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Influence of Different Nitrogen Sources and Leaching Practices on Soil Chemical Properties under Tomato Vegetation in a Greenhouse

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Abstract: A greenhouse study was carried out to determine the effects of different nitrogen sources and leaching practices on soil chemical properties. Tomato (*Lycopersicon esculentum*) was used as a test plant. All plots were fertilized equally for nitrogen, phosphor and potassium whereas nitrogen was applied at five different NH_4^+N/NO_3^-N ratios (N_1 = 100/0; N_2 = 75/25; N_3 = 50/50; N_4 = 25/75; N_5 = 0/100). No nitrogen applied plots (N_0) were also added to experiment. The changes and their relationships of soil soluble ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}), EC and pH were determined in soil samples taken from three soil layers (0-5, 5-15 and 15-45 cm) at the beginning and the end of the study. Soil samples were also taken before and after the soil leaching to determine the effects of leaching on the parameters mentioned above. Soil pH had different correlations with N treatments among soil layers and showed rising trends with soil depths which had statistically significant differences at $p<0.05$ level in all treatments. Soil leaching caused statistically significant differences on soil pH at $p<0.05$ level. There were increases in EC values in all N treatments over the study period. However, soil leaching decreased soil EC values in all plots. All cations were affected by all treatments and their interactions. The study showed that the chemical properties of soil especially soil pH was affected by the forms of N fertilizers.

Key words: Ammonium, EC, nitrate, pH, salts

INTRODUCTION

Nitrogen (N) is necessary for plant growth and is utilized in soils. Nitrogen from soils, fertilizer and manure is generally used inefficiently (30 to 60%) in most crop production systems (Kitchen and Goulding, 2001). Soil pH is important because of its plausible influence on the nitrification process (Sharmasarkar *et al*., 1999). The soil properties and management characteristics correlated with crop yield vary with crop and soil type (Cotching *et al*., 2004). Therefore, farmers have to know to manage soil pH, salinity and fertility by monitoring water quality and choosing the right fertilizers. Effects of long-term applications of various nitrogen sources on chemical soil properties were investigated by Malhi *et al*. (2000). They reported that the soil acidification was the greatest with ammonium sulfate, followed by ammonium nitrate and urea, with no effect of calcium nitrate. Riley (2007) pointed out that the soil reaction remained close to neutral with the use of calcium nitrate and manure, but declined with the use of ammonium nitrate in long-term fertilizer trials on loam soil.

The use of synthetic ammonium fertilizers is known to cause a rapid shift in soil chemical properties which are initiated by microbial nitrification. This shift may result in soil acidification (Stamatiadis *et al*., 1999).

Higher rates of fertilizer use in combination with no leaching by natural rainfall, but high evaporation and transpiration under plastic covered or plastic greenhouse conditions have promoted soil secondary salinization (Cao *et al*., 2004). Many problems, e.g., soluble salt accumulation, degradation of soil quality and decrease in soil productivity, have already appeared in soils of vegetable greenhouses under application of fertilizers and other chemicals (Zhang *et al*., 2006). Therefore, one of the most important parameters to be considered is the soil leaching in greenhouses.

The effects of fertigation strategies on tomato yield have been extensively studied; however, the effects of nitrogen forms on soil chemical properties in greenhouse conditions have been poorly examined. This research is a part of the study in which effects of different NH_4^+N/NO_3^-N ratios on yields and plant growth on greenhouse tomato (*Lycopersicon esculentum*) crops

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were reported by Bozkurt and Sayilikan (2004). In the study, maximum total and early yields were observed in 75% NH_4-N treatment in the spring and the fall season. Mean fruit weights were significantly different in both seasons. In the fall season, plant length, number of cluster and number of fruits per cluster were significant. In the spring season, numbers of fruits per cluster and plant lengths were found to be statistically significant.

This study aimed to examine the changes and inner relationship of soil soluble salts, EC and pH under different NH_4^+N/NO_3^-N applications for tomato cultivation in greenhouse conditions. The effects of soil leaching practices performed after the last harvest were also observed at the end of the study. The results obtained may be helpful in establishing nitrogen strategies to maintain soil quality and the increase the tomato yields in greenhouse production in the Mediterranean costal area.

MATERIALS AND METHODS

The experiment was carried out in a polyethylene greenhouse located at the experimental area (36°4' N, 35°15' E with a <10 m altitude) of the Samandagi Vocational College of Mustafa Kemal University in Hatay, Turkey. The study was conducted during the early spring season of the year 2002. Mean, minimum and maximum temperatures and mean relative humidity of greenhouse during the experimental periods were 17, 6.6, 42.2°C and 75%, respectively.

The greenhouse soil was solarized using polyethylene sheets before the study. Some mean physical and chemical properties of the experimental soils collected at the time of the plot establishment are shown in Table 1. Soil samples were taken from the center of each of the plot at depths of 0-5, 5-15 and 15-45 cm (D_3) using a hand sampler at the beginning and the end of the growing period to determine the change of soil chemical properties. The samples were also taken similarly before and after the soil leaching at the end of the study to determine the effects of leaching treatments on soil chemical properties. A total of 600 mm water was applied for soil leaching. All soil samples were air dried and passed through a 2 mm sieve. The samples were analyzed for pH, Electrical Conductivity (EC) in the saturation extract, total soluble salts, exchangeable sodium, soluble cations and anions by common methods (Richards, 1954; Sparks, 1996). Sulphate (SO_4) was calculated by subtracting total anion from total cation after the completion of analyses of anions-cations. Sodium Adsorption Ratio $\{(SAR = Na/[(Ca+Mg)/2]^{1/2})\}$ was calculated according to the formula developed by U.S Salinity Laboratory (USSL) (Richards, 1954).

Fertigation program recommended by Bar-Yosef (1991) for greenhouse tomato production as a function of time after planting was used in the study (Table 2). In the experiment, fertilizers were applied equally in all treatments within a drip irrigation system. Treatments consisted of five different NH_4^+N/NO_3^-N ratios (N_1 = 100%, N_2 = 75% NO_4^+N and 25%, NO_3^- N, N_3 = 50% NO_4^+ N and 50% NO_3^- N N_4 = 25% NO_4^+ N and 75% NO_3^- N, N_5 = 100% NO_3^- N) and the control (N_0 = no nitrogen) plots to determine the effects of NO_3^- N and NO_4^+ N on soil chemical properties in a growing season of greenhouse tomato cultivation.

Each plot had a 25.2 m^2 planting area having three rows with a 2.1 m width and 12.0 m length. There was one plant row between two plots as the side effect. The tomato variety Target-F1 was planted with 0.50X0.70 m spacing by hand on March 15, 2002.

Drip irrigation lateral lines were installed on the surface with one drip line for each crop line after planting. Quality of well irrigation water which could represent water used in the region is classified as C_3S_1 (Odemis *et al.*, 2006). Some other quality parameters determined in a laboratory were EC = 1.46 dS m^{-1}, pH = 7.91, TDS = 1180 mg L^{-1}, SAR = 2.03, Ca^{2+} = 1.32, Mg^{2+} = 7.39, Na^+ = 4.24, K^+ = 0.43, CO_3^{2-} = 0.75, HCO_3^- = 7.00, Cl^- = 4.69 and SO_4^{2-} = 0.94 meq L^{-1}. Daily readings of tensiometer, placed in 0.30 m soil depth were used to assist in irrigation scheduling (Clark *et al.*, 1991). Irrigation water depth was calculated based on evaporation pan, using a pan coefficient (Kp) of 1.0 as recommended by Locascio and Smajstrla (1996). The total pan evaporation occurred during the study (106 days after transplanting) was a 292.1 mm. The amount of water applied in all treatments was the same.

Statistical analysis: All statistical analyses were performed using MSTAT-C statistical analyses software (Freed, 1994). The effects of N treatments on soil chemical properties at different soil depths (layers) were analyzed by split-plot design with N treatment as the main plots and soil layers as subplots with three replications. Soil sampling times were accepted as season factor. The Duncan's test ($p<0.05$) was used to separate means for particular comparisons. The effects of leaching treatment on soil chemical properties at different depths were also showed similarly.

Table 1: Some characteristics of soils in the experimental plots

	Soil depth (cm)				Soil depth	
Chemical parameters	0-5	5-15	15-45	Physical parameters	0-30	30-60
pH	7.500	7.560	7.610	Saturation point (%)	50.97	50.33
Tuz (%)	0.097	0.075	0.083	Sand (%)	34.80	55.90
EC ($dS\ m^{-1}$)	2.229	1.886	1.631	Clay (%)	25.90	18.30
Na^+ ($meq\ L^{-1}$)	12.05	10.47	9.480	Silt (%)	39.30	25.80
K^+ ($meq\ L^{-1}$)	1.950	1.190	0.700	Texture	Loam	Sandy loam
Ca^{2+} ($meq\ L^{-1}$)	6.870	8.010	7.550	Lime (%)	20.19	21.11
Mg^{2+} ($meq\ L^{-1}$)	4.550	4.520	4.030	Field capacity ($g\ g^{-1}$)	40.96	44.50
CO_3^{2+} ($meq\ L^{-1}$)	1.400	2.000	1.600	Wilting point ($g\ g^{-1}$)	17.07	18.96
CO_3^{2-} ($meq\ L^{-1}$)	8.100	5.700	4.800	Bulk density ($g\ cm^{-3}$)	1.66	1.56
Cl^- ($meq\ L^{-1}$)	9.350	7.050	5.700			
HCO_3^- ($meq\ L^{-1}$)	6.560	8.230	9.250			
SAR	4.990	4.230	4.040			

Table 2: Amount of daily pure fertilizers (NPK) planned for treatments (kg/ha/day)

DAT(*)	N	P	K
1-10	0.15	0.00	0.10
11-20	0.35	0.07	0.15
21-30	0.75	0.13	0.15
31-40	1.25	0.15	0.30
41-50	2.10	0.35	6.00
51-60	2.50	0.47	6.00
61-70	2.60	0.50	1.90
71-80	2.85	0.53	2.50
81-90	3.65	0.60	6.00
91-100	6.15	0.96	12.50
101-110	7.70	1.06	13.00
11-120	6.35	1.28	8.20

(*)DAT: Days After Transplanting

RESULTS AND DISCUSSION

Soil pH: Based on soil analysis, pH values showed rising trends with soil depths in all treatments. Similar results have been also reported by Smethurst *et al.* (2001). The pH values in control (N_0) plots were not changed between seasons (soil sampling times) except for the deepest (D_3) soil layer. applications decreased pH values, however, NO_3^-N applications increased pH values in all soil layers (Fig. 1). Smethurst *et al.* (2001) declared that immediately after the first broadcast application of fertilizer at the highest rate {$(NH_4)_2SO_4$ (205 g N kg^{-1}) and triple super phosphate (202 g P kg^{-1})} decreased pH by up to 0.5. Wei *et al.* (2007) also reported that a large amount of nitrogen markedly decreased soil pH value, particularly using ammonium sulphate as nitrogen source in a solar greenhouse. Furthermore, Ruan *et al.* (2000) reported that whatever the phosphate source, rhizosphere pH declined in ammonium in comparison to nitrate treatment.

Based on the analysis of variance, pH values between soil layers showed statistically significant differences at $p<0.05$ level. However, seasons, N treatments and their interactions did not cause any significant differences (Table 3). The mean pH values of all soil layers were between 7.41 and 7.68. According to Duncan's test, the highest soil pH value (7.68±0.01) was determined in N_5D_3 (100% NO_3^-N) plots whereas the lowest values were found in N_1D_1 (7.42±0.09) and N_1D_2 (7.41±0.07) 100% NO_4^+N plots. Similar pH decreases due to the use of NO_4^+ fertilizers were previously reported by Maier *et al.* (1996, 2002). The magnitude of these decreases is dependant on N source, soil buffering capacity with regard to soil acidity and rate of N fertilization. Lea-Cox *et al.* (1999) confirmed that balancing the proportion of NO_4^+N/NO_4^-N in solution can be used to control pH. The close relationships increased with soil depth were found between soil pH and nitrogen forms. These findings pointed out that the soil pH changed with NO_4^+N/NO_3^-N ratios, concurrently (Fig. 2).

Soil leaching performed at the end of the experiment increased the soil pH values to higher level of leaching water pH (7.91) in all plots. The pH values were not changed extremely with soil depth after the leaching (Fig. 1). The soil leaching practice was able to uniform soil pH values in all soil layers. Soil leaching caused statistically significant differences ($p<0.05$ level) on soil pH. However, all the other factors and their interactions did not have a significant effect on soil pH (Table 4).

Electrical conductivity (EC): Irrigation water is the main source of adding salts to the soil (Heidarpour *et al.*, 2007). Applying saline water continuously for irrigation through surface drip irrigation systems might result in salt accumulation close to the soil surface (Oron *et al.*, 1999). In our study, there was an increase in soil EC values in all treatments over the studied period (Fig. 3). In control plots, EC values at the end of the study were higher than the initial EC values. Therefore, the use of ground water would be expected to increase soil EC values. Similarly, Bhingardeve *et al.* (2006) reported that pH and EC of soil

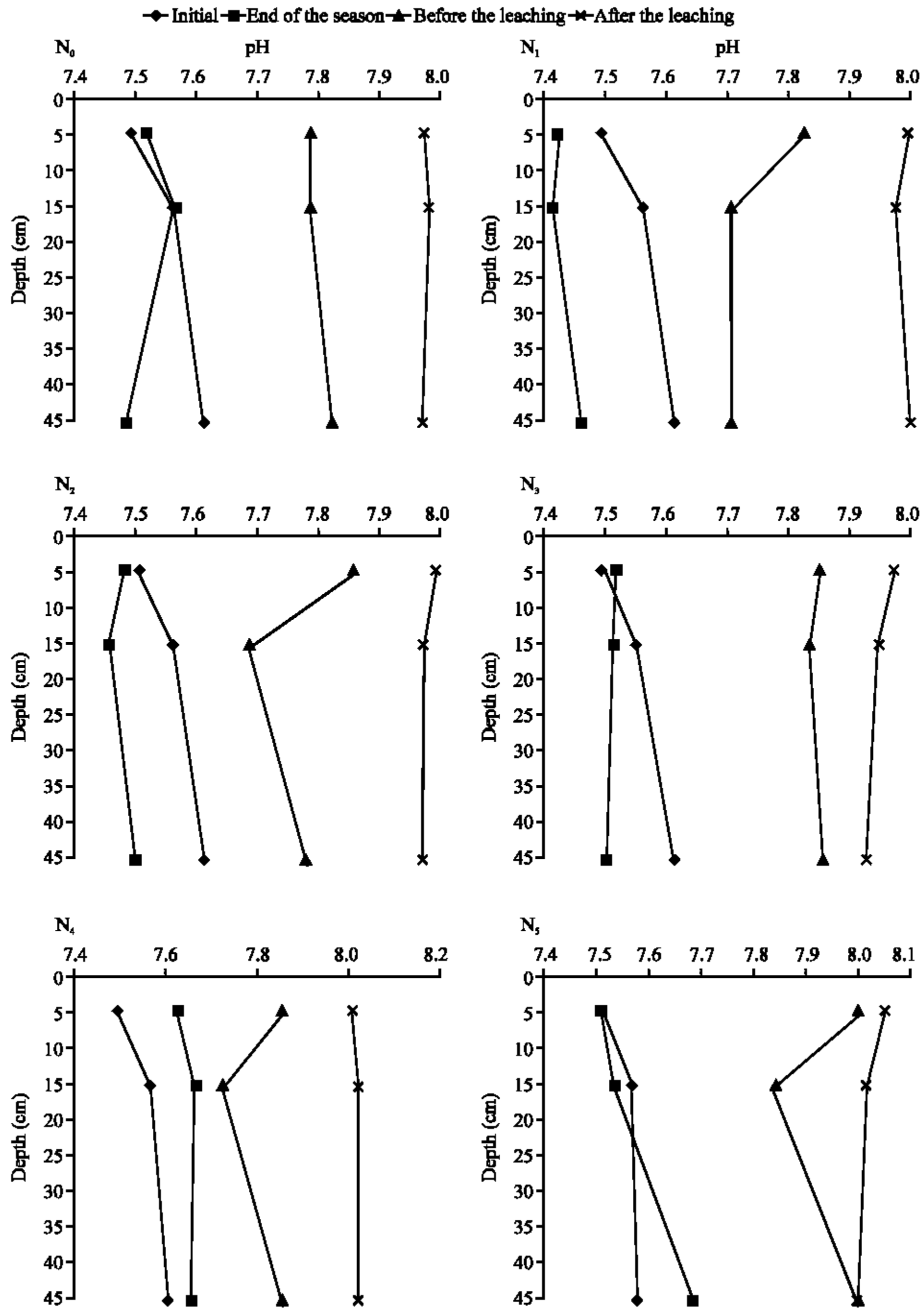

Fig. 1: Changes of soil pH with depth in N treatment plots of the experiment, N_0 = No nitrogen, N_1=100% NH_4^+ N, N_2 = 75% NH_4^+ N and 25% NO_3^- N, N_3 = 50% NH_4^+ N and 50% NO_3^- N, N_4 = 25% NH_4^+ N and 75% NO_3^- N and N_5 = 100% NO_3^- N

increased in both depths of soil (0-15 and 15-30 cm) at harvest stage of plant for saline and canal water treatments. The EC values were the highest in second (D_2) soil layer (5-15 cm) in which soil water was consumed the highest level by plant roots among all soil layers. Blanco and Folegatti (2002) reported that water uptake by plants and evaporation from the soil surface are the main reason of salt accumulation in root zone and the salt

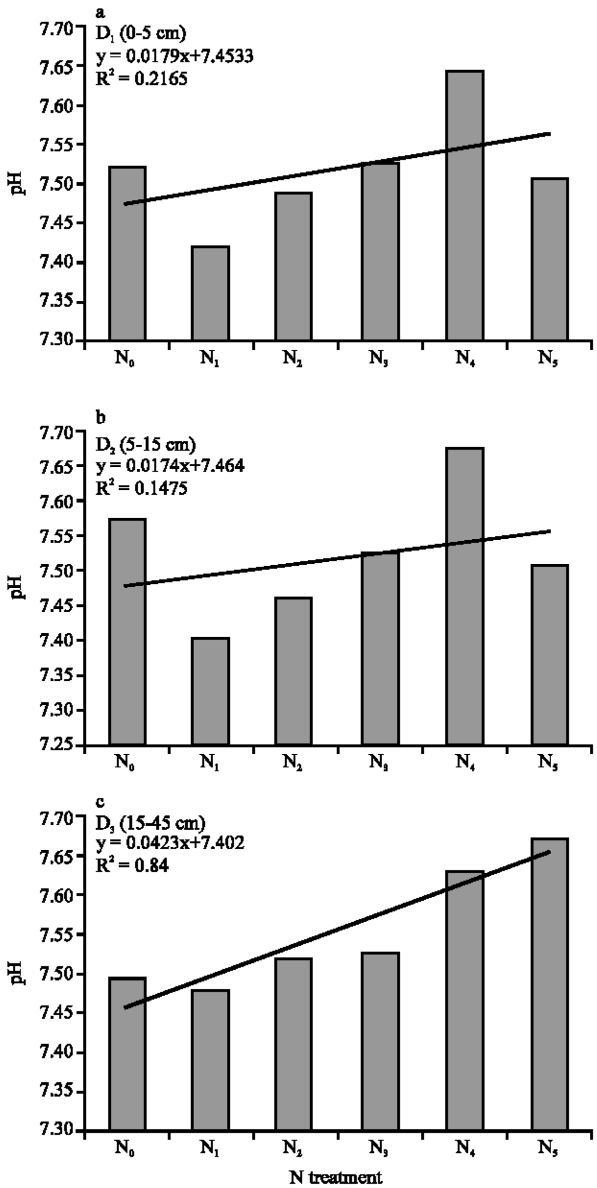

Fig. 2: Relationships of soil pH and N treatments in all soil layers, N_0 = no N; N_1 = 100% NH_4^+ N, N_2 = 75% NH_4^+ N and 25% NO_3^- N, N_3 = 50% NH_4^+ N and 50% NO_3^- N, N_4 = 25% NH_4^+ N and 75% NO_3^- N and N_5 = 100% NO_3^- N

concentration is proportional to the water volume removed by these processes. EC values in third soil layer (D_3) were lower than the second soil layer (D_2) except for N_3 treatment.

Based on the analysis of variance, differences in EC values were statistically significant in all treatments and their interactions except for seasons×soil layers interactions (Table 3). The mean EC values of all soil layers were between 1.434 and 3.275 dS m^{-1}. According to Duncan's tests, the highest soil EC value (3.275±0.275 dS m^{-1}) was determined in N_3D_3 plots, while the lowest values were found in N_4D_1 (1.434±0.054 dS m^{-1}) and N_5D_3 (1.494±0.116 dS m^{-1}) plots.

Soil leaching had a decreasing effect on soil EC in all plots (Fig. 3). The EC values were brought to initial values by leaching. Moreover, EC values of some plots almost decreased to EC level of leaching water (1.464 dS m^{-1}). According to analyses of variance, the differences of EC values between before and after the leaching were significant ($p<0.05$). N treatments and soil layers factors and interactions among these factors were also significant ($p<0.001$) (Table 4). In control plots, EC values increased with depth after the soil leaching. This tendency indicated that the salts leached from upper soil layers accumulated deeper soil layers as suggested by Tedeschi and Dell'Aquila (2005). Therefore, more attention should be paid to the amount of leaching water and leaching depth of soils. The depth must be leached is not less than plant rooting depth.

Salt components and other chemical properties in soils: No significant differences in soil Total Salt (TS) were found among the seasons, N treatments, season×N treatments and soil layers. However, significant differences were determined in the seasons×soil layers, N treatments×soil layers and seasons×N treatment×soil layers interactions (Table 3). Leaching treatment decreased amount of TS at three soil layers in all experimental plots. All factors and their interactions were found statistically significant except for the season factor in leaching treatment (Table 4).

Seasons, N treatments, soil layers and their interactions had a significant effect on all soil cations except for soil Mg^{2+}, which had no significant season×soil layer effect and soil Na^+, which had no significant season and season x soil layer effect (Table 3). The highest levels of Ca^{2+}, Mg^{2+} and K^+ contents were determined in N_1D_2 (N_1=100% NO_4^+N; D_2 = 5-15 cm) plots while the highest content of soil Na^+ was in N_3D_3 treatment plot. The lowest level over all cation contents was determined in N_5D_3 (N_5=100% NO_3^-N; D_3=15-45 cm) treatment plots. Komosa *et al.* (1999) reported that fertigation with ammonium nitrate caused leaching of magnesium directly underneath the dripper and accumulation of magnesium 20-40 cm below from the dripper. In our study, the highest content of Mg^{2+} was found in second soil layers (5-15 cm) among all soil layers. Whitney *et al.* (1991) declared that the upper soil layer (6-15 cm) of N-fertilized plots had reduced pH, available phosphorus and exchangeable Ca^{2+}, Mg^{2+} and Na^+ and

Table 3: ANOVA for soil salts, EC and pH in six treatments and three depths in N treatment soils

	F-values						
Parameters	Seasons (S)	N-treatments (N)	S×N	Soil layers (D)	S×DItem	N×D	S×N×D
pH	14.440^{ns}	2.45^{ns}	2.45^{ns}	4.87*	1.40^{ns}	0.34^{ns}	0.34^{ns}
EC	531.160*	3.44*	3.44*	13.24**	0.81^{ns}	5.59**	5.59**
TS	24.010^{ns}	1.61^{ns}	1.61^{ns}	1.17^{ns}	4.37*	3.96**	3.96**
Ca^{2+}	85219.560**	24.50**	24.50**	21.93**	6.59**	45.59**	45.59**
Mg^{2+}	490.830*	20.21**	20.21**	33.20**	2.26^{ns}	7.63**	7.63**
Na^{+}	7.470^{ns}	14.91**	15.28**	7.34**	0.04^{ns}	5.04**	4.64**
K^{+}	444.180*	7.31**	7.31**	99.76**	6.22**	4.40**	4.40**
CO_3^{2-}	22.270^{ns}	10.49**	10.49**	12.10**	4.17*	0.56^{ns}	0.56^{ns}
HCO_3^{-}	7.780^{ns}	2.03^{ns}	2.03^{ns}	200.78**	7.79**	0.97^{ns}	0.97^{ns}
Cl^{-}	1.470^{ns}	8.14**	8.14**	18.17**	0.14^{ns}	6.17**	6.17**
SO_4^{2-}	33.230^{ns}	15.45**	15.45**	30.47**	0.90^{ns}	10.00**	0.004**
SAR	0.580^{ns}	7.37**	7.37**	0.19^{ns}	0.35^{ns}	1.57^{ns}	1.57^{ns}

S: Seasons (Initial and end of the study); N: Nitrogen treatments (N_0= no nitrogen, N_1 =100% NH_4^+N, N_2 = 75% NH_4^+N and 25% NO_3^-N, N_3 = 50% NH_3^+ N and 50% NO_3^- N, N_4 = 25% NH_3^+ N and 75% NO_3^- N, N_5 = 100% NO_3^-N); D: Soil Layers (D_1: 0-5 cm, D_2: 5-15 cm and D_3: 15-45 cm); ^{ns}: Not significant; TS: Total Salts; EC: Electrical Conductivity; SAR: Sodium Absorption Ratio. *,** significant at the 0.05 and 0.01 levels, respectively

Table 4: ANOVA for soil salts, EC and pH in six treatments and three depths in leaching treatment

	F-values						
Parameters	Seasons (S)	N-treatments (N)	S×N	Soil layers (D)	S×DItem	N×D	S×N×D
pH	1200.46*	1.55^{ns}	0.83^{ns}	3.02^{ns}	1.7760^{ns}	0.3800^{ns}	0.360^{ns}
EC	995.49*	36.39**	66.69**	29.15**	25.1780**	9.6200**	9.032**
TS	19.61^{ns}	21.67**	19.25**	14.19**	6.9040**	2.7100*	2.360*
Ca^{2+}	86.14^{ns}	35.20**	65.30**	62.41**	39.6970**	6.3000**	11.860**
Mg^{2+}	1632.81*	9.42**	9.07**	4.21*	1.0470^{ns}	2.4800*	2.980*
Na^{+}	137.61^{ns}	28.28**	51.22**	19.99**	1.4790^{ns}	7.0400**	6.155**
K^{+}	18.46^{ns}	4.13*	1.45^{ns}	22.96**	1.6650^{ns}	1.8500^{ns}	1.530^{ns}
CO_3^{2-}	1324.71*	16.39**	14.98**	16.84**	3.8450*	12.7300**	19.500**
HCO_3^{-}	247.53*	21.36**	18.40**	84.39**	108.1800**	50.7000**	38.400**
Cl^{-}	63392.25**	146.58**	299.33**	44.71**	37.7840**	27.4000**	26.010**
SO_4^{2-}	180.91*	21.41**	24.04**	12.52**	9.0732**	4.2768**	2.720*
SAR	18.91^{ns}	2.67^{ns}	1.46^{ns}	15.71**	8.7357**	7.0180**	1.830^{ns}

S: Seasons (Initial and end of the study); N: Nitrogen treatments (N_0: No nitrogen; N_1:100% NH_4^+N; N_2:75% NH_4^+N and 25% NO_3^- N; N_3:50% NH_4^+N and 50% NO_3^- N; N_4 = 25% NH_4^+N and 75% NO_3^-N, N_5 = 100% NO_3^-N); D: Soil Layers (D_1: 0-5 cm, D_2: 5-15 cm and D_3: 15-45 cm); ^{ns}: Not significant; *,** significant at the 0.05 and 0.01 levels, respectively; TS: Total Salts; EC: Electrical Conductivity; SAR: Sodium Absorption Ratio

increased nitrate-N, ammonium-N and DTPA extractable Fe, Cu and Mn according to the control plots (no-nitrogen).

In control plots, all exchangeable cation levels decreased with soil depth at the end of the experiment. Kiziloglu *et al.* (2007) obtained similar results with our control plots in their study in which effects of wastewater irrigation on soil and cabbage-plant chemical properties were reported. However, in the N treatment plots, levels of exchangeable cations except for K which had shown the same tendency with control plots were gradually increased from soil surface to the second soil layers, probably due to much higher root density and than decreased with depth.

Leaching treatment affected the cation contents of soils. After the soil leaching, N treatment and soil layer factors had a statistically significant effect on all the cations. While the K^+ contents of soils were not changed extremely by the soil leaching, Ca^{2+}, Mg^{2+} and Na^+ contents were changed significantly. It appears that these tendencies of cations resulted from their individual contents in leaching water.

Contents of soil anions showed statistically significant differences among three soil layers, but no significant differences were observed between seasons. The effects of N treatments on soil anions were found statistically significant except for HCO_3^- which had only significant soil layer and season×soil layer interaction effects. While the lowest level of anion contents were determined in D_3 soil layers, the highest contents were in D_2 soil layers. The effects of the soil leaching on anion contents were found statistically significant in all parameters obtained and their interactions. Because of the leaching water had about ten times more HCO_3^- (7 meq L^{-1}) than CO_3^{2-} (0.75 meq L^{-1}), the contents of CO_3^{2-} in N treatment plots and all soil layers decreased, but contents of HCO_3^- increased. The Cl^- contents in all treatment plots closed to Cl^- level of the leaching water (4.69 meq L^{-1}) by rising or decreasing.

The N treatments and season×N treatment interactions had significant effects on the SAR, but had no significant effect at all other treatments and their interactions. The highest SAR value derived from the USSL formulation was determined in N_5D_1 plots in which

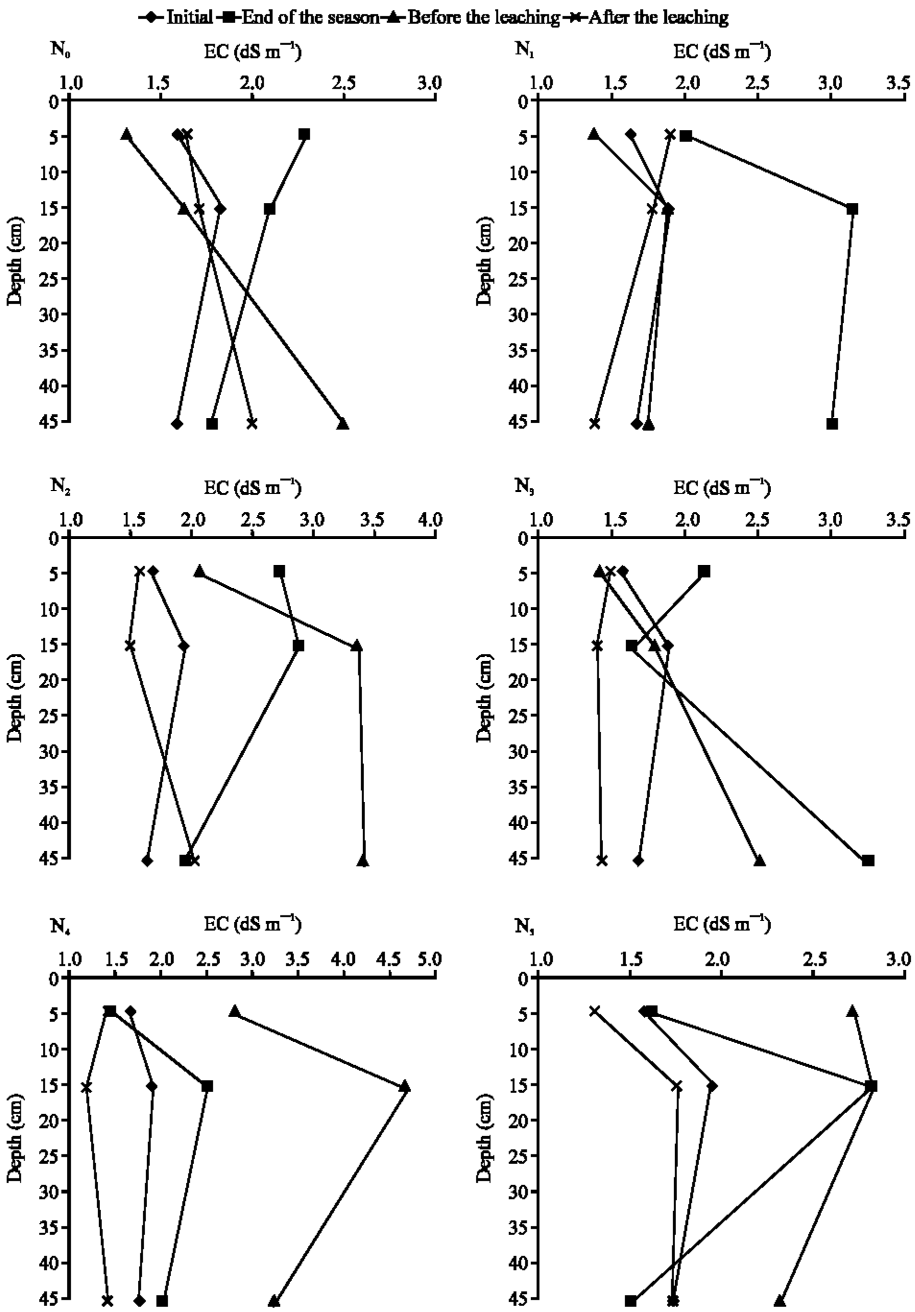

Fig. 3: Changes of soil EC with depth in N treatment plots of the experiment N_0 = no nitrogen, N_1 = 100% NH_4^+ N, N_2 = 75% NH_4^+ N and 25% NO_3^- N, N_3 = 50% NH_4^+ N and 50% NO_3^- N, N_4 = 25% NH_4^+ N and 75% NO_3^- N and N_5 = 100% NO_3^- N

Na^+ contents were high and Ca^{2+}+Mg^{2+} contents were low. SAR values changed considerably in the first soil layer compared to the other layers.

Relationship among EC, pH and other chemical properties in soils: Soil pH was significantly and negatively correlated with EC, all the cations and anions, but not with total salt which had negative correlation and SAR which had positive correlation. Soil total salt concentration was significantly correlated with EC and all the cations and anions, but not with pH and SAR. According to Wenqing *et al.* (2001), who conducted a field study on the effect of plastic greenhouse gardening on soil salt contents, among the constituentions,

Table 5: Correlation matrix among soil salts and with other chemical properties in N treatment plots

Parameters	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_3^{4-}	SAR	TS
pH	1.00											
EC	-0.351**	1.00										
Na^+	-0.340**	0.758**	1.00									
K^+	-0.424**	0.382**	0.231	1.00								
Ca^{2+}	-0.236*	0.705**	0.442**	0.306**	1.00							
Mg^{2+}	-0.302*	0.789**	0.501**	0.375**	0.755**	1.00						
CO_3^{2-}	0.297*	-0.150	-0.117	0.057	-0.199	-0.267*	1.00					
HCO_3^-	-0.299*	-0.304**	-0.206	0.396**	-0.333**	-0.496	0.012	1.00				
Cl^-	-0.251*	0.601**	0.590**	0.406**	0.663**	0.466**	-0.075	-0.117	1.00			
SO_4^{2-}	-0.257*	0.822**	0.615**	0.236*	0.864**	0.932**	-0.282*	-0.575**	0.493**	1.00		
SAR	0.068	-0.149	0.164	-0.201	-0.392**	-0.330**	0.155	0.136	-0.250*	-0.273*	1.00	
TS	-0.219	0.867**	0.591**	0.335**	0.616**	0.718**	-0.292*	-0.330**	0.490**	0.739**	-0.118	1.00

*, **Significant at the 0.05 and 0.01 levels, respectively; TS: Total Salt; EC: Electrical Conductivity; SAR: Sodium Absorption Ratio

Table 6: Correlation matrix among soil salts and with other chemical properties after the soil leaching

Parameters	pH	EC	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3^{2-}	HCO_3^-	Cl^-	SO_3^{4-}	SAR	TS
pH	1.00											
EC	-0.419**	1.00										
Na^+	-0.284*	0.761**	1.00									
K^+	-0.199	0.305**	0.096	1.00								
Ca^{2+}	-0.432**	0.791**	0.696**	0.234*	1.00							
Mg^{2+}	-0.443**	0.731**	0.660**	0.380**	0.719**	1.00						
CO_3^{2-}	-0.170	0.210	0.144	0.318**	0.143	0.323**	1.00					
HCO_3^-	0.396**	-0.454**	-0.356**	0.049	-0.367**	-0.332**	-0.553**	1.00				
Cl^-	-0.322**	0.833**	0.833**	0.167	0.797**	0.698**	0.081	-0.349**	1.00			
SO_4^{2-}	-0.495**	0.751**	0.766**	0.223	0.853**	0.808**	0.232	-0.520**	0.633**	1.00		
SAR	-0.320**	0.551**	0.480**	0.074	0.317**	0.475**	0.231	-0.491**	0.526**	0.397**	1.00	
TS	-0.339**	0.832**	0.736**	0.254*	0.755**	0.628**	0.135	-0.420**	0.799**	0.696**	0.536**	1.00

*, **Significant at the 0.05 and 0.01 levels, respectively; TS: Total Salt; EC: Electrical Conductivity; SAR: Sodium Absorption Ratio

Cl^-, NO_3^-, Ca^{2+} and Mg^{2+} had positive while HCO_3^- had negative correlation or very significant correlations with total salt, with correlation coefficients as 0.66, 0.80, 0.92, 0.80 and -0.64, respectively. Present results are in agreement with Roca-Perez *et al.* (2006) in which significant negative correlations was declared between carbonates with K and Mn in soils. Soil EC was significantly correlated with total salt and ions except for CO_3^{2-}. Significant correlations were determined among all cations except for N^+ and K^+ which had not significant correlation between them even though they were significantly correlated with the other cations, separately. While the concentrations of SO_4^{2-} in soils were significantly correlated with all other inspected parameters, remaining anions were not correlated with each other. SAR was significantly and positively correlated with Na^+ and negatively correlated with Ca^{2+}, Mg^{2+}, Cl^- and SO_4^{2-} (Table 5).

After the soil leaching at the end of the experiment there were some differences resulted from chemical properties of leaching water in inspected parameters of the soils. For this reason, inner relationships of the parameters also changed. Soil pH had significant correlation in all inspected parameters except for K^+ and CO_3^{2-} which were the least amount in leaching water. With the exception of SAR, EC values had same correlations before and after the leaching. Soil SAR values derived from the ratio of Ca^{2+} + Mg^{2+} to Na^+, which were significantly correlated with EC, showed a close relationship with EC after the soil leaching. While the internal correlations among all cations were not changed by soil leaching, internal correlation of anions were changed. The Ca^{2+} and Mg^{2+} had the same correlations with all anions before and after the soil leaching. However, some minor differences were determined in relationships of Na^+ and K^+ with anions. Total salt had closely correlation with all inspected parameters except for CO_3^{2-} after the soil leaching (Table 6).

CONCLUSION

The form of N fertilizers was regarded as important factor that effecting pH and salts in soils of greenhouses. While acidic characteristics of NO_4^+N fertilizers decreased soil pH values, NO_3^-N fertilizers increased soil pH. Although, the nitrogen source selection might be done primarily based on plant requirements, nitrogen forms should be used by rotation or mixture to stabilize of soil pH. It is suggested that the best procedure to control the soil pH and salts in greenhouses is to apply fertilizers rationally according to the soil fertility, fertilizer and irrigation water properties. Because of the technique of soil leaching was able to uniform soil pH and salt contents in all soil layers; it must be performed at least once a season.

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