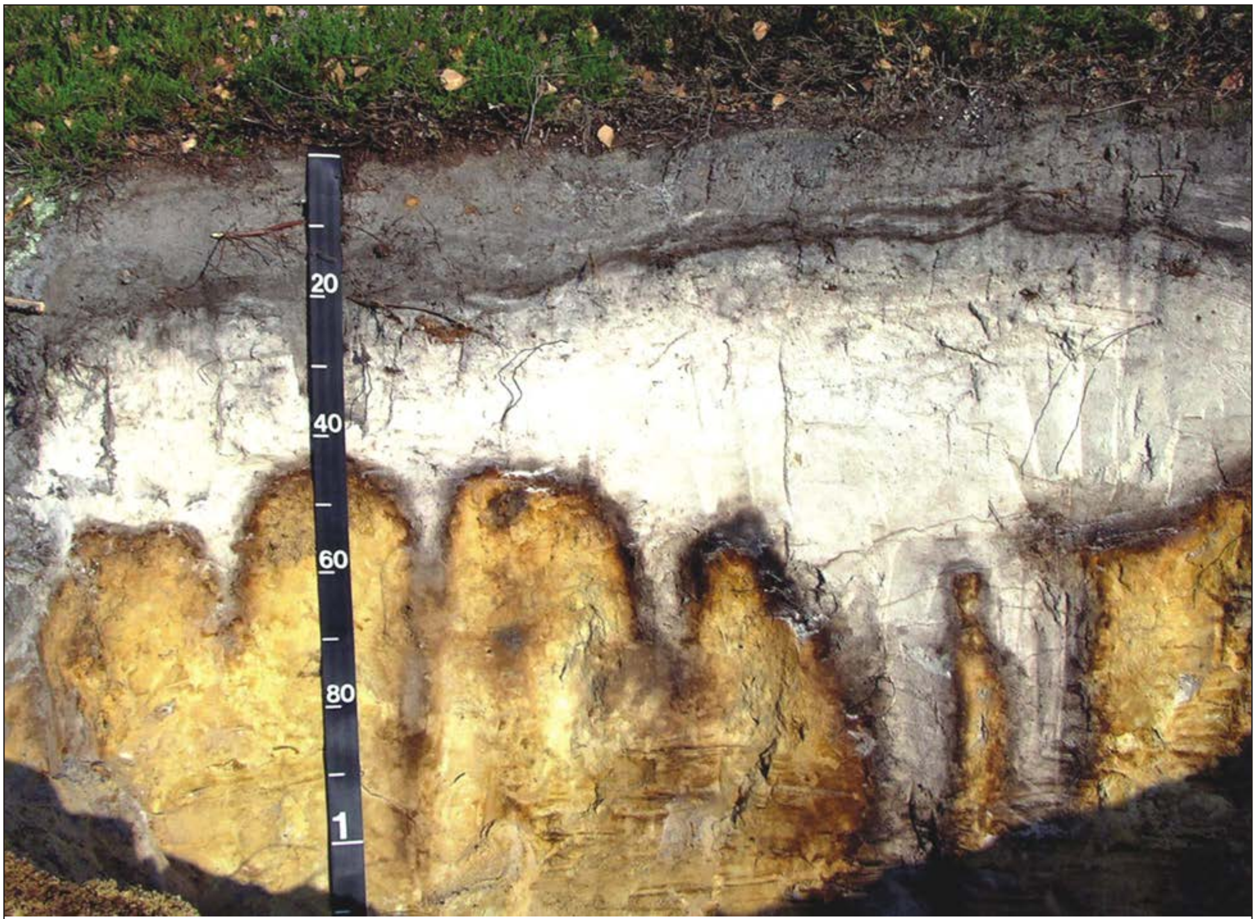

International Journal of
Soil Science

ISSN 1816-4978

Academic
Journals Inc.

www.academicjournals.com

International Journal of Soil Science 4 (3): 80-92, 2009
ISSN 1816-4978

Reuse of Date Palm by-Products for Efficient Use of Nitrogen Fertilizer

A.A. Al Al-Shaikh, G. Abdel-Nasser and A. Sh. Sallam
Department of Soil Sciences, College of Food and Agricultural Sciences,
King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

Abstract: The present study aims to improve the efficiency of nitrogen fertilizer applied to soil by reuse of date palm by-products after grinding and mixing with sandy loam soil. The date palm by-products collected from different areas, then air dried and grinded. Two fractions selected (i.e., less than 0.5 and 1-2 mm size). The powder mixed with sandy loam soil at the rates of 0.0, 1.0, 2.5, 5.0, 7.5 and 10.0% (w/w). The treated soil incubated at field capacity in plastic container for 30 days. After the incubation period, the soil was air dried and passed through a 2.0 mm sieve. The physical and chemical analyses of sandy loam and treated soils performed. The PVC transparent columns with of 6.0 cm diameter and 30.0 cm length packed with sandy soil at 1.6 g cm^{-3} soil bulk density to 20 cm depth and then a 5 cm surface layer of treated soil applied. The soil columns arranged as follows: 1) size fraction of date palm by-product, 2) the rate of date palm by-products applications and 3) rate of water applied (5 and 10 pore volumes). The fertilizer applied at the required rate (250 mg L^{-1}) to soil surface and then the water applied at required rates (0.2 and 0.4 cm min^{-1}). The leachate out of soil columns received. Volume of leachate and concentration of NO_3 was determined. At the end of experiment, the soil was cut to 2.5 cm slices for determining the soluble NO_3. Total NO_3 in soil and percolate were calculated and then the loss of fertilizers and fertilizer use efficiency calculated under the experimental conditions. The results showed that increasing the rate of date palm by-products reduced the NO_3 in leachate and increased NO_3 in soil columns. In addition, increasing water application rate increased fertilizers loss in the leachate. The fine fraction of date palm by-products reduced the NO_3 leaching out of soil by about 14.86 and 5.90% for low and high water application rate, respectively in case of fine fraction, reduced nitrate losses. The corresponding values for coarse fraction were 9.73 and 4.35%, respectively. According to the present results, it is possible to reuse the date palm by-products for increasing the fertilizers use efficiency and reduces the problems of groundwater pollution and accumulation of these by-products in farm.

Key words: Date palm by-product, nitrate losses, nitrate leaching, fertilizer, use efficiency, groundwater pollution

INTRODUCTION

With high rate and expense of N fertilizer presently used in modern agriculture, the nitrate leaching from agricultural soils has long considered as a major environmental problem.

Corresponding Author: A.A. Al Al-Shaikh, Department of Soil Sciences,
College of Food and Agricultural Sciences, King Saud University,
P.O. Box 2460, Riyadh 11451, Saudi Arabia

Several investigators have identified the most decisive factors determining the magnitude of leaching losses (Avnimelech and Raveh, 1976; Gustafson, 1983; Bergstrom and Brink, 1986; Bergstrom and Johansson, 1991).

The pollution of groundwater by nitrate is an international problem (Spalding and Exner, 1993; Zhang *et al.*, 1996), where in some countries has worsened in the recent years (Roberts and Marsh, 1987; Betton *et al.*, 1991). One source of nitrate is inorganic nitrogen fertilizers and there is many literature on the link between agriculture and nitrate pollution (Royal Society, 1983; National Research Council, 1993; Criado, 1996).

Soil texture, organic matter content, water flux, fertilizer type, fertilizer application rates and method of fertilizer application can have a major influence on nitrate leaching. The problem encountered when comparing NO_3-N leaching from different soils under field conditions (Abdel-Nasser, 2001, 2005; Al-Darby and Abdel-Nasser, 2006). It is known that NO_3-N leaching from sandy soil is generally greater than that from clay soils, but it is not generally recognized that macropore flow may be an important reason for this difference (Al-Darby and Abdel-Nasser, 2005; Simmelsgraad, 1998; Hoffmann and Johansson, 1999).

Many regions in the world used the groundwater as the only source of drinking water and agricultural use. Nitrate in drinking water becomes a significant concern only when people drink from a water supply that is highly contaminated with nitrate (such as groundwater). Nitrate poisoning of infants during the first three to four months of life is the major concern, in which nitrate can oxidizes the iron of hemoglobin in blood to form methemoglobin and cause a condition called methemoglobinemia (Shih *et al.*, 1997).

Column and lysimeter studies offer a good way of conducting controlled experiments under laboratory and field conditions (Bergstrom, 1990; Bergstrom and Johansson, 1991). Nitrate leaching from many types of soils or under different N-fertilization can be compared simultaneously in such cases using numerical models.

Therefore, the present study aims to reduce NO_3 losses and improves the efficiency of nitrogen fertilizer applied to soil by reuse of date palm by-products after grinding and mixing with sandy loam soil.

MATERIALS AND METHODS

Soil

The soil used in the present experiment was collected from surface layer (0-30 cm) from Kharj Government (Haradh road), Riyadh, Saudi Arabia. The texture was sandy loam. Some physical and chemical properties performed according to the methods described in Klute (1986). The results are presented in Table 1.

Soil Columns

The PVC transparent columns have an ID of 6.0 cm and a length of 30.0 cm. The base of column tightly sealed with silicone adhesive. At the base of columns, a glass tube with 5 mm diameter attached to collect the leachate. The columns were carefully hand-packed with air-dried soil to the desired bulk density (1.60 Mg m^{-3}) by gentle tapping .The columns filled to a depth of 20.0 cm.

Date Palm by-Products Powder

By-products of date palm cultivation were collected from many orchards from Al-Waseel area, Riyadh, Saudi Arabia and air-dried for one month then grounded to pass through 0.5 (fine fraction) and 1.0-2.0 mm (coarse fraction) sieve as a source of organic matter (during the

Table 1: Some physical and chemical properties of soil used in the present study

Parameters	Value
Particle size distribution (%)	
Sand	81.9
Silt	2.50
Clay	15.6
Textural class	Sandy loam
Calcium carbonate content (%)	9.29
Organic matter content (%)	0.05
pH	8.30
EC_e (dS m^{-1})	0.92
Soluble Cations (meq L^{-1})	
Ca^{2+}	6.25
Mg^{2+}	2.00
Na^{+}	1.60
K^{+}	0.45
Soluble Anions (meq L^{-1})	
CO_3^{+}	0.00
HCO_3^{-}	3.00
Cl^{-}	2.00
SO_4^{+}	5.30
NO_3 (2 M KCl extraction) (mg L^{-1})	32.0

Table 2: Particle fractionation of date palm by-product powder and mean weight diameter (mm)

Particle diameter	Mean diameter	Fine fraction (0.5 mm)	Coarse fraction (1-2 mm)
(mm)		(%)	
>2.0	3.000	0.00	1.41
2.0-1.0	1.500	0.50	55.81
1.0-0.850	0.925	0.70	30.66
0.850-0.500	0.675	5.02	3.71
0.500-0.250	0.375	32.80	5.71
0.250-0.150	0.200	25.38	1.20
0.150-0.125	0.138	10.73	0.20
0.125-0.106	0.116	9.53	0.20
0.106-0.075	0.091	9.03	0.30
0.075-0.063	0.069	2.11	0.20
0.063-0.053	0.058	1.91	0.20
0.053-0.038	0.046	1.50	0.20
<0.038	0.019	0.80	0.20
MWD* (mm)		0.26	1.21

*Mean weight diameter

period of May to August, 2008). The date palm by-products powder were tested at rates namely; zero, 1, 2.5, 5, 7.5 and 10% (w/w). Date palm by-products powder; 0.5 (fine) and 1.0-2.0 mm (coarse) fractions were mixed with sandy loam soil at desired rates and incubated for one month before starting the experiments during March 2009. The mixed soil added to the soil columns as top surface layer of 5 cm. Date palm by-product powder and the mixed sandy loam soil were analysis for some physical and chemical properties according to the recommended methods outlined in Klute (1986). Table 2 shows the particle size distribution of the date palm by-products powder. The results showed that MWD (Mean weight diameter) was 0.26 and 1.21 mm for fine and coarse fractions, respectively (Van Bavel, 1950).

Soil Hydraulic Properties

The soil water retention function, θ (h) and the unsaturated hydraulic conductivity function, k (h) of sandy loam soil and soil mixed with date palm by-product powder are determined according to the Mualem-van Genuchten model (Mualem, 1976; Van Genuchten, 1980) using the RETC model (Van Genuchten *et al*., 1991). Table 3 shows the recorded results.

Table 3: Parameters of soil hydraulic function for sandy loam and soil mixed with date palm by-products powder

Rate (%, w/w)	SOM (%)	θ_r ($cm^3\ cm^{-3}$)	θ_s ($cm^3\ cm^{-3}$)	α (cm^{-1})	n	K_s ($cm\ min^{-1}$)	ι	ρ_b ($g\ cm^{-3}$)
Fine fraction								
0	0.16	0.0481	0.3728	0.0511	1.6059	0.656	0.5	1.60
1	1.40	0.0561	0.4224	0.0484	1.6099	0.623	0.5	1.51
2.5	2.43	0.0660	0.4800	0.0461	1.6064	0.590	0.5	1.43
5	3.70	0.0854	0.6144	0.0450	1.6055	0.558	0.5	1.36
7.5	5.57	0.1004	0.7040	0.0425	1.5977	0.525	0.5	1.31
10	8.34	0.1165	0.7872	0.0380	1.6163	0.459	0.5	1.27
Coarse fraction								
0	0.16	0.0481	0.3728	0.0511	1.6059	0.656	0.5	1.60
1	1.02	0.0522	0.3904	0.0477	1.6092	0.642	0.5	1.54
2.5	1.90	0.0615	0.4224	0.0427	1.6163	0.619	0.5	1.48
5	3.20	0.0758	0.4513	0.0289	1.6223	0.591	0.5	1.41
7.5	4.91	0.0939	0.5121	0.0234	1.6322	0.536	0.5	1.37
10	7.02	0.1107	0.5443	0.0174	1.6755	0.514	0.5	1.32

θ_r: Residual soil water content, θ_s: Saturation soil water content, α and n: Shape parameters, K_s: Saturated hydraulic conductivity ($cm\ min^{-1}$), ι: Pore connectivity parameter and ρ_b: Soil bulk density ($g\ cm^{-3}$)

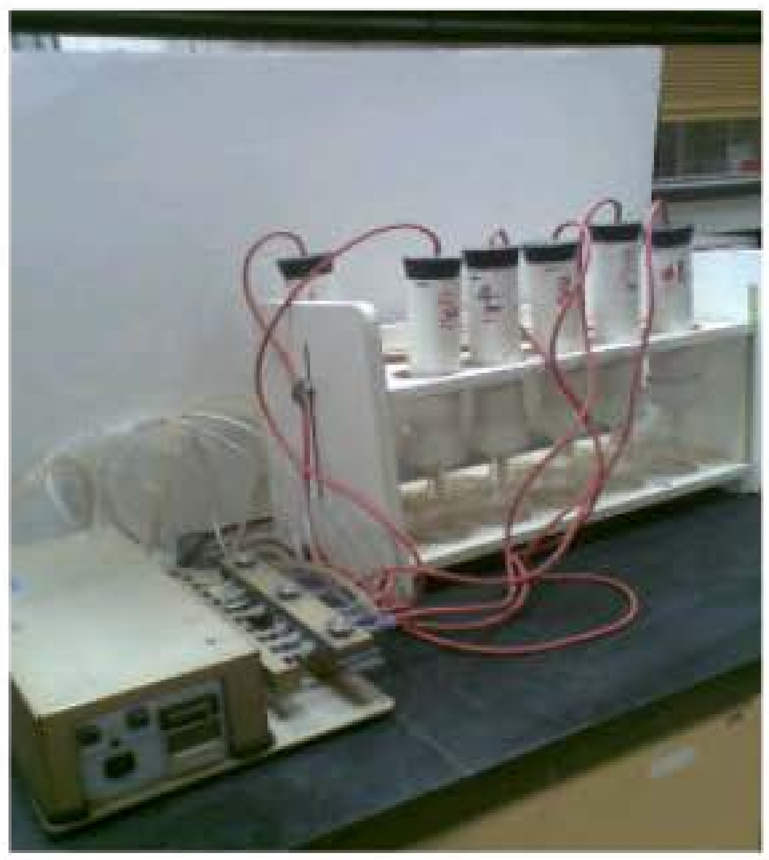

Fig. 1: A picture of the column experiment for nitrate leaching

Water and Nitrate Application

The soil columns saturated by adding water from bottom of each column to reach saturated conditions, for one day. Then the soil columns left to drain the excess water for one day to reach a field capacity conditions (this condition checked by taking a soil samples from a separate columns to check the soil water content). Nitrate solution (250 NO_3 mg L^{-1}) applied for 60 min at steady state rate using multi-syringe pump and then water applied at the same steady-state rate for 300 min (Fig. 1). The water or nitrate solution applied at two different constant rates namely; 0.2 and 0.4 cm min^{-1}. The soil columns were monitored for collecting the leachate at time interval of 15 min for 2 h and then 30 min for the rest time, 4 h (Abdel-Nasser, 2001, 2005).

Leachate Sampling

Water draining through the bottom of the soil columns led to glass collecting bottles that weighed at different periods to determine the drainage volume. Sub sample then taken from the accumulated leachate for determination of NO_3 concentration. The NO_3 flux calculated by multiplying leachate volume (cm^3) by the NO_3 concentration (mg L^{-1}). The NO_3 concentration was determined according to the method of Norman *et al*. (1985).

Soil Sampling

At the end of experiment, the soil sectioned at 2.5 cm for 10 cm depth and at 5.0 cm for the rest of each soil column to determine the concentration of nitrate by shaking 20 g samples of the soil with 50 mL of 2 M KCl solution for 30 min (MAFF, 1986). The NO_3 concentration measured by dual wavelength method using the scanning spectrophotometer (Norman *et al*., 1985).

Statistical Analysis

The treatments arranged in three-factor experiment. All the treatments were present in each of the three fully replicated, randomized blocks of split-split plot design, with water flux density as the main factor and fraction size and rates as the splitting factors. Statistical tools used included descriptive statistics, regression and correlation analysis. The analysis of variance performed according to SAS (2000). Least significant difference test was also used for means comparison at 95% confidence level ($p = 0.05$).

RESULTS

Nitrate Flux at Lower Boundary Condition

The observed NO_3 concentrations in the leachate at different time intervals as affected by water flux density and date palm by-products powder are shown Table 4 and 5. Both

Table 4: Nitrate concentration (mg L^{-1}) in the leachate of soil amended with fine fraction of date palm by-products powder at low and high water flux rates

	Date palm by-products rate (%)					
Time (min)	0	1	2.5	5	7.5	10
Low water flux						
15	0.0	0.0	0.0	0.0	0.0	0.0
30	0.1	0.0	0.0	0.0	0.0	0.0
45	133.1	114.9	96.7	61.2	44.5	28.9
60	237.9	230.1	217.7	194.8	180.9	160.6
75	249.9	244.8	233.9	226.8	219.0	211.8
90	242.8	240.8	230.4	226.7	221.6	216.2
105	131.3	133.8	145.4	165.7	169.2	177.4
120	15.7	20.3	26.6	45.7	57.5	63.5
150	0.0	0.0	0.0	0.2	0.4	1.1
180	0.0	0.0	0.0	0.0	0.0	0.0
240	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0
360	0.0	0.0	0.0	0.0	0.0	0.0
High water flux						
15	0.0	0.0	0.0	0.0	0.0	0.0
30	229.3	226.0	218.0	195.7	169.3	147.3
45	245.1	243.1	243.3	241.3	243.3	240.2
60	245.1	243.1	243.3	241.4	243.9	241.5
75	239.6	238.8	240.2	240.1	243.4	241.1
90	21.1	25.2	31.3	50.9	84.8	102.7
105	0.0	0.0	0.1	0.3	1.5	2.9
120	0.0	0.0	0.0	0.0	0.0	0.0
150	0.0	0.0	0.0	0.0	0.0	0.0
180	0.0	0.0	0.0	0.0	0.0	0.0
240	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0
360	0.0	0.0	0.0	0.0	0.0	0.0

Table 5: Nitrate concentration (mg L^{-1}) in the leachate of soil amended with coarse fraction of date palm by-products powder at low and high water flux rates

	Date palm by-products rate (%)					
Time (min)	0	1	2.5	5	7.5	10
Low water flux						
15	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0
45	133.1	127.4	114.5	101.3	78.9	70.1
60	238.0	234.2	229.7	223.5	215.1	206.7
75	250.0	246.6	241.2	237.6	234.1	228.6
90	242.9	241.7	237.6	233.8	232.5	227.8
105	131.4	128.4	137.4	142.4	150.2	153.3
120	15.7	18.9	20.5	23.6	32.2	36.1
150	0.0	0.0	0.0	0.0	0.1	0.1
180	0.0	0.0	0.0	0.0	0.0	0.0
240	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0
360	0.0	0.0	0.0	0.0	0.0	0.0
High water flux						
15	0.0	0.0	0.0	0.0	0.0	0.0
30	233.9	231.3	228.0	222.8	212.7	207.1
45	250.0	248.4	245.3	244.1	242.3	239.6
60	250.0	248.4	245.3	244.1	242.3	239.6
75	244.4	243.2	242.2	240.6	240.1	237.5
90	21.5	22.0	27.3	28.1	37.4	40.8
105	0.0	0.0	0.0	0.0	0.1	0.1
120	0.0	0.0	0.0	0.0	0.0	0.0
150	0.0	0.0	0.0	0.0	0.0	0.0
180	0.0	0.0	0.0	0.0	0.0	0.0
240	0.0	0.0	0.0	0.0	0.0	0.0
300	0.0	0.0	0.0	0.0	0.0	0.0
360	0.0	0.0	0.0	0.0	0.0	0.0

water fluxes were able to move the NO_3 out of the soil columns according to their intensities. The NO_3 concentration at lower boundary increased as water flux increased. The maximum NO_3 flux attained early with highest water application rate (0.4 cm min^{-1}) and then delayed as the water flux density decreased. This result is true for both date palm by-product fractions (fine and coarse fraction), but the concentration of NO_3 in leachate was higher in case of coarse fraction (1-2 mm size). In addition, the results indicated that increasing the application rate of date palm by-product powder decreased the NO_3 concentration in leachate. The maximum NO_3 concentration in the leachate attained after 75 min in case of low water flux (0.2 cm min^{-1}) but it attained after 45 min in the case of high water flux (0.4 cm min^{-1}).

Nitrate Distribution Profile

Nitrate distribution profile at different date palm by-product fractions and water flux shown in Fig. 2a-d. The data clearly indicate that the NO_3 ion was concentrated in the surface layer of soil columns down to 7.5 cm with low water flux and 10 cm with high water flux. The NO_3 concentration was higher in the top 5 cm of soil column and then decreased in the following 2.5 cm. Other soil depths are NO_3-free down to the lower end of soil columns. Nitrate concentration in the top soil layer increased with increasing the application rate of date palm by-product powder. The soil mixed with fine fraction of date palm by-products powder tends to contain more NO_3 concentration than soil mixed with coarse fraction. Increasing water flux tends to decrease the NO_3 concentration in soil columns. The high water flux was able to move more NO_3 out of soil columns.

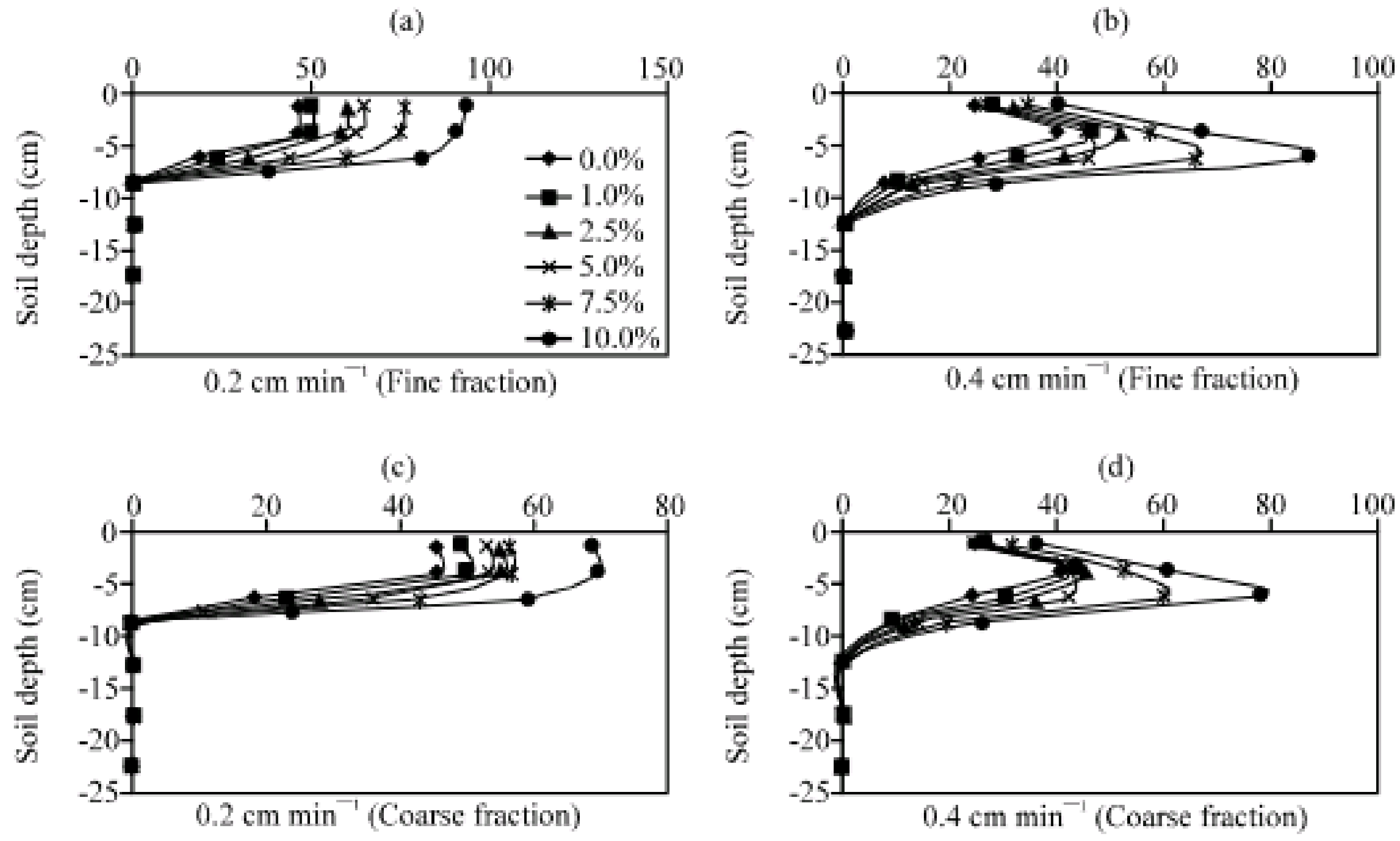

Fig. 2: (a-d) Nitrate concentration in solution of soil amended with date palm by-products at two water flux rate

Table 6: Mass balance recovery (mg) of nitrate in soil columns amended with fine fraction of date palm by-products powder

	Date palm by-products rate (%)					
Type	0	1	2.5	5	7.5	10
Low water flux (0.2 cm minG^1)						
Leachate	74.00	72.00	69.50	67.50	65.50	63.00
Soil solution	2.50	3.10	4.20	5.90	8.00	10.90
Total	76.50	75.10	73.70	73.40	73.50	73.90
Nitrate added	76.50	76.50	76.50	76.50	76.50	76.50
Mass recovery (%)	100.01	98.22	96.38	95.91	96.07	96.61
High water flux (0.4 cm minG^1)						
Leachate	150.70	149.00	148.00	145.20	143.40	141.80
Soil solution	2.30	3.00	3.80	4.20	6.10	8.10
Total	153.00	152.00	151.80	149.40	149.60	149.90
Nitrate added	153.00	153.00	153.00	153.00	153.00	153.00
Mass recovery (%)	100.01	99.33	99.25	97.66	97.75	98.00

Mass Balance Recovery

Table 6 and 7 show the mass balance recovery calculations of NO_3 in soil columns for different treatments. The results presented the NO_3 balance sheet (inflow and outflow calculations). The results indicated that mixing the date palm by-products powder with soil decreased the amount of NO_3 moved out the soil column and increased the amount of NO_3 retained in soil. The NO_3 mass recovery (%) was ranged between 95.91 and 100.71%. This means that the difference between added nitrate and leached NO_3 was less than 5%. This error accepted in case of laboratory experiments.

Statistical analysis of data presented in Table 8 and 9 indicated that all experimental treatments have highly significant effects on reducing NO_3 leaching out the soil columns and increased the soil retention of NO_3. The differences between treatments also are highly significant (Table 10). Table 11 shows the quadratic polynomial equations for the effect of date palm residues powder on nitrate content in leachate and soil solution. The results indicated that fine fraction of date palm by-products was more efficient by 1.5 times than coarse fraction in reducing nitrate losses by leaching.

Table 7: Mass balance recovery (mg) of nitrate in soil columns amended with coarse fraction of date palm by-products powder at low water flux (0.2 cm min^{-1})

	Date palm by-products rate (%)					
Type	0	1	2.5	5	7.5	10
Low water flux (0.2 cm minG¹)						
Leachate	74.000	72.60	71.10	70.00	68.40	66.80
Soil solution	2.500	3.10	3.90	5.00	6.20	8.20
Total	76.500	75.70	75.00	75.00	74.60	75.00
Nitrate added	76.500	76.50	76.50	76.50	76.50	76.50
Mass recovery (%)	99.980	98.98	98.09	98.04	97.46	98.01
High water flux (0.4 cm minG¹)						
Leachate	151.700	150.50	149.20	147.90	146.70	145.10
Soil solution	2.400	2.80	3.40	4.00	5.60	7.40
Total	154.100	153.30	152.60	151.90	152.40	152.50
Nitrate added	153.000	153.00	153.00	153.00	153.00	153.00
Mass recovery (%)	100.711	100.19	99.72	99.27	99.58	99.64

Table 8: Analysis of variance for nitrate content in leachate

Source of variance	df	SS	MS	F-value	p-value
Water flux density (A)	1	109231.000	109231.00000	757674.31	0.0000
Fraction size (B)	1	74.420	74.42000	516.21	0.0000
Date palm residues rate (C)	5	597.175	119.43500	828.45	0.0000
A×B	1	0.320	0.32000	2.22	0.1428
A×C	5	3.975	0.79500	5.51	0.0004
B×C	5	22.435	4.48700	31.12	0.0000
A×B×C	5	1.495	0.29900	2.07	0.0850
Residual	48	6.920	0.14417		
Total	71	109938.000			

Table 9: Analysis of variance for nitrate content in soil solution

Source of variance	df	SS	MS	F-value	p-value
Water flux density (A)	1	13.520	13.52000	162.24	0.0000
Fraction size (B)	1	7.220	7.22000	86.64	0.0000
Date palm residues rate (C)	5	329.275	65.85500	790.26	0.0000
A×B	1	1.805	1.80500	21.66	0.0000
A×C	5	7.150	1.43000	17.16	0.0000
B×C	5	6.730	1.34600	16.15	0.0000
A×B×C	5	2.875	0.57500	6.90	0.0001
Residual	48	4.000	0.08333		
Total	71	372.575			

Table 10: Mean effect and significance of the experimental treatments

Treatments	Nitrate in leachate (mg)	Nitrate in soil solution (mg)
Mean effect of water flux density		
0.2 cm min^{-1}	69.530	5.290
0.4 cm min^{-1}	147.430	4.430
LSD (p = 0.05)	0.048	0.054
Mean effect of fraction size		
Fine, <= 0.5 mm	107.470	5.170
Coarse, 1.0-2.0 mm	109.500	4.540
LSD (p = 0.05)	0.048	0.054
Mean effect of date palm residues powder rate (%, w/w)		
0.0	112.600	2.430
1.0	111.020	3.000
2.5	109.450	3.830
5.0	107.650	4.780
7.5	106.000	6.480
10.0	104.180	8.650
LSD (p = 0.05)	0.083	0.093

The results, indicated that the percent of NO_3 leaching ranged from 96.71 to 82.36% with low water flux (0.2 cm min^{-1}) and from 98.50 to 92.71% with high water flux (0.4 cm min^{-1}), in

Table 11: Quadratic polynomial equations for the effect of date palm residues on nitrate in leachate and soil solution

Water flux	Fraction size	Quadratic polynomial equation	R^2
Nitrate in leachate (mg)			
0.2 cm min^{-1}	Fine	$Y = 0.0228X^2-0.8998X+73.666$	0.9862
	Coarse	$Y = 0.0448X^2-1.4780X+73.582$	0.9882
0.4 cm min^{-1}	Fine	$Y = 0.0208X^2-0.8271X+151.45$	0.9903
	Coarse	$Y = 0.0343X^2-1.2157X+150.54$	0.9958
Nitrate in soil solution (mg)			
0.2 cm min^{-1}	Fine	$Y = 0.0319X^2+0.5054X+2.6735$	0.9988
	Coarse	$Y = 0.0152X^2+0.3925X+2.6382$	0.9944
0.4 cm min^{-1}	Fine	$Y = 0.0295X^2+0.2509X+2.5681$	0.9824
	Coarse	$Y = 0.0301X^2+0.1832X+2.5271$	0.9939

X is the rate of date palm residues powder (%, w/w). Y is the NO_3 content in leachate or soil solution (mg)

Table 12: Volume of leachate and mean moisture content of soil amended with fine and coarse fractions of date palm residue at two water flux rates

	Low water flux (0.2 cm min^{-1})		High water flux (0.4 cm min^{-1})	
Rate (%)	Volume of leachate (cm^3)	Average soil moisture (cm^3 cm^{-3})	Volume of leachate (cm^3)	Average soil moisture (cm^3 cm^{-3})
Fine fraction				
0	1658.6	0.360	3485.9	0.373
1	1650.2	0.370	3480.0	0.383
2.5	1645.1	0.381	3470.0	0.394
5	1625.0	0.408	3455.0	0.421
7.5	1615.1	0.426	3440.0	0.439
10	1600.7	0.443	3430.0	0.456
Coarse fraction				
0	1657.8	0.355	3485.9	0.372
1	1649.7	0.359	3483.4	0.376
2.5	1641.1	0.366	3479.5	0.382
5	1640.0	0.372	3476.0	0.388
7.5	1622.1	0.385	3467.5	0.400
10	1614.5	0.392	3464.2	0.407

case of soil mixed with fine fraction of date palm by-products powder as application rate increased from 0 to 10% (w/w). It resulted in decreasing the NO_3 leaching by about 14.35 and 5.79% for low and high water flux, respectively. The corresponding values for soil mixed with coarse fraction were from 96.71 to 87.29% and from 99.81 to 94.34% for low and high water flux, respectively. The decreasing in NO_3 leaching was 9.42 and 4.34%, respectively.

Soil Moisture Distribution

The results of the soil moisture distribution in soil columns as affected by water flux density and date palm by-products rate shown Table 12. The data clearly indicate that the mean soil moisture content increased as rate of application increased. The values were ranged from 0.360 to 0.443 cm^3 cm^{-3} with low water flux density and from 0.373 to 0.456 cm^3 cm^{-3} with high water flux density as the rate of fine fraction increased from 0 to 10%. The soil moisture contents were higher in case of fine fraction than coarse fraction. The values for coarse fraction were ranged from 0.355 to 0.392 cm^3 cm^{-3} with low water flux density and ranged from 0.372 to 0.407 cm^3 cm^{-3} with high water flux density as the rate of coarse fraction increased from 0 to 10%. This means that increasing rate of date palm by-products increased the mean soil moisture content. In addition, the soil mixed with fine fraction has more water content than soil mixed with coarse fraction. The soil moisture content reflected on the volume of leachate moved out the soil columns. The results indicated that volume of leachate decreased as increasing of date palm by-products rate and increased with coarse fraction than fine fraction.

DISCUSSION

Nitrate leaching strongly affected by the particle size distribution, the soil porosity and the occurrence of preferential flow paths (Cameria *et al*., 2003). Soils have varied retentive properties depending on their texture and organic matter content (Gaines and Gaines, 1994). Due to the higher proportion of large pores, coarse soils are usually more vulnerable to leaching than clayey soils (Wu *et al*., 1997). Fine soil does not specifically retain nitrate, but water does not pass easily through fine soil. Large surface areas of the individual fine particles and the large number of very small pore spaces can hold a large amount of water. Water filled pores of fine soils lack oxygen. Lacking oxygen, a group of soil bacteria, called facultative anaerobes, substitute nitrate for oxygen for respiration. When bacteria use nitrate as substitute foe oxygen, they convert nitrates to nitrogen gas through a process called denitrification. Nitrate loss through denitrification in fine soils reduces the amount of nitrates that can potentially leach to groundwater (Bhumbla, 2006).

The results clearly indicate that mixing sandy loam soil with date palm by-products powder, fine (less than 0.5 mm size) or coarse (1.0-2.0 mm size) increased the retained water in soil column then reduced the water moved out the soil columns ,therefore reduced the nitrate leaching because of more retention of nitrate in soil. The increased retention of nitrate attributed to the ability of soil mixed with date palm by-product powder to retain more water and consequently more nitrate against leaching.

The large amount of irrigation water used in agriculture makes the risk of leaching nitrates and other chemicals potentially greater in areas that irrigated. The increase in soil moisture that results from irrigation dissolves excess nitrate present in the soil profile and makes it more susceptible to leaching (Casey *et al*., 2002). Higher moisture content will also raise microbial activity including mineralization (Skopp *et al*., 1990). The increase in mineralization rates directly affects nutrient leaching (Doran, 1980).

Mixing the sandy loam soil (which had a coarser texture and lowest organic matter content) with organic matter (date palm by-product) would alter the soil moisture retention characterization (the mixed soil had finer texture and more organic matter content). The mixed soil more retained of nitrate; therefore, the leached nitrate was less than the sandy loam soil. This result confirms the fact that excessive rates of NO_3-N fertilizer avoided for sandy soils than for finer soils due to the low NO_3-N retention (Gaines and Gaines, 1994). The present result is logical because the NO_3-N is non-reactive solute (McMahon and Thomas, 1974). Macro-pore flow may be an important reason for this difference (Hoffman and Johansson, 1999). These differences attributed to the differences in pore size distribution. At pore scale, the variation of water and solute flow may be due to the different velocities of water and solute because of pore groups in soil. Mixing soil with organic matter resulted in decreasing the pore size distribution therefore restricted the water and solute flux in soil. The retention of NO_3-N to soil particles depends on soil type (high content of silt or clay), soil organic matter content and cation exchange capacity.

Nitrates that lost through leaching to groundwater can contribute to the groundwater nitrate pollution. The current public health standards for safe water require that Maximum Contaminant Level (MCL) should not exceed nitrate concentrations of 10 mg L^{-1} as NO_3-N or 45 mg L^{-1} NO_3 (USEPA, 1991, 1996; WHO, 2008).

Nitrate leaching from fertilizer depends upon the fertilizer types (ammonium, nitrate or organic), method of application and climate condition. Nitrate leaching may be greater when fertilizer contains the nitrate compound to the situations where ammonium nitrogen is the major component of a fertilizer (Bhumbla, 2006). Nitrate losses are likely to be higher when all nitrogen applied in one application compared to split application.

To avoid the groundwater pollution, frequent application of light rates of N-fertilizer performed to minimize the losses of NO_3 through soil profile (Petrovic, 1989). Thus, careful matching of nitrogen fertilizer application to crop needs can reduce nitrate leaching. In addition, application of organic matter to soil helps to reduce nitrate leaching. The more efficient technology to reduce the NO_3 leaching may be using the nitrification inhibitors, which when bed with fertilizers, slow the conversion of ammonium into leachable nitrate (Abdel-Nasser and El-Shazly, 1994; El-Shazly and Abdel-Nasser, 2000; Al-Darby and Abdel-Nasser, 2006).

The results clearly indicate that application of organic matter (date palm by-products) to soil increased the retained water in soil column then reduced the water moved out the soil columns, therefore reduced the nitrate leaching because of more retention of nitrate in soil. The increased retention of nitrate attributed to the ability of soil mixed with organic matter to retain more water and consequently more nitrate against leaching.

The present column experiment is useful for assessing relative behavior of NO_3 in soil, at different agricultural practices. Nevertheless, may not be suitable for describing chemical transport in the field scale, since it does not account for many chemical processes; normally occur under natural field conditions, include immobilization, mineralization, nitrification and plant uptake, which result in different amount of nitrogen available for leaching.

ACKNOWLEDGMENT

The authors would like to express great thanks to the Agricultural Research Center and the Deanship of Scientific Research, King Saud University for funding this research through the project supported by Saudi Basic Industries Corporation (SABIC).

REFERENCES

Abdel-Nasser, G. and S. M. EL-Shazly, 1994. The effect of nitrification inhibitor (8-Hydroxyquinoline) applied in combination with urea or ammonium sulphate on growth and leaf mineral composition of Washington Navel Orange plants. Comm. Sci. Dev. Res., 48: 67-82.

Abdel-Nasser, G., 2001. Laboratory study of groundwater pollution with nitrate. 1- Effect of N-fertilization rate and soil texture. J. Agric. Sci. Mansoura Univ., 26: 6591-6606.

Abdel-Nasser, G., 2005. Laboratory study of groundwater pollution with nitrate. 2- Effect of water and olive pomace applications. J. Agric. Sci. Mansoura Univ., 30: 4263-4276.

Al-Darby, A.M. and G. Abdel-Nasser, 2005. Nitrate movement through the unsaturated zone of a sandy soil in Saudi Arabia. Final report, Agriculture Research Center, Financial supported by Deanship of Scientific Research, King Saud University.

Al-Darby, A. and G. Abdel-Nasser, 2006. Nitrate leaching through unsaturated soil columns: Comparison between numerical and analytical solutions. J. Applied Sci., 6: 735-743.

Avnimelech, Y. and J. Raveh, 1976. Nitrate leakage from soils differing in texture and nitrogen load. J. Environ. Qual., 5: 79-82.

Bergstrom, L. and N. Brink, 1986. Effects of differentiated application of fertilizer N on leaching losses and distribution of inorganic N in soil. Plant Soil, 93: 333-345.

Bergstrom, L., 1990. Use of lysimeters to estimate leaching of pesticides in agricultural soils. Environ. Pollut., 67: 325-347.

Bergstrom, L. and R. Johansson, 1991. Leaching of nitrate from monolith lysimeters of different types of agricultural soils. J. Environ. Qual., 20: 801-807.

Betton, C., B.W. Webb and D.E. Walling, 1991. Recent trends in NO3-N concentration and loads in British rivers. IAHS, 203: 169-180.

Bhumbla, D.K., 2006. Agriculture practices and nitrate pollution of water. http://www.caf.wvu.edu/~forage/nitratepollution/nitrate.htm 27.9.2006.

Cameria, M.R., R.M. Fernando and L.S. Pereira, 2003. Monitoring water and NO3-N in irrigated maize fields in the sorraia watershed. Agric. Water Manage., 60: 199-216.

Casey, F.X.M., N. Derby, R.E. Knighton, D.D. Steele and E.C. Stegman, 2002. Initiation of irrigation effects on temporal nitrate leaching. Vadose Zone J., 1: 300-309.

Criado, S.R., 1996. Considerations on main factors which take part in contamination of ground-water in Spain with relationship to other EU Countries. Fertil. Res., 43: 203-207.

Doran, J.W., 1980. Soil microbial and biochemical changes associated with reduced tillage. Soil Sci. Soc. Am. J., 44: 765-771.

EL-Shazly, S.M. and G. Abdel-Nasser, 2000. Influence of some nitrification inhibitors on improving nitrogen fertilizer efficiency and some physiological and biochemical aspects of Flame seedless grapevines. Alex. J. Agric. Res., 45: 249-268.

Gaines, T.P. and S.T. Gaines, 1994. Soil texture effect on nitrate leaching in soil percolates. Comm. Soil Sci. Plant Anal., 25: 2561-2570.

Gustafson, A., 1983. Leaching of nitrogen from arable land into groundwater in Sweden. Environ. Geol., 5: 65-71.

Hoffmann, M. and H. Johansson, 1999. A method for assessing generalized nitrogen leaching estimate for agricultural land. Environ. Model. Assess., 4: 35-44.

Klute, A., 1986. Water Retention: Laboratory Methods. In: Methods of Soil Analysis, Part I, Physical and Mineralogical Methods, Klute, A. (Ed.). Agronomy Monograph No. 9, American Society of Agronomy, Madison, WI. USA., pp: 635-662.

MAFF, 1986. The Analysis of Agricultural Materials. HMSO, London, pp248.

McMahon, M.A. and G.W. Thomas, 1974. Chloride and tritiated water flow in disturbed and undisturbed soil cores. Soil Sci. Soc. Am. Proc., 38: 727-732.

Mualem, Y., 1976. A new model for predicting the hydraulic conductivity of unsaturated porous media. Water Resour. Res., 12: 513-522.

National Research Council, 1993. Soil and Water Quality: An Agenda for Agriculture. National Academy Press, Washington, DC, pp: 516.

Norman, R.J., J.C. Edberg and J.W. Strucki, 1985. Determination of nitrate in soil extract by dual-wavelength ultraviolet spectrophotometry. Soil Sci. Soc. Am. J., 49: 1182-1185.

Petrovic, A.M., 1989. Golf course management and nitrates in groundwater. Golf Course Manage., 57: 5464-5464.

Roberts, G. and T. Marsh, 1987. The effects of agricultural practices on the nitrate concentrations in the surface water domestic supply sources of Western Europe. Int. Assoc. Hydrol. Sci., 164: 365-380.

Royal Society, 1983. The Nitrogen Cycle of the United Kingdom. 1st Edn., Royal Society, London, UK.

SAS Institute, 2000. The SAS System for Windows Version 8. SAS Inst., Cary, NC.

Shih, R.D., S.M. Marcus and C.A. Genese, 1997. Methemoglobinemia attributable to nitrate contamination of portable water through boiler fluid additives. Morb. Mortal. Wkly Rep., 46: 202-204.

Simmelsgraad, S.E., 1998. The effect of crop, N-level, soil type and drainage on nitrate leaching from Danish soil. Soil Use Manage., 14: 30-36.

Skopp, J., M.D. Jawson and J.W. Doran, 1990. Steady state aerobic microbial activity as a function of soil water content. Soil Sci. Soc. Am. J., 54: 1619-1625.

Spalding, R.F. and M.E. Exner, 1993. Occurrence of nitrate in groundwater-A review. J. Environ. Qual., 22: 392-402.

USEPA, 1991. National primary drinking water regulations: Final rule 40 DFR parts 141, 142 and 143. Fed. Res., 56: 3526-3597.

USEPA, 1996. Environmental indicators of water quality in the United States. 1st Edn., EPA, USA., pp: 230.

Van Bavel, C.H.M., 1950. Mean weight diameter of soil aggregates as a statistical index of aggregation. Soil Sci. Soc. Am. Proc., 14: 20-23.

Van Genuchten, M.T., 1980. A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J., 44: 892-898.

Van Genuchten, M.T., F.J. Leij and S.R. Yates, 1991. The RETC Code for Qualifying the Hydraulic Functions of Unsaturated Soils. Agricultural Research Services, California, USA.

WHO, 2008. Guidelines for Drinking Water Quality. 1 Recommendations. 2nd Edn., World Health Organization, Geneva, ISBN: 9789241547611.

Wu, J.J., D.J. Bernardo, H.P. Mapp, S. Geleta and M.L. Teague *et al*., 1997. An evaluation of nitrogen runoff and leaching potential in the high plains. J. Soil Water Conserv., 52: 73-80.

Zhang, W.L., Z.X. Tian, N. Zhang and X.Q. Li, 1996. Nitrate pollution of groundwater in Northern China. Agric. Ecosyst. Environ., 59: 223-231.