INTRODUCTION

Rice is one of the most important cultivated crops in the world [1]. Since nitrogen fertilizer has a vital role to reach rice potential yield, it is accounted as a significant share of fertilizer consumption among agricultural crops and urea is the most commonly used nitrogen fertilizer [6, 8]. Nitrate from nitrogenous fertilizers is accounted as a major source of groundwater contamination because of its high solubility and mobility in the environment. Applied nitrogen fertilizer should not contribute to contaminate groundwater, so using appropriate levels of nitrogen fertilizer is necessary to both supply crop need and mitigate nitrogen leaching and other nitrogen losses ways. Prediction of nitrate leaching is required for assessment and control of groundwater contamination as well as development of nutrient management protocols [4]. Nitrogen leaching occurs when soil is saturated, a usual condition in traditional flooded paddy fields.

In general, nitrogen fertilizers usually contain nitrogen in one of three forms: ammonium, nitrate and urea. Of course, the most common form is urea, being the organic compound, CO(NH)₂. When urea is applied in flooded paddy fields, it is converted to ammonium (NH₄) and through urea hydrolysis to nitrate (NO₃) through

The Effect of urea fertilizer quantity and splitting on nitrate losses during rice growth season

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ABSTRACT

If suitable amount of nitrogen is not available for plant in the soil, physiological symptoms of nitrogen lack can decrease rice yield, but using nitrate more than recommended level make increase in nitrogen leaching. Split nitrogen fertilizer application can address this issue. The present study was carried out to determine the effects of, and split application of urea fertilizer on the amount of nitrogen leaching. In order to predict the concentration of nitrate from urea (CO(NH)₂) source in drain water percolated out of root zone during crop season especially when it is split, a pot experiment was conducted in a silty-clay soil at the rice research institute of Iran, located in Rasht, Guilan province. The study was a factorial based on a Randomized Complete Block Design (RCBD) with three replications and two factors. The first factor was the amount of N fertilizer as the first factor i.e. 50, 125, 200 and 275 kg urea ha⁻¹ and number of its split as the second factor including: basal application at transplanting, two split applications i.e. at transplanting and at the beginning of tillering, and finally three split applications i.e. at transplanting, at the beginning of tillering and just before flowering. Fertilizer treatments were applied on a local cultivar, Hashemi, being a well known cultivar in the region. The results indicated that by increasing of fertilizer quantity, nitrate losses increase and leaching losses decrease while fertilizer was used in split form. It was also observed the time of maximum nitrate losses during crop season. When urea fertilizer quantity increased from 50 to 275 kg urea ha⁻¹, total of leaching losses increased from 79 to 124 mg l⁻¹. The leaching losses of nitrogen decreased when fertilizer was used in split form. The highest nitrogen leaching was with basal application, whereas the lowest was with three splits treatment. The nitrate loss was higher in the beginning of the season compared with the rest of growing season. When fertilizer was used in split form, the leaching losses were decreased. Furthermore, three splits treatment had the lowest losses as compared with other treatments. So that to mitigate nitrate leaching proper dose of urea fertilizer and two or three splitting method are recommended.

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nitrification. Nitrate is soluble and moves with the water percolating through the soil and is not adsorbed to soil particles. On the other hand, ammonium gets adsorbed to the soil particles and is taken up by the plants. Both nitrate and ammonium forms of nitrogen, common forms of nitrogen in the soil are lost through leaching. When water percolates in the soil, nitrate forms leach with water, whereas ammonium forms adsorbed to negatively charged soil clay lattice; so that ammonium forms leach less [5, 15]. More than 98% of the leached nitrogen was in ammonium forms in soybean experiment according to Marko et al. [13]. The leached nitrogen contaminates the groundwater resources through percolation of water.

The amount of leached nitrogen depends on soil condition and nitrogen fertilizer management [3, 18, 19]. The most important factors determining the quantity of leached nitrogen to groundwater are both soil texture and soil structure, rainfall and irrigation amounts and timing, crop type and the timing and the amount of nitrogen fertilizer application [10]. Leaching of nitrate from applied fertilizers is considered as the main source of pollution of groundwater underlying flooded rice fields. Due to flood condition, nitrate losses from applied fertilizers can be high in rice fields. However, evaluation of nitrate losses from rice fields is complicated because of the variable nature and different properties of soils and the complexity of N-transformation processes that occur under flood conditions in rice fields [1]. Generally, important urea transformations in flooded paddy fields include urea hydrolysis, volatilization, nitrification and denitrification, while the hydrological pathways of nitrogen loss mainly involve surface runoff and vertical leaching [6, 11, 12]. In recent years, paddy fields have been considered as ecological wetlands for purifying agricultural pollutants like nitrogen [9, 14]. The spatial variability of NO3 leaching from a wheat field was investigated using monthly analysis version of N-LEAP mode [16]. Nitrogen content in drain water which is one of primary concern in estimating nitrate loads to groundwater was affected by slight increase or decrease in urea hydrolysis, nitrification, volatilization and denitrification of constant rates [4].

If water and nitrogen are not managed properly, many losses will occur by numerous pathways. Therefore, there is a considerable interest in technologies that enhances nitrogen use efficiency and productive use of applied irrigation water leading to increased productivity [2]. When nitrogen is applied as basal at the beginning of the crop season, nitrogen is more susceptible to losses, especially nitrogen leaching [7, 20]. Splitting total nitrogen application into two or more applications can improve both nitrogen efficiency and yield and mitigate nitrogen leaching. By delaying application of a fraction of nitrogen amount until the crop roots is better able to take up nitrogen can lessen nitrogen leaching [20].

Not much research has been carried out to evaluate different levels of nitrogen amount and its splitting [10], especially in the studied area. This study was conducted to predict the concentration of nitrate in the drain water percolating out of the root zone during crop season of rice from urea source especially when it is split.

**MATERIALS AND METHODS**

A pot experiment was conducted in a silty-clay soil for two crop seasons. This study was conducted at the rice research institute of Iran (37°12 ’N, 49°38 ’28 ”E, 24.6 m a.s.l.), located in Rasht, Guilan province, where rice is the most cultivated crop. The climate of Rasht was determined to be so humid, based on Köppen method according to 50-year climatic data (1956-2005). Some weather, soil and irrigation water characteristics are presented in Table 1, Table 2 and Table 3. This soil has been always a paddy soil for a long time. The rice variety was ‘Hashemi’ so popular in Guilan province.

The study was a factorial based on a Randomized Complete Block Design (RCBD) with three replications. The amount of N fertilizers was accounted as a first factor i.e. 30, 60, 90, and 120 kg N ha⁻¹ or 50, 125, 200 and 275 kg urea ha⁻¹, and the times of nitrogen application were the second factor i.e. basal application at transplanting, two splits application i.e. at transplanting and at the beginning of tillering, and finally three splits applications i.e. at transplanting, at the beginning of tillering and just before flowering. The dimensions of pot were 25*25*25 cm. The pots were filled with paddy field soil with a layer of coarse sand at the bottom. The water samples were taken by a hose which was at the side of pots inserted to the bottom of the pots. The effects of treatments on nitrogen leaching were determined by measuring total nitrogen in drained water of the pots every five days.

**Table 1:** Some physical and chemical soil characteristics

<table>
<thead>
<tr>
<th>Organic C %</th>
<th>Total nitrogen %</th>
<th>Absorbable P mg/kg</th>
<th>Absorbable K mg/kg</th>
<th>Sand %</th>
<th>Silt %</th>
<th>Clay %</th>
<th>Soil texture</th>
<th>Crop season</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.65</td>
<td>0.123</td>
<td>5.2</td>
<td>142</td>
<td>12</td>
<td>48</td>
<td>40</td>
<td>Si. C</td>
<td>First</td>
</tr>
<tr>
<td>2.46</td>
<td>0.228</td>
<td>20</td>
<td>234</td>
<td>8</td>
<td>44</td>
<td>48</td>
<td>Si. C</td>
<td>Second</td>
</tr>
</tbody>
</table>

**Table 2:** Some climatic data at Rasht meteorological station

<table>
<thead>
<tr>
<th>Crop season</th>
<th>Month</th>
<th>Tmax (°C)</th>
<th>Tmin (°C)</th>
<th>RHmax (%)</th>
<th>RHmin (%)</th>
<th>Sunshine hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First</td>
<td>First</td>
<td>First</td>
<td>First</td>
<td>First</td>
</tr>
<tr>
<td>April</td>
<td>30.2</td>
<td>32.6</td>
<td>0</td>
<td>-0.6</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Second</td>
<td>First</td>
<td>Second</td>
<td>First</td>
<td>Second</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>14</td>
<td>50</td>
<td>218</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
May  27.2  33  1.9  8.6  100  100  35  21  220  118
June  32.8  30.5  11.6  12.2  98  100  30  31  194  232
July   34.2  32.6  16.6  12.2  98  100  38  37  223  204
August 35.4  32.2  16.2  18  100  100  31  37  196  223
September 34.6  32.6  15.6  14.4  100  100  36  35  144  157

RH: relative humidity
T: temperature

Table 3: Some physical and chemical characteristics of irrigation water

<table>
<thead>
<tr>
<th>Na</th>
<th>Mg</th>
<th>Ca</th>
<th>SO₄</th>
<th>Cl</th>
<th>HCO₃</th>
<th>CO₃</th>
<th>pH</th>
<th>SAR</th>
<th>TDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>6.5</td>
<td>3.9</td>
<td>0.4</td>
<td>4.4</td>
<td>4.6</td>
<td>1.2</td>
<td>8.2</td>
<td>1.7</td>
<td>951</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

The Fig. 1 indicates total nitrate leaching and its average for two years experiments during rice growing season. Nitrogen losses from different nitrogen treatments varied. When urea fertilizer quantity increased from 50 to 275 kg urea ha⁻¹ i.e. from 30 to 120 kg N ha⁻¹, total and average of leaching losses increased from 79 to 124 and from 7 to 11.3 mg.l⁻¹ (ppm), respectively. These results are in agreement with the results of Schepers et al. [17] who reported that increase in nitrogen application resulted in more nitrogen leaching. Furthermore, the leaching losses decreased when fertilizer was used in split form, for instance leaching decreased 11 to 22% when three splits application used instead of basal application. The highest nitrogen leaching was with basal application, whereas the lowest nitrogen leaching was recorded in three splits treatment. In basal application whole urea applied together and produced nitrate in the surface layers of submerged soil moves easily by diffusion and percolate into lower layers.

The average of nitrogen losses through leaching in the beginning of the season, in the middle of season and at the end of season during two years experiments is shown in Fig. 2. The results indicated that the nitrate loss was higher in the beginning of the season as compared with rest of growing season, especially with basal application. Higher nitrate leaching may be due to both low activity and low extent of roots in this period. After this period, rice plants take up more nitrogen from soil resulted in a lower nitrate leaching.

Fig. 3. shows the variation of nitrate losses affected by different fertilizer levels during the crop season at different intervals. This variation can be attributed to the variations in the drain rate during crop season. Similar results were obtained by Chowdary et al. [4]. The direct association between the water percolation rate and nitrate losses by leaching is expected. Leaching losses of nitrate is higher during the first week of fertilizer application and it decreased as the time advanced. Higher loss of nitrate immediately after the application of fertilizer was due to the increase in concentration of dissolved nitrogen in soil solution. This obviously demonstrates the importance of avoiding excess urea fertilizer application in paddy fields. This result is in agreement with that of Iqbal [10] who studied nitrogen leaching from paddy field under different fertilization rates in China.

![Fig. 1: Total and average of nitrate leaching in different treatments of urea application amount (50, 125, 200 and 275 kg/ha) in different split number (1, 2 and 3)](image-url)
Fig. 2: The average of nitrate leaching in the beginning of season, in the middle of season and at the end of season with different urea application amount (50, 125, 200 and 275 kg/ha) in different split number (1, 2 and 3).

Fig. 3: The average of nitrate leaching during crop season with different urea application amount.

Fig. 3 shows the variation of nitrate losses affected by different fertilizer splitting during rice growing season. When fertilizer was used in split form, the leaching losses were decreased during the crop season. Furthermore, three splits treatment had the lowest losses as compared with other treatments. It was expected that plant has the highest opportunity for nitrate uptake in three splits, and this could be due to the decrease of nitrate losses. Fluctuation of nitrate leaching was approximately the same in each treatment except of the first part of growing season. It was found that nitrate leaching was actually proportionally related to nitrogen application amount. As a result, nitrate leaching declined much more quickly with basal application finally reaching a constant level in all treatment. These results are in agreement with Iqbal [10] findings.
Fertilizers from both inorganic and organic sources will be endlessly applied to increase and sustain agricultural production to supply increasing demand for food. Simultaneously, the impact of inappropriate fertilizers use on the environment should be tackled. This can help us sustaining crop production while protecting the environment. Furthermore, nitrogen fertilizer comprise a considerable share in crop production charge, so using appropriate dose of nitrogen with a relevant splitting method results in an increased relative economic benefit with respect to environment. Different chemical compounds should be examined for their nitrification retarding characteristics to inhibit oxidation of ammonium to nitrate and therefore mitigate nitrate leaching.

Nitrate leaching can be mitigated by improving water productivity. Nitrate is leached into lower layer of soil by drain water. So decreasing water losses from root zone layer results in less nitrate leaching. Using slow-release fertilizer and nitrification inhibitors, as well as puddling of paddy fields are recommended to mitigate nitrate leaching. In Guilan province, crop residues are usually burn after harvest. Where, maintaining crop residue after rice harvest can increase soil organic carbon which immobilizes the residual nitrate from nitrogen fertilizers ended up in minimizing nitrate leaching.

Conclusion:
The objective of the present study was to evaluate the effect of different urea fertilizer rates with the nitrate splitting method applied in two or three times on the nitrate leaching as compared with basal application for rice cultivation. In this study, it was found that if urea fertilizer quantity is increased, as well as nitrate losses will be increased whereas the leaching losses will be decreased when fertilizer is used in split form i.e. two or three topdressing. It was also observed that nitrate losses decreased during rice growing season. Two major factors that control nitrate leaching losses are concentration of nitrate in the soil profile at the time of leaching and quantity of water drained from the root zone. Much research is needed to find the most relevant method for timing and splitting nitrogen application in paddy field. Great emphasis should be placed to reduce nitrate losses and enhancing nitrogen efficiency. The cumulative effect of leached nitrate on the quality of groundwater should be evaluated, especially when nitrate is reduced to nitrite. If this groundwater used for irrigation or drinking, nitrite or nitrate return to the food chain. Nitrite and nitrate contribute in the formation of nitrogenous carcinogenic compound i.e. nitrosamines, causing human gastric cancer.

Fig. 4: The average of nitrate leaching in different split treatments and the basal application treatment

REFERENCES


