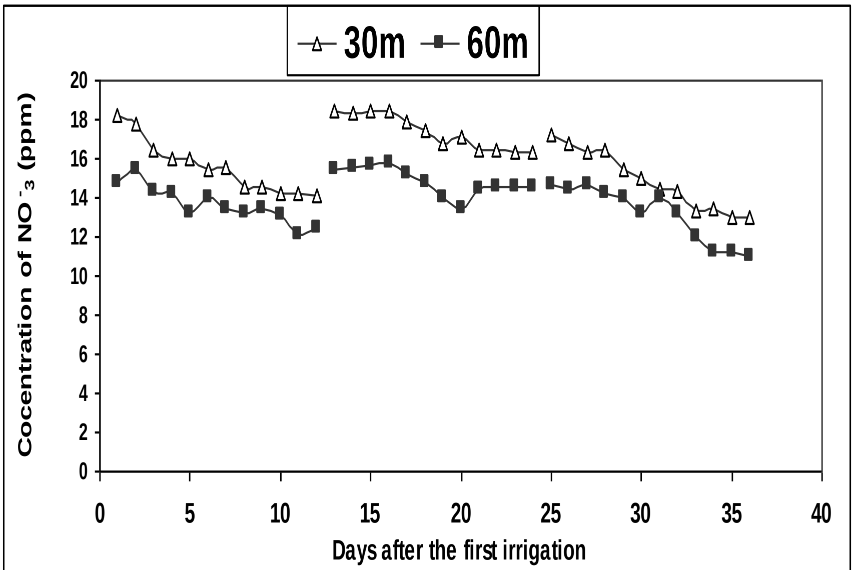

Fig (6) : Average concentration of NO^-_3 in drainage water from the 30-m and 60-m spacings in the second season (Three-irrigations).

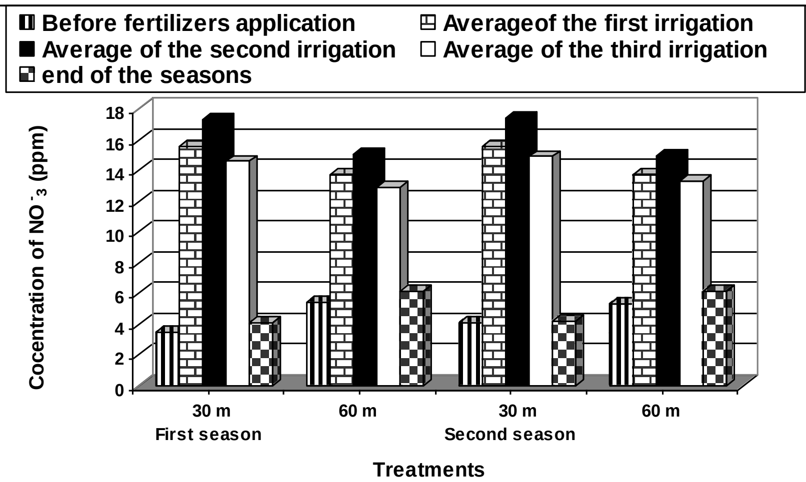

Fig (7) : Average concentration of NO^-_3 in drainage water from the 30-m and 60-m spacings through both season of study.

Concentrations of NO_3^- in drainage water were higher under 30 m drain spacing more than 60 m spacing. The average NO_3^- concentrations for 30 m and 60 m spacings in the first season were 12.9 and 11.9 ppm, respectively. Total drain flow during the first season was 311 mm for 30 m spacing and 235 mm for 60m spacing. The estimated losses of NO_3^- were 16.7 kg/fed for 30 m drain spacing and 11.7 kg/fed for 60 m drain spacing. Also, in the second season, NO_3^- concentrations were 13 ppm and 11.9 ppm for 30 m and 60 m spacings, respectively. Total drain flow in the second season was 309.2 mm for 30 m spacing and 236.7 mm for 60m spacing. The estimated losses of NO_3^- in the second season were 16.8 kg/fed for 30 m drain spacing and 11.8 kg/fed for 60 m drain spacing. Data reveled that NO_3-N lost by leaching was increased with decreasing drainage spacing. This may be explained on the assumption that the drainage spacing of 30 m gave a good drainage efficiency, improve soil physical and chemical properties and subsequently gave a better soil structure and improve hydraulic conductivity which affects water down movement carrying many nutrients in soluble forms. Similar results were obtained by Ibrahim et al., (2003), Kladivko et al., (2004) and Ramadan et al. (2004). In this concern, Kladivko et al. (1991) stated that nitrate concentrations in tile drainage water were usually >10 ppm and affects greatly with tile drain spacing.

Nitrate in groundwater:

NO_3^- concentration in the groundwater**,** after fertilizer application, ranged from 12.4 to 20.1 ppm during the two growing seasons. This concentration was reduced at the end of the growing seasons (Table 3). After fertilization, NO_3^- concentration in groundwater with 30 m spacing (16.8 and 17.1 ppm) was higher than 60 m spacing (14.3 and 14.7 ppm) for the first and the second seasons, respectively.

Table (3): Average concentrations of NO-3 (ppm) in groundwater before fertilizer application, after irrigation and the end of seasons for 30-m and 60-m drain spacings

Seasons	Drain spacing	Before Fertilization	Days after irrigations (Average three-irrigations)								End of seasons
			1	2	3	4	5	6	7	8	
First	30m	4.1	20.1	18.9	18.2	16.8	15.5	15.1	15.6	14.2	4.5
	60m	6.1	16.5	15.8	14.9	15	13.5	13.5	12.8	12.4	6.4
Second	30m	4.2	19.6	19.5	18.5	16.9	17	15.8	15.2	14.5	4.2
	60m	5.9	16.2	15.6	15.5	15.6	14.3	13.7	13.8	12.7	6.2

Yield and N-uptake:

Data in Table (4) show that the root and shoot yields of sugar beet in both seasons were higher under 30 m spacing than 60 m spacing. Root and shoot yields under 30 m spacing were higher than 60 m spacing by about 17.1 and 6.4 % respectively for the first season and about 24 and 7.3%, respectively, for the second season. Such findings may be attributed to the effect of narrow drain spacing on improving soil properties which affects water-air relationships in the root zone and root penetration. Similar results were obtained by Moustafa et al. (1987), Sharma and Komal (1998) and Ibrahim et al. (1999).

There were no obvious differences between sugar percentages in both spacings under both seasons. In the seam table, the yield of gross sugar (ton/fed) in both seasons was higher for 30 m spacing than 60 m one due to higher root yield in 30 m spacing than 60 m one.

Data in Table (4) show clearly that the N-uptake (kg/fed) by root and shoot were paralleled to the yields values. N-uptake of root and shoot with 30 m spacing were higher than 60 m spacing by 11.36 and 3.51 kg/fed, respectively in the first season. The corresponding values for the second season were 10.48 and 3.47 Kg/fed, respectively. This N was adjacent the plant and was therefore not available for leaching. The primary loss of N from the fields was through tile drainage. Similar results were reported by Korany and El-Said (1998), El-Shahawy *et al*. (2001), Ibrahim et al. (2003) and Antar (2005)

Table (4): Beet root, shoot and gross sugar yield (ton/fed.) and N uptake (kg/fed.) by plant for 30-m and 60-m drain spacing in both seasons

Seasons	Drain spacing	Yield (ton/fed.)		Sugar %	Gross sugar (ton/fed.)	N-uptake (kg/fed.)		
		Root	Shoot			Root	Shoot	Total
First	30m	22.88	4.87	17.71	4.052	60.40	28.25	88.65
	60m	19.54	4.58	17.69	3.456	49.05	24.73	73.78
Second	30m	23.15	5.12	17.56	4.065	59.96	29.90	89.86
	60m	18.67	4.77	17.81	3.325	49.48	26.43	75.91

Fertilizer application efficiency (FAE):

Fertilizer application efficiency reflects the ability of the plants to utilize the soil fertilization. Soil fertilization consists of artificial application plus the base content of specific element before cultivation. As shown in Table (5), drainage spacing of 30 m had the highest FAE of nitrogen (79.15% and 80.23%) compared to 60 m one (64.72% and 66.58%) for both seasons, respectively. This is due to the effect of narrow drain spacing (30m) on conditioning water-air relationships in the root zone and its effect on mobility of nutrients to the plant root. On the other side, the plots with wide drain spacing (60m) which have a larger volume of groundwater with an aerobic condition in the groundwater and also more denitrification is expected. Similar results were obtained by Myrold and Tiedje (1985).

Table (5): Nitrogen application efficiency (%) as affected by drainage conditions of sugar beet for both seasons

Seasons	Drain spacing	Nitrogen application efficiency (%)		
		Applied, kg/fed	N-uptake, kg/fed	Efficiency,%
First	30m	112	88.65	79.15
	60m	114	73.78	64.72
Second	30m	112	89.86	80.23
	60m	114	75.9	66.58

Conclusion:

Nitrate losses, however, occurs throughout the growing season, and the major mass losses occur when the majority of the water flow occurs. Nitrate-nitrogen concentrations of subsurface drain effluent always exceed the maximum contaminant level of 10 mg/L (U.S. Environmental Protection Agency, 1991). Research should be focused on designing practical strategies to minimize the preferential flow during the first few irrigations after fertilizers application and consequently nitrate loss. Continued research is also needed on ways to better predict and apply N to more closely match the needs of the crop during the growing season.

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إنتقال النترات فى الأراض الطينيه وفقدها الى المصارف الحقلية المغطاه من اليوريا المضافه لبنجر السكر

عنتر شعبان عنتر

مركز البحوث الزراعية- معهد بحوث الأراضى والمياه والبيئه- الجيزة – مصر

اجريت تجربتين حقليتين خلال الموسيمين 2006/2005 و2007/2006 فى الأراضى الطينيه فى شمال الدلتا بمحافظة كفر الشيخ منطقة فوه. وذلك لدراسة تاثير مسافتين للصرف المغطى (30 و60 متر بين الحقليات) على فقد النترات من الأرض الى المصارف المغطاه.حيث تم إضافة السماد النيتروجينى بمعدل 80 كيلوجرام للفدان فى صورة يوريا لمحصول بنجر السكر على دفعتين قبل الرية الاولى والثانية على التوالى.

تشير النتائج الى زيادة مستوى الماء الأرضى مع مرور الزمن بعد الرى، وان هبوط الماء الأرضى كان سريع مع مسافة الصرف 30 مترعن 60 متر،و معدل تصريف المصارف للماء اعلى فى مصارف 30 متر وتراوح من 0.09الى9.15 مم/يوم مقارنة بالمسافة 60 متر حيث تراوح من 0.34 الى 7.48 مم/يوم. محتوى النترات فى الأرض قل مع زيادة عمق التربة والمحتوى العالى للنترات وجد بعد إضافة السماد وتراوح من 29.4 الى 61.5 جزء فى المليون وقل ذلك المحتوى فى نهاية المواسم. بعد إضافة السماد قل محتوى النترات بدرجه بسيطه فى المسافة 30 متر عن المسافة 60 متر، وفى نهاية المواسم قل محتوى النترات فى المسافة 30 متر عن المسافة 60 متر بمقدار 26.3% و 24.9% فى المواسم الأول والثانى على التوالى.

كما قل تركيز النترات فى ماء الصرف خلال الموسمين مع الزمن وتراوح من 11 الى 18.5 ملجرام/اللتر وقل ذلك التركيز فى نهاية المواسم وكان التركيز اعلى فى مصارف 30 متر عن مصارف 60 متر. فى الموسم الأول كان متوسط تركيز النترات 12.9 و11.9 مليجرام/اللتر للمسافتين 30 و60 متر على التوالى، وكان الفقد المقدر للنترات 16.7 كيلوجرام نيتروجين/للفدان فى المسافه 30 متر و11.7 كيلوجرام نيتروجين/للفدان للمسافه 60 متر. وفى الموسم الثانى كان الفقد المقدر للنترات 16.8 و11.8 كيلوجرام نيتروجين/للفدان للمسافتين 30 و 60 متر على التوالى. تركيز النترات فى الماء الأرضى تراوح من 12.4 الى 20.1 ملجرام/اللتر وقل ذلك التركيز فى نهاية المواسم وكان التركيز اعلى فى مسافة 30 متر عن مسافة 60 متر.

النتائج تبين زيادة إنتاج محصول بنجر السكر من الجذور والعروش والسكر الخام مع المسافة 30 متر عن المسافة 60 متر. وان نتائج النيتروجين الممتص فى الجذور والعروش توازى نتائج المحصول، حيث تبين زيادة النيتروجين الممتص فى الجذور والعروش(كيلوجرام/فدان) فى المسافة 30 متر عن المسافة 60 متر. وايضا وجدت زيادة فى كفائة إضافة النيتروجين المضاف (%) فى المسافة 30 متر عن المسافة 60 متر. النتائج تبين فقد للنترات من الأرض الى المصارف وكمية هذا الفقد ملازمه لكمية المياه المتدفقه الى المصارف. ويجب ان تركز الأبحاث القادمة على تقليل هذا الفقد بعد إضافة السماد. ويجب ان يستمرالبحث ايضا لتحديد انسب وسيله لاضافة النيتروجين حتى تقابل إحتياجات النبات فقط خلال موسم النمو لتقليل الفاقد فى مياه الصرف.