ATRAZINE AND NITRATE TRANSPORT THROUGH A CLAY SOIL INTO SUBSURFACE TILE DRAINS OF DIFFERENT SPACINGS

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ABSTRACT

Leaching of agrichemicals into subsurface tile drainage water is a concern for water quality. Nitrate in drainage water is also an economic loss to producers beside its environmental problems. A field experiment was conducted to study the transport of nitrtate and atrazine (a herbicide) through a clay soil of Nile Delta (Fuwwa district), and to evaluate their losses into subsurface tile drains of different spacings (30 m and 60 m). Corn was planted on the experimental site. A total of 120 Kg N/fed as urea and 0.75 Kg/fed of atrazine was applied to the soil during cultivation. Daily water table depths and drain flow rates were determined. Concentrations of nitrate and atrazine were measured in the soil and groundwater throughout the growing season. Water samples were collected from the subsurface tile outlets and from porous suction cups installed at different soil depths in the growing season of 2002, and analyzed for nitrate and atrazine. Corn grain yield and N uptake were also determined at the end of the growing season.

The soil of studied site had a shallow water table (overall mean of 60.8-78 cm). Drain discharge was higher for 30 m drain spacing (0.32-13.33 mm/day) than the 60 m one (0.44-9.73 mm/day). NO_3^- content of the soil decreased with the increasing of soil depth and the distance from drain lines. This change varied during the growing season from 28 to 59.5 ppm and reduced in the end of the growing season to 11-28.5 ppm. NO_3^- concentration in the drainage water during the growing season reduced with time and ranged from 11.2 to 16.8 mg/L, and was higher under 30 m drain spacing than 60 m drain spacing. While, NO_3^- concentration in the drainage water in the end of the growing season was higher under the 60 m drain spacing treatment than under 30 m one. NO_3^- concentration in the groundwater ranged from 12 to 17.8 ppm, and was higher for 30-m drain spacing than 60-m spacing. The obtained data showed that, concentration of NO_3^- in the water of the suction cups reduced with time after irrigation and with the increasing soil depth and distance from the drain lines. This means that NO_3^- is transported to the drains.

Atrazine was already detected in subsurface tile flow within 1 day of pesticide application. This early arrival of atrazine to drains is consistent with concepts of preferential flow and non-equilibruim sorption/desorption. The loss of atrazine in drainage water is greater for 30 m drain-spacing plot than the 60 m one. Atrazine concentration in the soil decreased with soil depth and was higher between the drains than above the drain lines, and was higher under 60-m spacing than 30-m spacing. Atrazine was still present in the soil and in drainage water 15 days after application. Grain yield from the 30-m drain spacing plots was greater than the 60-m spacing plots. The N uptake by corn was higher under 30 m drain spacing treatment than the 60 m treatment. Research should be focused on desiging practical strategies to minimize the preferential flow during the first few irrigations after chemicals application. Continued research is also needed on ways to better predict and apply N to more closely match the needs of the crop and minimize N present in the soil at the end of the growing season.

Key words: Atrazine, nitrate, drain spacing, discharge rate, preferential flow, corn yield, N uptake.

INTRODUCTION

Subsurface drainage is necessary to remove excess water from the poorly drained soils and allow for crop production. Previous tile drainage research has dealt primarily with water movement, but not water quality. Since root zone drainage is the primary objective of subsurface drainage. However, research has shown that subsurface drainage water can carry substantial amounts of sediments, nutrients, and detectable levels of certain pesticides (Baker and Johnson, 1981; Kladivko et al., 1991). Nitrate and herbicides contamination of tile drainage water from intensive agricultural production systems has become a serious environmental and economic concern. Increases in nitrate concentration in tile drainage appeared within 2 to 3 months after N was applied (Hubbard et al., 1984). Hence there is the need to develop alternative soil, crop, and water management strategies to reduce leaching losses and increase N uptake by crops. Kladivko et al. (1991) stated that nitrate concentrations in tile drainage water were usually > 10 mg N L^{-1} and affected greatly with tile drain spacing. Subsurface drains integrate the effects of spatial variability on a field scale and may be a better tool for the study of water quality than measurement methods such as suction cups and soil cores (Richard and Steenhuis, 1988). Atrazine is a commonly used herbicide in corn growing areas of Egypt. Because of its heavy usage, moderate persistence, and mobility in soils (Walker, 1987; Erickson and Lee, 1989), monitoring of atrazine movement under field conditions is essential to assess its potential to contaminate groundwater.

Several researchers have monitored tile drainflows to study nutrients and pesticides losses from different agricultural management practices (Buhler et al., 1993; Gaynor et al., 1995; Drury et al., 1993 and 1996). The analysis of drain flows provide information on the quality of water that moves between and below the drains. Drainage studies can therefore be useful in assessing the impact of agricultural management practices on surface and groundwater quality. A consequence of preferential flow is that solute movement can occur which bypasses portions of the bulk soil enabling a surface-applied chemical to move faster and further in the soil profile. The effect of different tile drain spacings on preferential flow is not well known. The objective of the present study was to evaluate the impact of subsurface drainage system with different drain spacings on: 1) leaching of the herbicide atrazine and nitrate into tile drains, 2) Yield and N uptake by corn (Zea mays L.).

MATERIALS AND METHODS

A field study was conducted to determine the impact of tile drainage system on nitrate and atrazine (a herbicide) losses. The experimental site located at Fuwwa district, Kafr El-Sheikh Governorate (North Nile Delta). The soil has a clayey texture, the average textural analysis for this soil is 8.7 % sand, 37.9 % silt and 53.4 % clay. The drainage system was installed in May 2002, and consists of PVC tile drains placed 1.2 m deep with a slope of 0.1%. The tile lines were spaced to simulate a 30-m and 60-m spacing. Three drain lines (90 m long) were installed at each spacing. The center drain on each spacing was used to measure drain discharge and to collect drain water samples. The field was plowed with moldboard plow to a depth of 20 cm. Corn (Zea mays L.), single pioneer hybrid No.10, was planted on the site on 19 June 2002. Field operations were conducted in a timely fashion for corn production in this area. All plots received a total of 120 Kg N/fed (as urea), 200 Kg Ca-superphosphate/fed, and 50 Kg K-sulfate/fed during cultivation. Atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) was sprayed to the soil surface at rate of 0.75 Kg/fed, as commercial material with 80% active ingredient, during cultivation (for the first time in this soil). After corn planting, irrigation water was applied within one day after herbicide application. The experiment was conducted under furrow irrigation. In addition to planting irrigation, all plots received seven irrigations every 10-12 days.

To monitor water table heights and to collect groundwater samples, observation wells were installed above drain and midway between each two drains at 1/8, 1/4 and 1/2 drain distance as recommended by Dieleman and Trafford (1976). Drain discharge rates were manually measured six times every day when drain flow occurred, by measuring the amount of water running from tile line during a short interval and converting to mm/day. The average daily discharge rates were used in this study. Suction cups were installed in the field at 60, 90, and 120 cm depth. Water samples were collected from the suction cups by applying a vacuum. Several water samples from tile effluent, groundwater and suction cups were collected at different times of the day and composite daily samples were taken for analysis. The waters of tiles, groundwater and suction cups were analyzed for NO_3^- using Kjeldahl method (Cottenie et al., 1982), and atrazine by gas chromatography as described by U.S. Department of Health and Human Services (1994)).

The water infiltration rate of the soil was determined using double cylinder infiltrometer as described by Garcia (1978). The soil hydraulic conductivity (K) was measured in the field in several auger-holes during different irrigation cycles using the auger-hole method according to Van Beers (1970). Undisturbed soil samples were collected along the soil profile to a depth of 1.2 m to determine soil bulk density according to Klute (1986). Disturbed soil samples were taken to a depth of 1.2 m, before cultivation, after the first irrigation, and at the end of the growing season. Soil samples were analyzed for NO_3^- (according to Cottenie et al., 1982) and atrazine (according to Horwhz, 1975 and Koskinen et al., 1991). Corn was harvested on 7 October 2002 from all treatments. Grain yield was determined. Grains, leaves and steems samples were taken and dried at 80 °C, grounded with a mill and its total N content was determined using Kjeldahl digestion (Cottenie et al., 1982, and Drury et al., 1993).

RESULTS AND DISCUSSION

Water table depth and drain discharge:

Results of water table measurements in figures 1 and 2 indicate that the decrease of distance from tile drain had lowered the water table level or had decreased the hydraulic head above the drains level. The rate of fall of water table in drains with 30 m spacing was larger than that with drain with 60 m spacing. The water table level is often above the drain level and becomes deeper as the distance from the tile drains decreases. The average daily water table depth in 30 m drain spacing plots, throughout the growing season, was 78 cm. The corresponding value in 60 m spacing was 60.8 cm. It is worthy to mention that the neighbor fields were cultivated with rice, which may be caused water seepage to the experimental field.

Changes of hydraulic head (in Figs. 1 and 2), as affected by the distance from drain lines, are in accordance with the results of infiltration rate and hydraulic conductivity of the soil (table 1). The infiltration rate (IR) and hydraulic conductivity (K) values decreased with the increasing of the distance from drain lines. The IR and K values were higher under 30-m drain spacing than 60-m spacing. The average bulk density values of the soil (0- 120 cm) were 1.242 Mg/m^3 for 30-m drain spacing plots and 1.252 Mg/m^3 for 60-m spacing (data not shown).

Table 1: Infiltration rate (IR) and hydraulic conductivity (K) of the soil at different distances from drain.

	30 m					60 m				
	Above*	L/8	L/4	L/2	Average	Above	L/8	L/4	L/2	Average
IR (cm/d)	61.9	40.3	34.6	30.2	41.8	57.6	30.2	28.8	20.2	34.2
K (cm/d)	45.5	31.3	23.0	16.6	29.1	44.6	23.0	16.7	14.4	24.7

* Above = above the drain L = drain spacing

Drain discharge measurements (Fig. 3) showed that the discharge was higher for 30 m drain spacing (0.32-13.33 mm/day) than the 60 m one (0.44-9.73 mm/day). The discharge decreased with time and reached

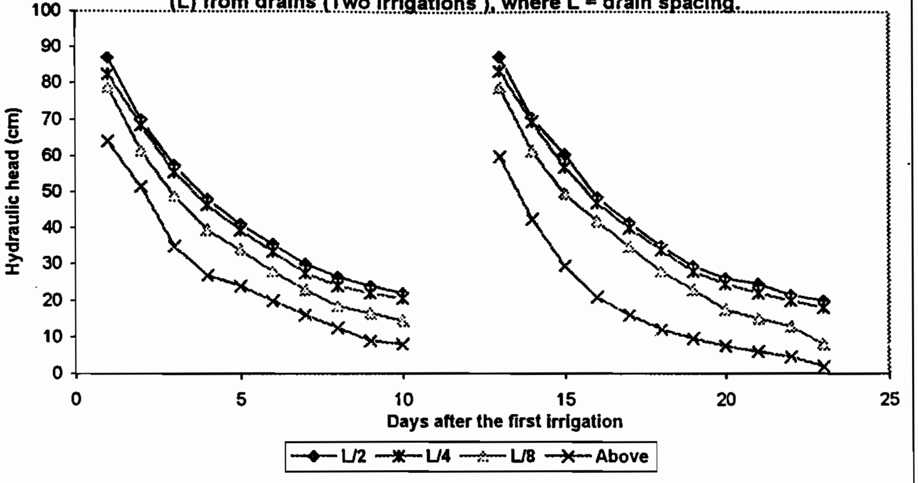


Fig (1) : Average hydraulic head (cm) in 30-m spacing at different distances (L) from drains (Two irrigations), where L = drain spacing.

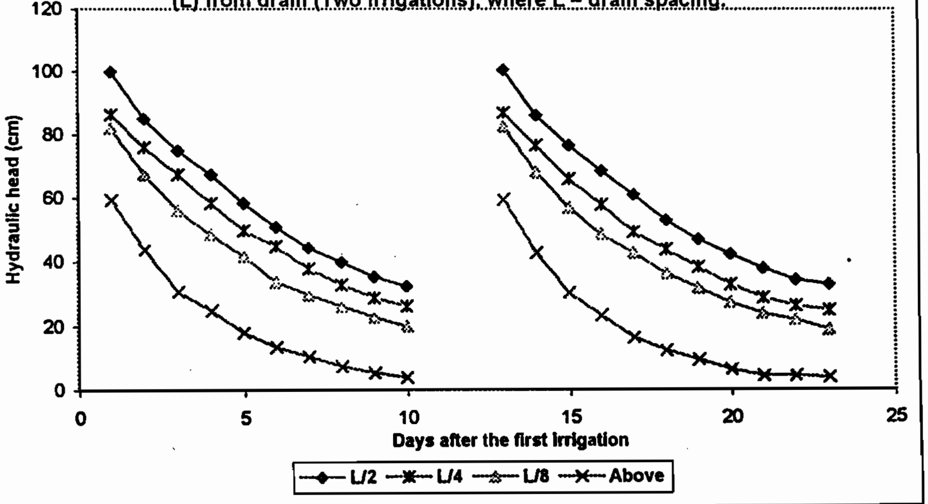


Fig (2) : Average hydraulic head (cm) in 60-m spacing at different distances (L) from drain (Two irrigations), where L = drain spacing.

after 10 days from irrigation to 0.32-0.47 mm/day for 30 m spacing and to 0.44-0.72 mm/day for 60 m spacing. The cumulative drain discharge, throughhout the growing season, was 1683.2 m^3/fed in the case of 30-m drain spacing and was 1346.6 m^3/fed in the 60-m spacing.

Nitrate:

Data presented in table (2) show that NO_3^- content of the soil decreased markedly with the increasing of soil depth. NO_3^- content of the soil before fertilizers application was 14.5-28.5 ppm. After fertilizers application the NO_3^- content in the soil varied from 28 to 59.5 ppm. This content reduced in the end of the growing season to 11-28.5 ppm. NO_3^- content of the soil after the first irrigation decreased with the increasing of the distance from drain lines. This submitted the movement of nitrate toward the drains. The opposite trend was found at the end of the growing season. This may be due to the leaching of NO_3^- in the area adjacent to the drain lines. Concentrations of nitrate in the soil profile (0-120 cm) after the first irrigation were somewhat higher under 30 m drain spacing (an average of 45.9 ppm) than 60 m one (42.2 ppm). Plots with wide drain spacing would have a larger volume of groundwater with anaerobic condition in the groundwater and although more denitrification was expected. At the end of growing season the average concentration of nitrate in the soil profile was nearly the same in both drain spacings (19 ppm).

NO_3^- concentration in the drainage water during the growing season (Fig. 4) reduced with time and ranged from 11.2 to 16.8 mg/L, this concentation was 6.3 mg/L before fertilizers application. The concentration of NO_3^- was somewhat higher under 30 m drain spacing (with an average of 13.8 mg/L) than 60 m drain spacing (with an average of 13.0 mg/L). While, NO_3^- concentration in the drainage water in the end of the growing season was higher under the 60 m drain spacing treatment than 30 m ones (Fig. 5). Total drain flow during growing season was 404 mm for 30 m drain spacing and 323 mm for 60 m spacing. The average NO_3^- concentration for 30-m and 60-m drain spacing were 13.8 and 13.0 mg/L respectively. The estimated loss of NO_3^- was 23.2 Kg/fed for 30 m drain spacing and 17.5 Kg/fed for 60 m spacing.

Fig. (3): Average drain dicharge rate after irrigation from the 30-m and 60-m spacings (Two irrigations)

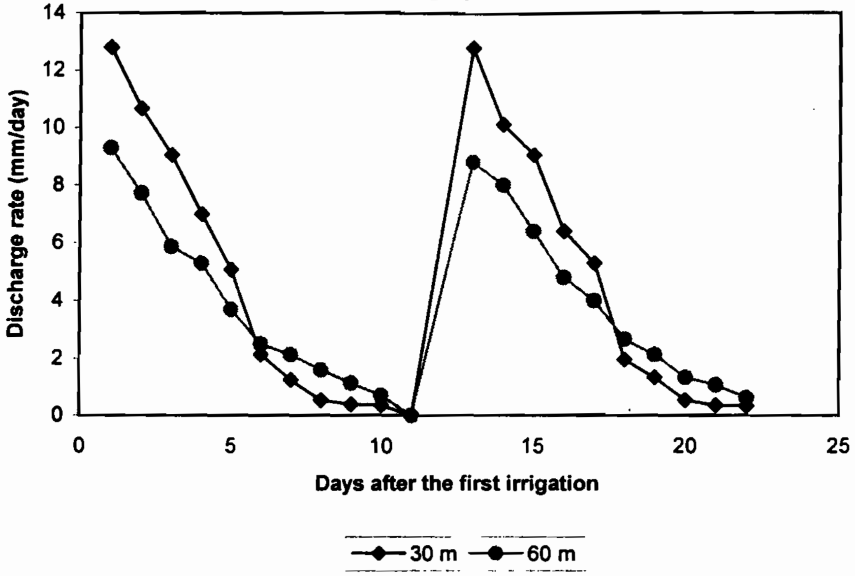


Fig. (4): Average concentration of NO_3^- in drainage water from the 30-m and 60-m spacings (Two irrigations)

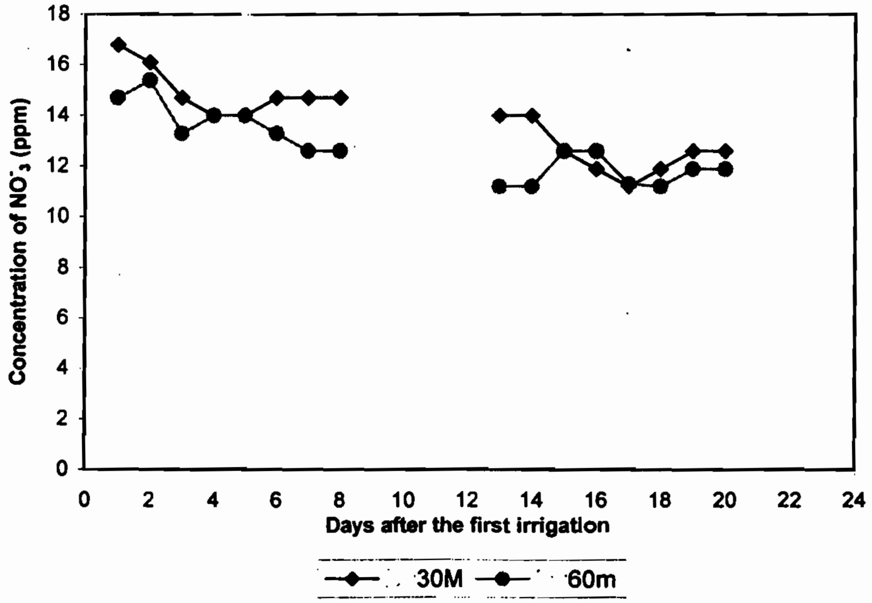


Table 2: Average NO_3^- concentrations (ppm) at different soil depths and at different distances from drains, before planting, after the first irrigation, and at the end of corn growing season.

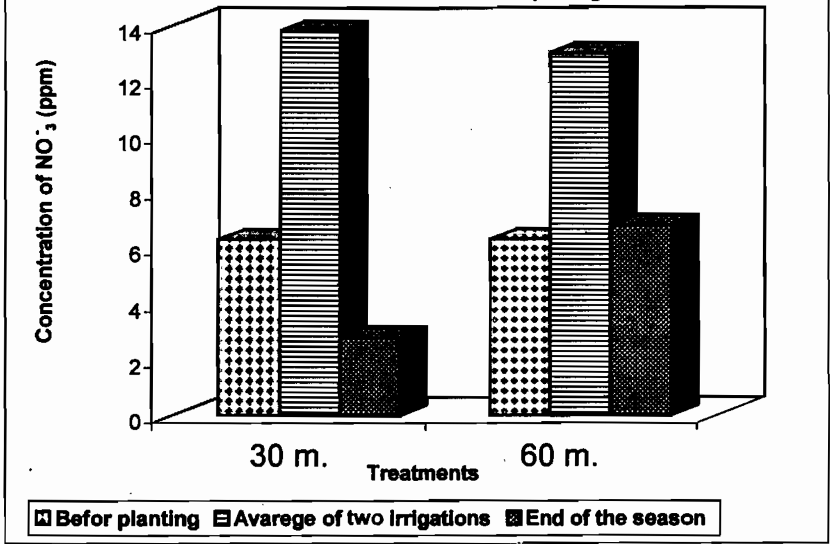
Soil depth (cm)	**Before planting**	**After the first irrigation**							
		30 m				**60 m**			
		L/2	**L/4**	**L/8**	**above**	**L/2**	**L/4**	**L/8**	**Above**
0-15	28.5	52.5	59.5	56.5	59	52.5	52.5	56.5	56.5
15-30	22.5	49	45.5	45.5	56.5	42	45	49	52.5
30-60	22.5	45.5	42.5	45	49	35.5	38.5	42	45.5
60-90	14.5	38.5	31.5	45.5	45.5	38.5	36.5	35	43.5
90-120		35	38.5	38.5	38.5	31.5	28	28	35
Average	22	44.1	43.5	46.2	49.7	40	40.1	42.1	46.6
		At the end of growing season							
0-15	28.5	28.5	27	25	25	28.5	28.5	25	28.5
15-30	22.5	25	20	21	18	27	23	21	21
30-60	22.5	18	18	20	16	23	16	18	12.5
60-90	14.5	14.5	14	15	12.5	16	11	13	13
90-120		17	13	18	14.5	13	14.5	13	13
Average	22	20.6	18.4	19.8	17.2	21.5	18.6	18	17.6

* L = drain spacing ** above = above the drain line

Nitrate-nitrogen concentration of subsurface drain effluent always exceed the maximum contaminant levels of 10 mg/L (U.S. Environmental Protection Agency ,1991). High concentrations are especially concerning if the drains discharge into a water body that used as a drinking water source. Nitrate in subsurface drainage is also an economic loss to producers because the nitrogen is no longer available for crop use.

NO_3^- Concentration in the groundwater, after the first and second irrigations, ranged from 12 to 17.8 ppm (table 3). This concentration after the first irrigation was somewhat higher for 30-m drain spacing (an average of 16.3 ppm) comparing with the 60-m spacing (14 ppm). There were no obvious differences between nitrate concentration in both spacing after the second irrigation with an average of 13.4 ppm for 30 m spacing and 13.6 ppm for 60 m spacing. On the other hand, NO_3^- content in groundwater was reduced at the end of the growing season to 6.1 ppm under 30-m spacing and to 6.8 ppm under 60-m spacing.

Fig. (5): Average concentration of NO_3^- in drainage water from the 30-m and 60-m. spacings.



Data presented in figures 6 to 10 show that, concentration of NO_3^- in the water of the suction cups reduced with time after irrigation, increased with the next irrigation and then reduced again. Also, NO_3^- concentration reduced with the increasing soil depth and distance from the drain lines. This means that NO_3^- was transported to the drains. The concentration of NO_3^- during the growing season was higher under 30 m drain spacing than 60 m one. The opposite trend was obtained at the end of the growing season. Shallow water table depth under 60 m drain spacing reduced NO_3^- concentrations in soil, in the water of suction cups and in groundwater.

Fig. (6): Average concentration of NO_3^- in the water of suction cups at different depths (D) for 30-m spacing.

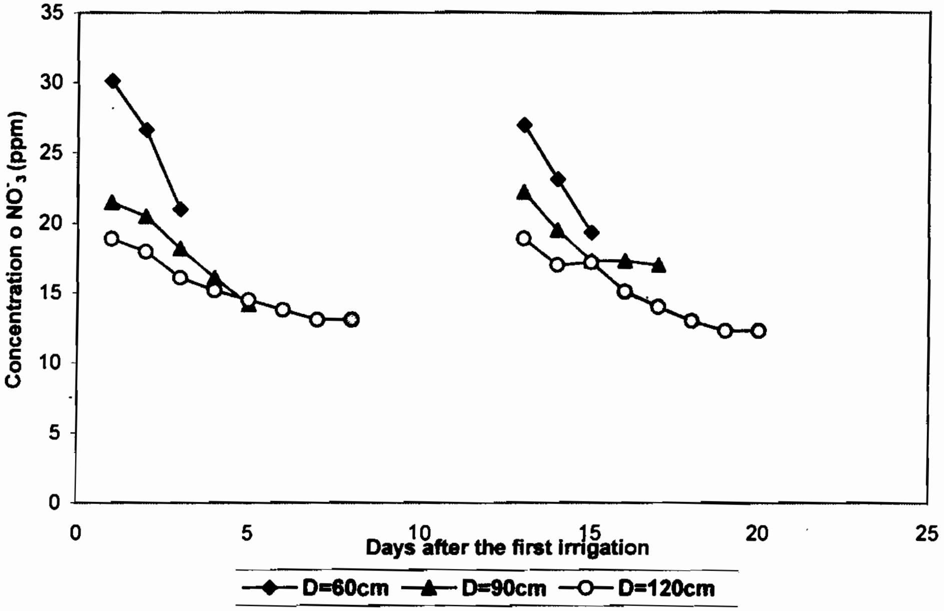


Fig. (7): Average concentration of NO_3^- in the water of suction cups at different depths (D) for 60-m spacing.

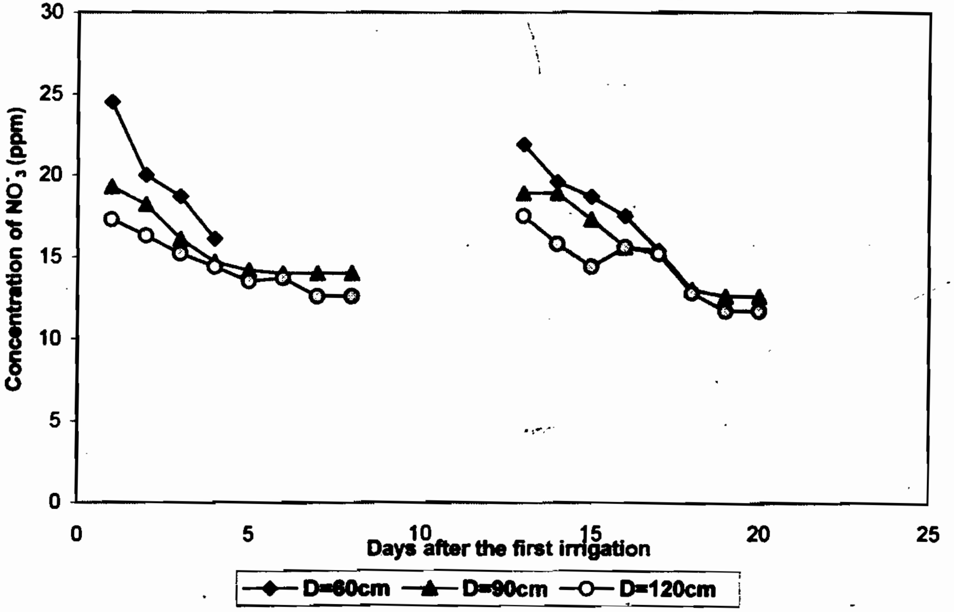


Fig. (8): Average concentration of NO^-_3 in the water of suction cups at 60 cm depth (for 30-m and 60-m spacings)

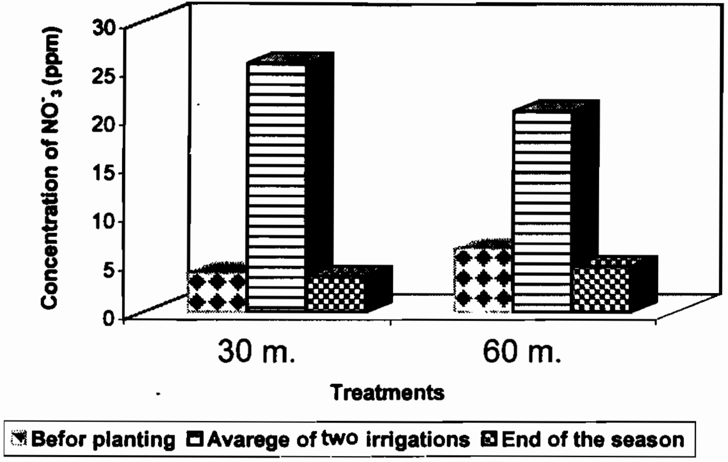


Fig. (9): Average concentration of NO^-_3 in the water of suction cups at 90 cm depth (30-m and 60-m spacings)

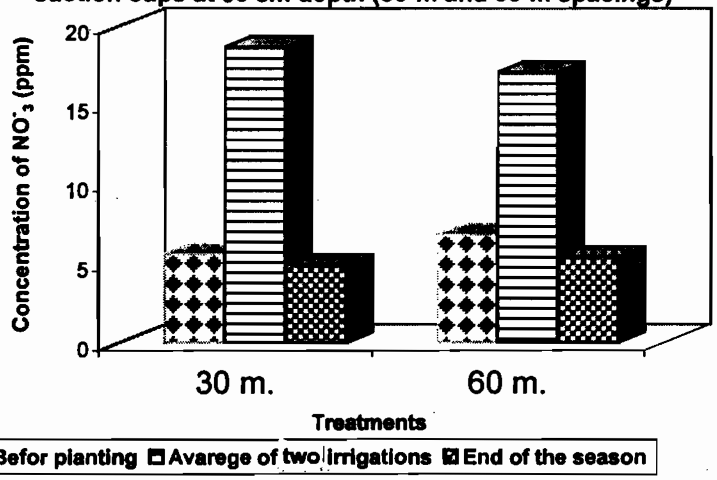
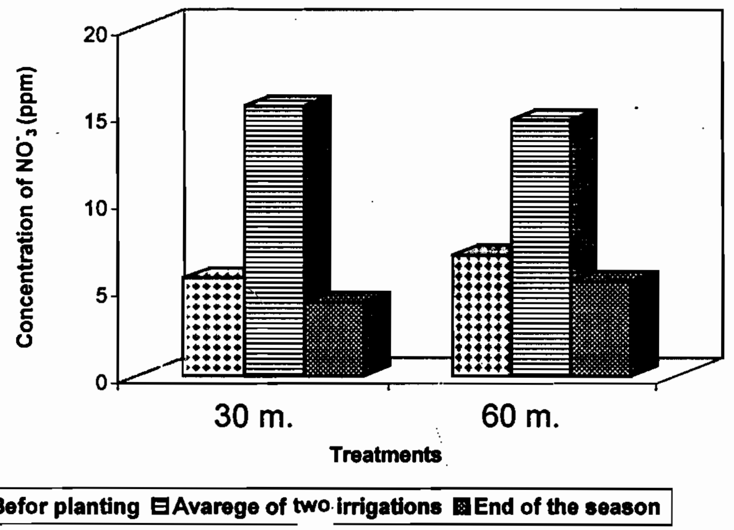


Table 3: Average concentrations of NO_3^- (ppm) in groundwater after two supsequent irrigations, for the 30-m and 60-m drain spacings.

Drain spacing	Before planting	Days after the first irrigation						
		1	2	3	4	5	6	7
30 m	7.0	14.9	16.3	17.2	17.8	16.6	17.2	14.2
60 m	7.5	14.0	14.7	13.7	14.5	14.2	13.8	13.3
	At the end of growing season	Days after the second irrigation						
		1	2	3	4	5	6	7
30 m	6.1	13.1	13.5	13.5	13.1	13.7	13.7	13.5
60 m	6.8	12.0	13.5	14.5	14.9	13.8	13.0	13.3

Fig. (10) :Average concentration of NO_3^- in the water of suction cups at120 cm depth (30-m and 60-m. spacings)



Atrazine:

Concentration of atrazine in tile-drain water is presented in table (4). Atrazine was already detected in subsurface tile flow within 1 day of pesticide application (one day after irrigation). This early arrival of atrazine to drains is consistent with concepts of preferential flow and non-equilibruim sorption/desorption. Preferential flow of atrazine through macropores could be of greater importance in this fine-textered soil. Similar results are found by Kladivko et al. (1991 and 1999). Everts et al. (1989) and Kanwar (1991) also concluded that preferential flow appeared to be the primary mechanism by which adsorbed tracers reached tile drainage. The loss of atrazine in drainage water is greater for 30 m drain-spacing plot than the 60 m one. The maximum contaminant level of 3 µg/L (U.S. Environmental Protection Agency ,1991) for atrzine in drinkiing water was not obtained in tile drainage water.

Table 4: Average concentrations of atrazine (µg/L) in tile drainage water from the 30-m and 60-m drain spacings, after different days from pesticide application.

Treatment	one day	7 days	15 days
30 m	2.37	0.28	0.20
60 m	0.72	0.25	0.25

Atrazine concentrations in soil samples taken at different soil depths are presented in table (5). Atrazine concentration decreased with soil depth. Atrazine concentrations in the soil samples were higher between the drains than above the drain lines, and were higher under 60-m spacing than 30-m spacing. Atrazine was still present in the soil and in drainage water 15 days after application.

Table 5: Average concentrations of atrazine in the soil (µg/Kg) as influenced by soil depth and drain spacing.

Soil depth (cm)	Time after application	30 m spacing		60 m spacing
		Above the drain	Between two drains	Between two drains
0-15	one day	3.34	3.86	6.09
	15 days	0.22	0.77	0.90
15-30	one day	2.82	3.05	3.04
	15 days	0.48	1.10	1.86
30-60	one day	1.93	1.64	3.04
	15 days	0.48	0.79	1.56

The lower discharge under 60 m spacing (Fig.3) resulted in lower concentration of NO_3^- and atrazine in drainage water compared to 30 m one (Figs. 4 and 5; table 4). This may be attributed to greater preferential flow of pesticide and nitrate with drain spacings of 30 m than 60. In this concern, Bolton et al., (1970) showed that the volume of water drained under a particular crop was the most important factor affecting nutrient loss. Total mass of NO_3^-, atrazine and water removed by subsurface drains on a per area basis was greater for the

30-m spacing than the 60-m spacing. This may be attributed to the greater drainage efficiencey under 30 m than 60 m. Herbicide and NO_3^- leaching is most significant during the periods when most of the drainflow occurs.

Drainage studies can be useful for assessing the impact of agricultural management practiices on surface and ground water quality. The concentrations of NO_3^- in the water of the suction cups and in groundwater reduced with the increasing soil depth and distance from the drain lines, but with many excpetions. Subsurface drains integrate the effects of spatial variability on a field scale and may be a better tool for studing chemical leaching than many other measurement methods such as suction cups and soil cores (Richards and Steenhuis, 1988). The narrow drain spacing (30 m) generally had greater leaching losses of herbicides to the drains than did the wide drain spacing (60 m). The wider drain spacings could perhaps have greater deep seepage losses of pesticides than the narrow drain spacings, but they also have longer travel times for water and chemicals originating from greater distances from the drains. These longer travel times would allow more of the chemical to be degraded before it reaches the drain. Kladivko et al. (1999) showed that preferential flow of pestcides to the drains was less important on the wide drain spacing than on the narrow drain spacing, suggesting that preferential flow to shallow tile drains is of most significance in the close vicinity of the drains.

Grain yield and N uptake:

Grain yield of corn from the 30-m drain spacing plots was significantly greater than the 60-m spacing plots (table 6). The total N uptake by corn was paralleled to the yield results, whereas more N was obtained in the plots of 30 m drain spacing treatment than the 60 m treatment. Since a total of 120 Kg N/fed was applied to all corn treatments, the N uptake in grains, leaves and steems were 2.561%, 1.085 % and 1.073 % for 30 m drain spacing. The corresponding values for 60 m drain spacing were 2.514%, 1.062% and 1.044% , respectively. This N was removed from the site with the plant was therefore not available for leaching. The primary loss of N from the corn field was through tile drainage. Through proper drainage system improved yields and N uptake in grain lowered leaching losses is possible. In this concern, Kladivko et al. (1991) reported that lower corn yields and crop uptake can result in increased NO_3^- concentrtation in tile drainage.

Table 6 Corn grain yield and N uptake by plant for 30-m and 60-m drain spacing treatments.

Treatment	Grain yield (Kg/fed)	N uptake (%) in		
		Grains	Leaves	Steems
30 m	4976	2.561	1.085	1.073
60 m	4596	2.514	1.062	1.044

Conclusion:

Results of this study indicated that atrazine contaminated the tile drainage water from clay soil. The majority of the herbicides losses to the tile occurred during the first drainage event (after the first irrigation) following application. Research and management efforts should be focused on minimizing this early movement or preferential flow, because the remainder of the season contributes very little to total mass losses of pestcides. Preferential flow may be the major transport mechanism of importance for pesticides on fine-textured soils. Convective transport through the soil matrix appears to be so slow that degradation or irreversible sorption may prevent most of the rest of the pesticide from ever leaching to the tile depth. Similar results were found by many researchers (Everts et al., 1989; Kladivko et al., 1991; Buhler et al., 1993; Kladivko et al., 1999; Moorman et al.,. 1999). Atrazine transport was event-driven with peak concentrations occurring at the beginning of each new flow (irrigation and drainage) event. The concentrations dropped as the flow event continued.

Nitrate transport, however, occurs throughout the season, and the major mass losses occur when the majority of the water flow occurs. Similar results were found by Czapar et al.(1994) ; Jayachandran et al. (1994); Randall et al. (2000). Research should be focused on understanding preferential flow mechanisms in fine-textured soils and desiging practical strategies to minimize this flow during the first few irrigations after chemicals application. Continued research is also needed on ways to better predict and apply N to more closely match the needs of the crop and minimize N present in the soil at the end of the growing season.

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إنتقال الأترازين والنترات فى أرض طينية إلى المصارف الحقلية المغطاة ذات المسافات المختلفة

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يعتبر فقد الكيماويات فى ماء الصرف هاما في تحديد نوعية المياه، كما أن فقد النترات في ماء الصرف يعتبر خسارة اقتصادية . ولقد أجريت هذه الدراسة الحقلية بهدف تقدير

إنتقال النترات، ومبيد الاترازين فى أرض طينية بشمال الدلتا (مركز فوة – محافظة كفرالشيخ). وذلك تحت ظروف صرف مغطى بأبعاد مصارف تساوى ٣٠م ، ٦٠م . زرعت أرض التجربة بالذرة وأضيف لها أثناء الزراعة ١٢٠ كجم نتروجين / فدان على صورة يوريا ، ٠,٧٥ كجم اترازين/فدان بالرش. وقد تم قياس مستوى الماء الأرضي يوميا بواسطة آبار ملاحظة وأخذت عينات مياه منه بصفة دورية .ولقد تم قياس تصريف المصارف يومياً . وتم تقدير كل من النترات والأترازين فى الأرض والماء الجوفى خلال موسم النمو . كما أخذت عينات مياه بصفة دورية من ماء الصرف والماء المتجمع فى أكواب مسامية موضوعة فى الارض على مسافات مختلفة من المصرف وعلى أعماق مختلفة قدر فيها كل من النترات والاترازين . وفى نهاية الموسم تم تقدير محصول الحبوب ومقدار النتروجين الكلي في أجزاء النبات المختلفة.

ولقد أوضحت نتائج الدراسة أن مستوي الماء الأرضي مرتفع وأن معدل تصرف المصارف كان أعلى للمصارف التى على أبعاد ٣٠م (٠,٣٢ – ١٣,٣٣مم/يوم) مقارنة بالتى على ابعاد ٦٠م (٠,٤٤ – ٩,٧٣مم/يوم) ويقل محتوى الأرض من النترات بزيادة العمق وزيادة المسافة من المصرف . ومحتوى النترات فى الأرض خلال موسم النمو يتراوح بين ٢٨ – ٥٩,٥ جزء فى المليون ويقل فى نهاية الموسم إلى ١١ – ٢٨,٥ جزء فى المليون .ومحتوى النترات فى ماء الصرف خلال موسم النمو يقل مع الوقت ويتراوح بين ١١,٢ – ١٦,٨ ملليجرام/لتر ويكون أعلى بالنسبة للمصارف التى على أبعاد ٣٠م عن تلك التى على أبعاد ٦٠م ، بينما يلاحظ العكس فى نهاية موسم النمو . كما وجد أن محتوى الماء الجوفي من النترات يتراوح بين ١٢ – ١٧,٨ جزء فى المليون ويكون أعلى تحت أبعاد المصارف ٣٠م مقارنة بالتى على أبعاد تعادل ٦٠م. ويقل محتوى النترات بالماء المأخوذ من الأكواب المسامية مع الوقت ومع زيادة عمق الأرض والبعد عن المصرف ، وهذا يدل على إنتقال النترات إلى المصارف.

ولقد تم ملاحظة الأترازين فى ماء الصرف بعد مرور يوم واحد من إضافته للأرض وهذا الوصول المبكر للمبيد إلى المصارف سببه ما يسمى بالسريان المفضل أو السريع (preferential flow) . ونجد أن محتوى الأترازين فى ماء الصرف من المصارف التى على أبعاد ٣٠م أعلى من المصارف التى على أبعاد ٦٠م . ويقل الأترازين فى عينات الارض مع زيادة العمق ويكون أكثر بين المصارف عنه فوق المصرف وأعلى فى معاملات الـ٦٠م عن الـ٣٠م . ويلاحظ وجود الاترازين فى الأرض وماء الصرف بعد ١٥ يوم من الإضافة.

وأوضحت النتائج أيضاً أن محصول الحبوب وامتصاص نبات الذرة للنيتروجين كان أعلى تحت أبعاد المصارف ٣٠م مقارنة بالتى على أبعاد ٦٠م . ونخلص من هذه الدراسة أنه يحدث حركة سريعة للمبيد والنترات إلى المصارف . ويجب أن تركز الأبحاث القادمة على تقليل هذه الحركة السريعة أثناء الريات الاولى بعد إضافة الكيماويات إلى الارض . ويجب أن يستمر البحث أيضاً لتحديد أنسب طرق إضافة النيتروجين التى تقابل فقط احتياجات النبات بحيث نقلل تواجد النيتروجين فى الأرض فى نهاية موسم النمو.