Asian Journal of Chemistry Vol. 19, No. 7 (2007), 5639-5646

Investigation of Seasonal Changes in Nitrate Contents of Soils and Irrigation Waters in Greenhouses Located in Antalya-Demre Region

ILKER SÖNMEZ, MUSTAFA KAPLAN and SAHRIYE SÖNMEZ*
Department of Soil Science, Faculty of Agriculture
Akdeniz University, 07059, Antalya, Turkey
E-mail: ssonmez@akdeniz.edu.tr

This study was conducted to determine nitrate contents of soils and irrigation waters obtained from wells in greenhouses located in Antalya-Demre region and to investigate seasonal changes in nitrate contents. From 28 greenhouses, soil samples from 0-20 and 20-40 cm depths and irrigation water samples were collected in 3 different seasons. Analysis showed that average nitrate content in soils at 0-20 cm depth was 141.39 mg kg^{-1} and at 20-40 cm depth 108.14 mg kg^{-1}. During the sampling periods, nitrate contents showed an increase at both depths. The average nitrate content in irrigation water samples was found to be 70.83 mg L^{-1} and showed seasonal changes. Nitrate present in irrigation waters provide an advantage in terms of nitrogen input in agricultural production. However, due to the fact that farmers utilize irrigation waters from wells for both drinking and irrigation purposes, some of the irrigation waters investigated cause health concern as drinking water since their nitrate contents exceed maximum level of 50 mg L^{-1} set by WHO. According to these finding, it is clear that the applications in the region increase ground water pollution. Therefore, it is important to know nitrate content of irrigation waters before their use.

Key Words: Nitrate, Electrical conductivity, Soils, Antalya, Turkey.

INTRODUCTION

With 171316 ha, 35 % of greenhouse area of Turkey is located in Antalya province. Demre is one of the important greenhouse regions in Antalya province with 8874 ha greenhouse area. In Demre region, which is an important vegetable supplier to domestic and international markets, environmental pollution has become a great concern due to intensive agricultural practices. Excessive fertilization was found to increase soil salinity[1] and excessive nitrogen fertilization resulted in nitrate pollution in groundwater[2]. In addition, organic wastes occurring at the end of harvesting period contribute to environmental pollution[3]. Polluted soil and water resources also cause health concern.

Well water is one the main water sources for mankind. Farmers utilize well waters for drinking and irrigation purposes[2]. However, well waters, especially near agricultural areas, are not suitable as drinking water due to hygienic and toxicological factors caused by nitrate leaching from fertilizers to underground and eventually to well waters[4]. High level of nitrate results in reduction of biological activities, childbirth deaths, low childbirth weight and low body weight in farm animals[5]. Nitrate ion itself is not toxic to human body. However, nitrite ion, which is formed as a result of reduction of nitrate, cause a blood disorder called methemoglobinemia (blue baby syndrome) among infants and may lead to infant deaths[6].

In a study conducted with well waters in Antalya-Kumluca region by Kaplan *et al.*[2], nitrate contents of well waters ranged from 2.46 mg L^{-1} to 164.91 mg L^{-1} and EC values from 548 to 1643 dS cm^{-1}. It was found that 50 % of well waters analyzed were polluted by nitrate. The scientists recommended that nitrate contents of these well waters used as irrigation water must be taken into consideration in fertilization programs. However, it was seen that nitrate analysis is not normally included in routine irrigation water analysis in the region.

This study is conducted to determine nitrate contents of soils and irrigation waters obtained from wells in Antalya-Demre region where an intensive greenhouse production is practiced and to investigate seasonal changes in nitrate contents.

EXPERIMENTAL

Soil and water samples were collected 3 times, beginning (October), middle (February) and end (June) of the vegetation period from 28 tomato greenhouses located in Antalya-Demre region. Total of 168 soil samples were collected by using the soil sampling techniques as described by Jackson[7], from depths of 0-20 and 20-40 cm and from locations representing each greenhouse. Total of 84 water samples were taken as described by Ayyildiz[8].

Nitrate content of the soil samples was measured as described by Fresenius *et al.*[9]. 10 g of wet soil were shaken in 50 mL bidestile water for 15 min and extracted using Whatman 42 filter paper. Into 10 mL of this extract 2 mL of 0.5 % Na-salicylate was added and dried at 105ºC. After cooling down in desiccator, 2 mL of H_2SO_4 (d = 1.84 g/cm^3) was added. After the solution was cooled down again, 15 mL double distilled water and 15 mL 40 % NaOH was added and double distilled water was added to the final volume of 50 mL. Nitrate was measured with spectrophotometer at 420 nm. Electrical conductivity (EC) of each soil sample was measured in saturated paste extracts by using conductivity meter[10]. Saturated paste extracts were prepared by adding double distilled water to *ca.* 500 g soil sample with stirring until it reached to a condition of complete saturation[10]. The saturated were allowed to equilibrate for 18 h. The extracts obtained by vacuum was analyzed for EC.

Nitrate in water samples was measured using the similar method used for the soil samples[9]. Two mL of 0.5 % Na-salicylate was added to 10 mL water sample and dried at 105ºC. After cooling down in desiccator, 2 mL H_2SO_4 (d = 1.84 g/cm^3) was added. After the solution was cooled down again, 7.5 mL double distilled water and 7.5 mL 40 % NaOH was added and final volume was made 25 mL and nitrate was measured with spectrophotometer at 420 nm. EC of water samples was measured directly with conductivity meter[11]. As required by the method, nitrate analysis for soil and water samples was done in 12 h after the sample collection.

RESULTS AND DISCUSSION

Nitrate contents and EC values of Demre region greenhouse soils collected from depth of 0-20 cm and 20-40 cm was given in Table-1.

Seasonal changes in average nitrate contents of greenhouse soils located in Demre region was shown in Fig. 1. In soils, at depths of 0-20 and 20-40 cm, average nitrate contents appeared to increase during the vegetation period. Significant relationships at 0.1 % level were observed between sampling periods at both soil depths for nitrate contents (r = 0.837***, r = 0.605*** and r = 0.642***, respectively). The nitrate contents of soils at both depths increased during the sampling period due to nitrogen input through fertilization and irrigation (Table-1). At the depth of 0-20 cm, average nitrate contents were found to be higher than at the depth of 20-40 cm. When the average nitrate value of 3 sampling periods was calculated, the average nitrate content at the 0-20 cm depth was found to be 141.39 mg kg^{-1} while this values was 108.15 mg kg^{-1} at the 20-40 cm depth. Ahnstedt *et al.*[12] observed a similar result that nitrate content decreased with increasing soil depth. The soil depth of 0-20 cm, which is the effective root depth when the fertilization with drip irrigation is practiced, is known to have highest amount of fertilizer concentration. Therefore, high level of nitrate in this depth is expected. Meanwhile, soil depth of 20-40 cm is where nitrate leaches from above and accumulates. Indeed, Ersahin and Karaman[13] reported increasing nitrate levels in groundwater due to nitrate leaching through irrigation.

While nitrate contents of soils at both depths increased during the vegetation period, EC values, in general, showed a decrease during the same time frame (Fig. 1). Statistical analysis showed significant positive relationship between EC and nitrate values at 0-20 cm depth at 0.1 % level for 1st, 2nd and 3rd sampling periods (r = 0.744***, r = 0.641*** and r = 0.801***, respectively). It is thought that when the EC value is high nitrate

TABLE-1
NO_3^- (mg kg^{-1}) CONTENTS AND EC (dS m^{-1}) VALUES OF DEMRE REGION GREENHOUSE SOILS

Greenhouse No	Soil NO_3^- (mg kg^{-1})						Soil EC (dS m^{-1})					
	I Period (cm)		II Period (cm)		III Period (cm)		I Period (cm)		II Period (cm)		III Period (cm)	
	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40
1	220.99	171.47	255.01	132.23	199.02	186.22	8.02	6.65	7.56	5.33	5.67	6.05
2	31.34	12.25	57.14	38.60	129.53	79.02	4.23	3.58	1.81	2.66	3.13	2.59
3	128.14	69.25	265.15	211.39	112.77	141.06	6.84	5.82	6.98	5.85	6.48	6.72
4	19.73	25.01	244.56	217.10	243.94	135.13	4.15	2.90	5.67	6.98	5.34	3.56
5	90.72	39.70	350.46	164.11	277.81	177.02	5.96	4.08	6.05	4.54	5.67	4.32
6	45.07	11.82	177.79	122.00	122.71	92.24	4.95	3.69	3.78	4.32	3.24	3.49
7	51.84	30.16	282.23	77.42	132.06	148.09	3.42	2.19	4.54	2.06	2.83	2.75
8	135.85	96.08	354.61	67.14	214.96	297.15	6.84	4.01	7.56	6.05	5.67	6.98
9	85.35	38.75	197.09	139.26	79.08	53.67	5.54	3.75	3.78	5.04	1.81	2.32
10	122.38	76.73	103.09	105.54	18.52	90.88	6.84	4.47	3.94	2.59	1.68	2.45
11	63.83	27.61	46.34	68.31	686.95	225.95	3.58	2.67	3.94	3.24	9.07	5.67
12	80.45	72.15	43.87	30.54	18.50	31.89	3.69	3.28	3.49	5.34	2.32	2.83
13	102.75	77.30	147.48	94.63	111.29	181.05	5.82	5.06	4.22	6.05	5.67	8.24
14	40.70	98.85	17.15	14.18	112.66	99.24	4.15	4.01	5.34	3.13	5.04	5.85
15	117.30	104.00	57.47	36.18	80.98	123.01	4.95	3.42	4.03	3.49	5.04	4.48
16	147.15	93.50	323.66	190.60	134.21	123.04	4.30	3.88	6.48	2.83	4.48	4.54
17	147.25	81.20	115.78	40.18	134.37	182.03	7.75	5.17	4.77	4.32	5.67	7.56
18	129.45	75.95	47.36	49.98	108.39	160.59	5.96	4.85	5.67	3.78	6.05	6.98
19	125.00	82.55	79.16	36.15	164.11	93.29	4.95	4.01	4.32	4.32	8.24	5.85
20	100.10	65.55	127.74	102.12	46.32	191.80	6.29	6.29	5.67	8.25	5.04	5.34
21	82.80	68.82	231.98	186.26	143.59	129.48	4.95	4.23	5.34	4.12	4.12	4.03
22	109.98	57.91	61.78	90.09	39.44	47.44	5.41	4.56	3.36	4.54	2.83	2.92
23	100.31	60.60	12.06	4.43	38.98	49.84	4.65	2.64	2.16	2.16	1.89	2.12
24	103.03	89.05	338.34	302.70	640.69	251.72	7.75	6.46	6.98	6.05	11.33	8.24
25	145.40	63.45	131.17	333.95	73.50	102.81	8.30	5.06	5.67	4.12	3.78	4.77
26	214.20	208.75	65.70	92.50	79.09	56.26	8.61	7.27	4.32	5.34	4.12	3.49
27	179.40	119.40	137.36	130.87	278.50	269.91	12.24	8.61	8.25	5.67	6.98	9.07
28	82.65	55.60	121.05	111.24	58.63	100.91	4.30	3.75	3.78	3.94	2.83	4.32
Max.	220.99	208.75	354.61	333.95	686.95	297.15	12.24	8.61	8.25	8.25	11.33	9.07
Min.	19.73	11.82	12.06	4.43	18.50	31.89	3.42	2.19	1.81	2.06	1.68	2.12

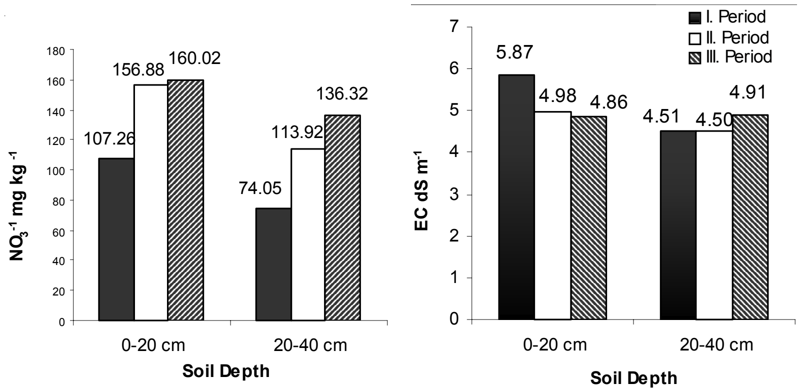

Fig. 1. Seasonal changes of average NO_3^- (mg kg^{-1}) contents and EC (dS m^{-1}) values at 0-20 and 20-40 cm soil depths

is the effective anion and when the EC value is low in soil other anions and cations become effective. The reason for that is the fact that the relation between nitrate application and fertilizer application levels is not strong enough. In some terms nitrate is the primary nutrient applied to soils with fertilizers while in some other terms other cations and anions are added. When the seasonal changes were investigated, no significant relationship was found between EC and nitrate contents.

At the depth of 20-40 cm, positive relations were observed between EC and nitrate contents. In the first and third sampling periods the relations between EC and nitrate values were significant at 0.1 % level (r = 0.667*** and r = 0.782***, respectively). In the second sampling period, however, no significant relation was observed.

Nitrate contents and EC values of irrigation waters obtained from wells in Demre region was given in Table-2.

Average nitrate contents of irrigation waters obtained from wells showed some seasonal changes. In general, in the beginning of the vegetation period, nitrate contents of irrigation waters from wells were high. During the vegetation period, nitrate content were first dropped and then increased. It is thought that the high nitrate content in the beginning of the vegetation period is due to fertilization and irrigation applications in the previous production period causing nitrate leaching and accumulation in aquifers. Indeed, Power and Scheders[14] and Kaplan and Akay[15] pointed out that nitrate pollution in water is mainly caused by irrigation for prevention of salt accumulation in the root zone.

In water, nitrate is one of the effective anions forming EC. According to statistical analysis, there is a relationship between EC values and nitrate contents at 1 % level in the 1st sampling period (r = 0.491**), at 5 % level

TABLE-2
NO_3^- (mg L^{-1}) CONTENTS AND EC (dS cm^{-1}) VALUES OF IRRIGATION WATERS FROM WELLS IN DEMRE REGION

Green house no.	NO_3^- (mg L^{-1})			EC (dS cm^{-1})		
	I Period	II Period	III Period	I Period	II Period	III Period
1	126.20	100.37	113.86	1556	1585	1573
2	0.97	1.88	23.08	900	268	868
3	95.88	80.18	127.97	1318	1224	1519
4	134.74	118.20	157.20	1497	1230	1683
5	65.16	30.23	18.55	1685	1127	661
6	132.13	152.97	162.64	1386	1391	1540
7	132.07	120.84	106.67	960	832	830
8	70.91	20.52	32.36	1043	976	1142
9	52.95	20.80	23.96	589	440	511
10	2.27	35.18	2.55	1031	379	388
11	1.43	29.55	2.30	1022	280	390
12	1.55	44.37	0.53	958	342	242
13	68.79	46.69	99.72	1850	1031	1427
14	0.33	8.81	2.79	1349	430	1481
15	6.09	8.18	2.59	1547	1446	1433
16	173.25	120.26	167.42	1856	2110	2100
17	72.30	7.35	118.51	1854	1789	2060
18	3.04	6.89	2.27	1737	349	1754
19	99.13	70.78	31.49	2057	2260	1040
20	70.19	40.68	14.99	1480	2030	629
21	131.81	15.92	132.16	1169	1016	1378
22	35.79	4.68	30.86	728	579	685
23	88.75	16.80	99.20	1059	963	1056
24	136.25	90.93	144.42	1235	855	1203
25	169.86	171.39	33.83	3616	1140	778
26	65.08	7.81	34.06	1695	875	823
27	0.34	41.61	1.72	879	316	919
28	6.83	31.61	2.20	505	366	411
Max.	173.25	171.39	167.42	3616	2260	2100
Min.	0.33	1.88	0.53	505	268	242

in the 2nd sampling period (r = 0.392*) and at 0.1 % level in the 3rd sampling period (r = 0.655***). Seasonal changes in nitrate contents in irrigation water from wells also caused similar changes in EC values. Our findings are in agreement with those reported by Nagarajah *et al.*[16] and Kaplan *et al.*[2] who observed positive relationship between nitrate contents and EC values in irrigation waters.

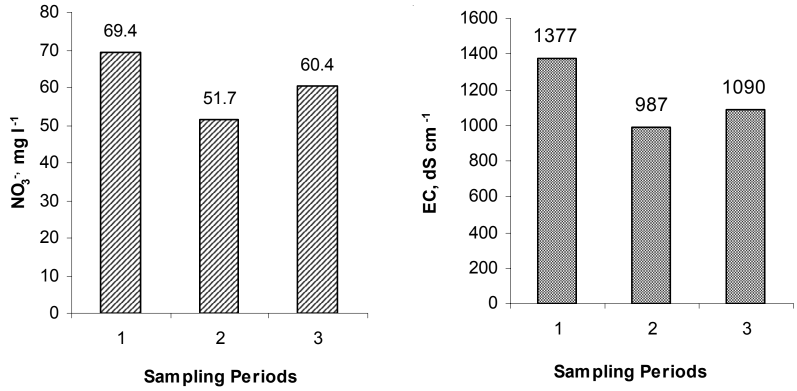

Fig. 2. Seasonal changes of average NO_3^- (mg L^{-1}) contents and EC (dS cm^{-1}) values at irrigation waters obtained from wells

Analysis of soil and irrigation water samples obtained from wells revealed presence of high level of nitrate. Even though presence of excess nitrate in soil seems to be an advantage for agricultural production, possibility of nitrate leaching to groundwater as a result of irrigation necessitates preventive measures. High nitrate contents of soils must be taken in to consideration while preparing fertilization schedules. It is also possible that excess nitrate in the root zone causes problems due to the fact that nitrate is a constituent of salt. However, excessive irrigation to solve the salinization problem also contributes to the nitrate pollution of groundwater. High nitrate contents in well waters is of great health concern since farmers in the region may use them as drinking water. 45 % of well waters in Demre region exceeds maximum nitrate level of 50 mg L^{-1} set for drinking water by World Health Organization. Like soil nitrate content, nitrate level of irrigation water from wells must also be taken into account in fertilization programs. These waters may be mixed with better quality waters and applied to production fields to solve or prevent high nitrate and EC problem. These findings indicate the importance and necessity of irrigation water analysis that also includes nitrate measurements.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to The Scientific Studies Management Unit of Akdeniz University for supporting this research project.

REFERENCES

1. I. Sönmez and M. Kaplan, *J. Faculty of Agriculture, Akdeniz University*, **17**, 155 (2004).
2. M. Kaplan, S. Sönmez and S. Tokmak, *Tr. J. Agriculture Forestry*, **23**, 309 (1999).
3. S. Sönmez, M. Kaplan., S. Orman and I. Sönmez. *J. Faculty of Agriculture, Akdeniz University*, **5**, 19 (2002).
4. M. Aktas, Plant Nutrition, Ankara University Agriculture Faculty Press No: 1429, Ankara, Turkey (1995).
5. Anonymous, Nitrate: Health Risks to Consumer. www.nitrate.com/nitrate1.htm (2004).
6. Anonymous, Nitrate and the World Health Organization http://www.lenntech.com/hazardous-substances/nitrate (2006).
7. M.L. Jackson, Soil Chemical Analysis, Prentice Hall of India Private Limited, New Delhi (1967).
8. M. Ayyildiz, Irrigation Water Quality and Salinity Problems. Ankara University Agriculture Faculty Press No:879, Ankara,Turkey, edn. 2 (1983).
9. W. Fresenius, K.E. Quentin and W. Schneidler, Water Analysis a Practical Guide to Physico-Chemical, Chemical and Microbiological Water Examination and Quality Assurance, Springer-Verlay, Berlin Heidelberg, Newyork (1988).
10. J.D. Rhoades, Soluble Salts, In Methods of Soil Analysis, Madison, WI, USA, p. 167 (1982).
11. M. Ayyildiz, Irrigation Water Quality and Salinity Problems. Ankara University Agriculture Faculty Press No: 636, Ankara, Turkey (1976).
12. B. Ahnstedt, G. Butters and J. Davis, Manure Application Rates Impact Nitrate Accumulation in the Soil Profile, http://www.colostate.edu/Depts/SoilCrop (2004).
13. S. Ersahin and M.R. Karaman, *Agric. Water Manage.*, **51**, 1 (2001).
14. J.F. Power and J.S. Scheders, *Agric. Ecosystems Environ.*, **26**, 165 (1989).
15. M. Kaplan and S. Akay, Salinity of Irrigation Water of Greenhouses and Its Effects on the Soil Salinity in KumLuca and Finike Regions. IXth International Symposium of Scientific Centre of Fertilizers, 25-30 September 1995, Kusadasi, Turkey, pp. 379-384. (1995).
16. S. Nagarajah, B.N. Emerson, V. Abeykon and S. Yogalingam, *Tropical-Agriculturist*, **144**, 61 (1988).

(*Received*: 28 December 2006; *Accepted*: 19 June 2007) AJC-5749