Effect of nitrogen fertilizers on nitrate leaching from a saline soil profile under corn and barley cultivation

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ABSTRACT: Nitrogen as a macronutrient has an eminent role in plant nutrition. Excessive use of nitrogen fertilizers in agriculture has resulted in leaching of fertilizers and contaminating groundwater and surface water systems. The objective of this study was to investigate the effect of three types of nitrogen fertilizers on nitrate leaching and soil and plant conditions in a saline soil in Rudasht, Isfahan province. A complete randomized design with four replications was conducted in 12 lysimeters. Three nitrogen fertilizers of urea, ammonium nitrate and ammonium sulphate were applied. The lysimeters had a silty clay loam soil. Corn and barley were planted in June and October and were harvested in October and June of next year, respectively. Soil chemical characteristics were measured by standard laboratory methods. The results showed that changes of EC during the corn cropping season were negative for depth of 0-30 cm and positive for depths of 30-60 and 60-90 cm as a result of applied fertilizers. Comparison of soil salinity changes during corn and barley cropping seasons confirms that ammonium sulphate has been more effective on soil salinization as compared to ammonium nitrate and urea. Application of these fertilizers didn’t cause significant changes in weight of areal parts of corn plants and grain yield of barley. Corn shoot analysis showed that ammonium sulphate is more effective in enhancement of N and reduction of Na in corn shoot as compared to the other applied fertilizers. Where saline irrigation water contains harmful elements, application of ammonium sulphate is preferred over urea and ammonium nitrate. Ammonium sulphate has the least and ammonium nitrate has the highest NO<sub>3</sub>-N contamination potential of groundwater.

Keywords: Nitrogen fertilizer, Nitrate leaching, Saline soil, Corn, Barley.

Introduction

Nitrogen as a macronutrient has an eminent role in plant nutrition. Some nitrogen fertilizers such as urea and ammonium nitrate have a high mobility and leaching potential. Excessive use of nitrogen fertilizers in agriculture has resulted in leaching of fertilizers and their derivatives below the root zone, contaminating groundwater (Wierenga, 1977). Groundwater pollution caused by leaching of NO<sub>3</sub>-N from agricultural systems has caused public concerns for decades (Ersahin and Rustu Karaman, 2001). Hallberg (1989)
reported that the application of fertilizers to irrigated crops has been the most extensive human cause of NO$_3$ pollution in groundwater.

Nitrate contamination of drinking water, especially for untreated ground waters, is considered to increase the risk of diseases like methemoglobinemia and stomach cancer (Magee, 1982; Pavoni, 2003). Agricultural fertilizers are the most important nitrogen resources. International Fertilizer Industry Association (2006) reported that about 9.09×10$^7$ Mg of nitrogen fertilizers are added to soil worldwide annually. Other sources of nitrogen are contributions to soil derived from animal manure as NO$_3$ (Eghball, 2000) and domestic wastewater (Reddy and Dunn, 1984), atmospheric deposition (Rubio et al., 2002) as well as in situ decomposition of organic matter in well-aerated soils. To preserve the groundwater and reduce economic losses for the farmers, a rapid and accurate estimation of NO$_3$-N moving below the root zone is crucial (Ersahin and Rustu Karaman, 2001). Treatment of water polluted by nitrate is so difficult and expensive that a necessary attempt should be applied to prevent water contamination by nitrate.

In addition to the considerable knowledge that has been accumulated on the mechanisms and causes of the contamination, more information on the environmental impact of current fertilization, irrigation and land use strategies is needed to establish proper management practices that will minimize the pollution of groundwater resources and decrease economic losses for farmers (Wierenga, 1977; Everts et al., 1989). Watershed studies are particularly valuable to calculate nitrogen balances and quantify the relative importance of different sources of inputs and outputs. (Ventura et al., 2008).

Feng et al. (2002) reported that extensive development of inter-planting tillage might be a viable measure to reduce groundwater pollution, and that the application of optimized minimum amounts of water and nitrogen to meet realistic yield goals, as well as the timely application of N fertilizers and the use of slow release fertilizers can be viable measures to minimize nitrate leaching. Ventura et al. (2008) reported that crop management and especially N fertilization techniques are important in reduction of nitrogen losses. For annual crops, the N uptake efficiency is <50%, even when followed by good management practices (Ju and Zhang, 2003; Gillian et al., 1985) and about 30–50% of applied N fertilizer is leached into groundwater (Zhang, 1987). Using best management practices and near optimum N rates, the amount of NO$_3$–N leaching has been estimated to be 41% for irrigated maize (Kessavalou et al., 1996). In saline soil, leaching is one of the most effective techniques for soil reclamation. In order to keep salt balance at a safe level in saline soil leaching fraction should be higher than normal soil. In this regards in saline soil nitrate leaching is one of the critical problems occurring in this situation.

The objective of this study was to investigate the effects of three types of nitrogen fertilizers on nitrate leaching in a saline soil profile in Rudasht region, east of Isfahan province located in central Iran.

**Materials and methods**

Rudasht region is located 65 km east of Isfahan (32° 29' N and 52° 10' E, 1560 m amsl). It is one of the salt affected zones of Isfahan province (Houshmand et al., 2005). To achieve the objectives, a randomized complete block experiment with 3 nitrogen fertilizers including urea (46 % N) with a rate of 70 gram per lysimeter, ammonium nitrate (17.5% ammoniacal-N (NH$_4^+$) and 17.5% NO$_3$-N) with a rate of100 gram per lysimeter and ammonium sulphate (21% N and 24% S) with a rate of 170 gram per lysimeter with four replications was conducted in 12 lysimeters, 1 m inside diameter and 2 m deep. Bottom of each lysimeter was covered with 20 cm course gravel to act as a filter. Two crops of corn and barley were planted in the lysimeters in June and October 1998, respectively. In each year, the soil condition around the lysimeters was the same as inside each lysimeter. The soil texture was silty clay loam based on soil mechanical analysis. (Soil textural triangle diagram).

Irrigation time was determined by using an evaporation pan. Urea and ammonium nitrate were applied in three equal rations before planting time, mid season and in plant flowering time. Ammonium sulphate was applied in two parts before planting time and in plant flowering time during the growing season (ration of nitrogen fertilizers. was based on their mobility). Corn and barley were harvested in October 1998 and June 1999, respectively.

After harvest, the weight of the aerial parts of corn plants and grain yield of barley were measured. Soil chemical characteristics including electrical conductivity (EC), acidity (pH), organic carbon (OC), phosphorus (P), potassium (K), manganese (Mn), Zinc (Zn), iron (Fe), Copper (Cu), chloride (Cl), sulphate (SO$_4$), bicarbonate (HCO$_3$), sodium (Na) and calcium plus magnesium (Ca + Mg) were measured by standard
laboratory methods. Data were analyzed statistically following the methods described by Gomez and Gomez (1984) and SAS software (SAS Institute, 1997) was used to carry out the statistical analysis. Duncan method with attention to confidence level of 95 percent was used for comparison of means. The results of the first two years of this research are presented in this paper.

Results and discussion

Table 1 illustrates more details of water characteristics and soil conditions before corn and barley were seeded (at the beginning of first and second years of the study).

4-1-Changes in soil parameters after corn and barley harvest
Table 2 shows changes in soil parameters after corn and barley were harvested. These data are the average of three soil depths of 0-30, 30-60 and 60-90 cm. As it is shown in this table, there is no statistical difference (p < 0.05) between all measured soil parameters (except bicarbonate for corn) in fertilizer treatments. Therefore, the three applied fertilizers didn't have important effect on soil chemical properties. Comparison of Tables 1 and 2 shows that EC, SO$_4$ and HCO$_3$ of soil have increased under corn and barley

4-2-Salinity differences along the soil profile
Figures 1 and 2 show soil EC changes (the difference between initial and final soil EC) in the soil profile during corn and barley cropping seasons because of the three applied fertilizers of urea, ammonium nitrate and ammonium sulphate. As illustrated in Figure 1, EC changes during the corn cropping season is negative for depth of 0-30 cm (reduction in soil salinity) and positive (increase in soil salinity) for two depths of 30-60 and 60-90 cm for the applied fertilizers. This means that in depth of 0-30 cm, salts have been leached and in the other soil depths salts have been accumulated during corn cropping season. Application of ammonium sulphate caused the least reduction in soil salinity of depth of 0-30 cm as compared to urea and ammonium nitrate. The average salinity of soil depths at the beginning and end of the season indicated that for three fertilizers of urea, ammonium sulphate and ammonium nitrate, soil salinity increased 14.2, 23.3 and 15.3 percent during corn cropping season, respectively.

4-3-Soil SAR changes during barley cropping season
Soil SAR was reduced along the soil profile during barley cropping season (Fig. 3). The highest reduction in soil SAR (- 42.4%) was caused by the application of ammonium sulphate. The least reduction in soil SAR (- 2.3%) occurred in soil depth of 60-90 cm and application of urea. This means that leaching efficiency of the lower soil layers is less than the upper depths. It should be noted that the effects of fertilizers on soil salinity aren’t the same as their effects on soil SAR. The least reduction in soil salinity was obtained using ammonium sulphate, but the least soil SAR was obtained using this fertilizer too.

4-4-Yield and weight of areal parts
In order to consider corn and barley conditions as a result of application of different nitrogen fertilizers, areal parts’ weight of corn plants and grain yield of barley plants in each lysimeter was recorded. The changes in weight of areal parts of corn plants and grain yield of barley are shown in Table 4. As shown in this table, the highest areal parts’ weight of corn (40.9 ton/ha) is obtained by using ammonium sulphate, and areal parts’ weight was reduced by 3.5 and 7 percent by application of urea and ammonium nitrate, respectively. But these changes were not statistically significant (p<0.05).

Application of nitrogen fertilizers didn’t have significant effect (p<0.05) on barley grain yield (Table 4). The highest grain yield (4588 kg/ha) was obtained by applying urea, and application of ammonium sulphate and
ammonium nitrate reduced grain yield by 4.8 and 6.6 percent with respect to urea. But these changes were not significant statistically (p<0.05).

4-5-Corn shoot analysis
To compare the effects of different fertilizers on accumulation of elements in shoot in a short growing period, corn shoot analysis was performed. This analysis indicated that minimum accumulation of elements such as Ca, Mg, Fe, Mn, Zn, Cu and B in plant shoot occurred when ammonium sulphate was applied (Table 4). The maximum accumulation of P and K occurred using ammonium sulphate too. It means that application of this fertilizer caused less salt absorption and more nutrition adsorption by plants as compared to other fertilizers. Statistical analysis showed that except for Ca and Mg, these changes were not significant (p<0.05). Figure 4 illustrates changes in nitrogen (N) and sodium (Na) content of corn shoot as a result of different applied fertilizers. Application of ammonium sulphate caused the highest amount of N and the lowest amount of Na accumulation in corn shoot during the growing season. Application of urea and ammonium nitrate increased Na accumulation by 82.4 and 135.3 percent and decreased N by 14 and 11.3 percent, respectively. Statistical analysis showed that N changes were not significant (p<0.05), but Na changes were significant. Therefore, by looking at the results of Table 4 and Figure 4, it is clear that ammonium sulphate is more effective in enhancement of N and reduction of Na in corn shoot as compared to the other applied fertilizers. Therefore, in areas where saline irrigation water contains a lot of harmful elements, application of ammonium sulphate is preferred over urea and ammonium nitrate.

4-6-Efflux of Nitrate from soil profile
The most important factor for using a nitrogen fertilizer is its stability to remain in the plants' root zone. The lesser a nitrogen fertilizer leaches down the soil profile, the higher its quality to be used in agriculture. In this study, the amount of drainage water and NO$_3$-N concentration was measured after each irrigation event. As shown in Figure 5, the lowest amount of efflux N-NO$_3$ belongs to ammonium sulphate and application of urea and ammonium nitrate increased nitrate leaching 26.1 and 43.5 percent for corn and 38.9 and 49.1 percent for barley, respectively. The amount of nitrate leaching in corn which fertilized with ammonium nitrate was greater than urea and this value for urea was greater than ammonium sulphate significantly (>0.5). The reason may be higher solubility of ammonium nitrate and urea compared to ammonium sulphate. The second reason may be interaction of ammonium sulphate with soil particles mostly clay size. In this case the NH$_4^+$ ions can attached to clay surface and do not leach easily. The leached nitrate in ammonium nitrate and urea was more than ammonium sulphate for barley crop. Both for corn and barley nitrate leaching from lysimeter fertilized with ammonium sulphate was at least where ammonium nitrate showed the highest contamination potential.

4-7-interaction between treatments and cropping
The soil parameter variation pattern under different treatments and cropping were similar but salinity varied in different pattern. The amount of N-NO$_3$ leaching from soil profile showed similar pattern in different treatments (except for Ammonium sulphate) and cropping

Conclusions
Groundwater contamination by leaching of nitrogen fertilizers below the root zone is a crucial environmental problem. A lysimetric study was performed to investigate the changes caused by three types of fertilizers (urea, ammonium sulphate and ammonium nitrate) on soil parameters and corn and barley. The results showed that there was no statistical difference (p < 0.05) between measured soil parameters in fertilizer treatments. In 0-30 cm depth, salts have been leached and in the other soil depths salts have been accumulated during corn cropping season. Application of ammonium sulphate caused the least reduction in soil salinity of depth of 0-30 cm as compared to urea and ammonium nitrate. Soil salinity changes along the soil profile during the barley cropping season showed that in all soil depths, salinity was reduced. The highest weight of corn areal parts and grain yield of barley were obtained by using ammonium sulphate and urea respectively. Application of nitrogen fertilizers didn’t have significant effect (p<0.05) on areal parts’ weight of corn and grain yield of barley. Measurement of NO$_3$-N from drained water showed that ammonium sulphate has the least and ammonium nitrate has the highest contamination potential. Therefore application of nitrogen in the
form of ammonium sulphate is more effective to be used in saline soils (under leaching) as compared to urea and ammonium nitrate.

References