Lateral Losses of $^{15}$N-Fertilizer on a Sandy Soil and Its Impact on Plant N-Recovery in Irrigated Sudangrass

Mohamed Naceur, Khelil, Jean Pierre Destain, Saloua Rejeb and Belgacem Henchi

A 2 years field experiment was conducted on a sandy soil to assess losses of labeled fertilizer in irrigated Sudangrass. $^{15}$N-fertilizer was applied at different rates (0, 50 and 100 kg N.ha$^{-1}$) to 1m² confined and unconfined micro plots and with different water irrigation qualities (well water VS treated wastewater) to Sudangrass. The assessment of micro plot design proves a significant effect of 0.20m deep frame in increasing fertilizer N uptake by Sudangrass. Nitrogen derived from fertilizer was significantly higher in the confined micro plots, regardless of plant parts, water qualities or nitrogen rates. Confining micro plot increased significantly atom % $^{15}$N enrichment and fertilizer N recovery in Sudangrass leaves, stem, grain and roots. Residual effect was about 2% in the unconfined micro plot and increased when barrier was used. Neither fertilizer rate nor water quality had an effect on the $^{15}$N-fertilizer remaining in the 0-60 cm layer at harvest. About 33 to 49% of $^{15}$N-labeled fertilizer was left in the 0-60cm layer at final harvest when barrier was installed, and mostly present in the surface 0-20 cm layer. The N unaccounted for in the soil-plant system was about threefold higher when unconfined micro plot was used, regardless fertilizer N rate and water qualities.

Keywords: Irrigation; lateral movement of N; $^{15}$N-fertilizer; nitrogen balance

1. INTRODUCTION

The use of $^{15}$N labeled fertilizer has become increasingly important in field studies for drawing up the balance sheet of fertilizer N. In addition, nitrogen-15 allows to distinguish between fertilizer N and indigenous N, providing the possibility to measure both total amount of N deriving from fertilizer and taken up by crops or left in soil, and fertilizer N loss during crop growth. However, the high cost of $^{15}$N labeled fertilizer limits its employment to a micro plot within a larger plot [20, 7]. Some workers have alleviated problems linked with lateral movement of labeled fertilizers in field studies [3, 13]. Overcome lateral movement of $^{15}$N is of a considerable importance especially in field studies to determine recovery of fertilizer N by crops. Lateral exchange of $^{15}$N labeled fertilizer outside the micro plot and unlabeled N inside the micro plot is a potential source of error in field studies to determine recovery of fertilizer N by crops. Several studies has pointed to know how small a micro plot must be before lateral movement introduces significant errors. In theirs studies [21]on the lateral movement of $^{15}$N anhydrous ammonia and urea-ammonia nitrate solution applied to field maize, suggested that the minimum size of unconfined $^{15}$N micro plot required, should be 2 m by 2 m without restriction by borders. According to [25], plants witch is at least 0.5 m from the border of unconfined $^{15}$N micro plot can provide reliable data. Accurate values for plant uptake of fertilizer N could be obtained by sampling the center plant of 3-row plots at least 214 cm long and 71 cm apart [15]. If residual fertilizer N is to be determined, he suggested that a four-row plot may be required and that soil samples should be taken from the space between the tow center rows. In other investigations, to eliminate problems associated with lateral movement of labeled N, they install barriers in the soil to confine the micro plots [18, 6]. However, the establishment of confined micro plots is more time-consuming than unconfined micro plots [28]. According to [18], the major advantage in using confined $^{15}$N micro plots in field studies is that they can stop diffusion and mass flow of $^{15}$N to outside of the micro plots and unlabelled N to inside the micro plots. Depending on [14], a 0.25 m deep frame was effective in preventing lateral movement of $^{15}$N in the upper zone and was appropriate for studying changes of applied $^{15}$N labeled fertilizer during the growing season.

The objective of the current study was to assess confined and unconfined micro plots effects on (i) the nitrogen derived from fertilizer (Ndff%), (ii) the recovery of nitrogen fertilizer by Sudangrass ($^{15}$NRF) and on (iii) the $^{15}$N-labeled fertilizer left in the soil.

2. MATERIALS AND METHODS

This field study was conducted in summer during 1997 and 1999, as part of a larger study, on a well-drained sandy soil of the experimental field of the Rural, Water and Forest Research Institute "INRGREF" of Tunisia. The field had been for Sudangrass production for at least 2 years prior to the experiment. Some physical and chemical properties of the soil are presented in Table 1.
properties of the experimental soil are presented in Table 1.

Table 1: Some physical and chemical properties and water contents of the experimental soil.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>0 - 20</th>
<th>20 – 40</th>
<th>40 – 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loam (%)</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Sand (%)</td>
<td>83</td>
<td>92</td>
<td>94</td>
</tr>
<tr>
<td>EC (mmhos.cm⁻¹)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>pH</td>
<td>7.8</td>
<td>7.3</td>
<td>7.3</td>
</tr>
<tr>
<td>O M (%)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.0</td>
</tr>
<tr>
<td>CaCO₃ (%)</td>
<td>0.2</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.059</td>
<td>0.047</td>
<td>0.036</td>
</tr>
<tr>
<td>WHC (mm)</td>
<td>1.79</td>
<td>1.28</td>
<td>1.12</td>
</tr>
<tr>
<td>WWP (mm)</td>
<td>6.67</td>
<td>4.45</td>
<td>3.28</td>
</tr>
<tr>
<td>AW (mm)</td>
<td>14.64</td>
<td>9.50</td>
<td>6.48</td>
</tr>
<tr>
<td>C/N</td>
<td>3.4</td>
<td>2.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

WHC: water holding capacity. WWP: water at wilting point. AW: available water calculated for 20 cm of soil (AW = 2[da (WHC – WWP)] with da: apparent density of soil = 1.5).

The treatments comprised (i) two irrigation water qualities, treated wastewater (TWW) and well water (WW) and, (ii) different rates of nitrogen fertilizer, two nitrogen levels (0 and 100 kg N.ha⁻¹) when Sudangrass is irrigated with WW and three nitrogen levels (0, 50 and 100 kg N.ha⁻¹) when TWW was used for irrigation. The N composition of the treated waste water ranged from 19.2 to 40.3 mg.L⁻¹ of total N, with an average of 37 mg N.L⁻¹, and accounted less than 5 mg.L⁻¹ of NO₃⁻. N. The experiment was organized in a randomized complete block design (20 blocks) with four replications. Each treatment block was 15 by 4 m. Nitrogen was split at raising and after each harvesting time at equal rate. For that reason, only two of the three fractions planned were applied, with a total rate of 0 and 66 kg N.ha⁻¹ in WW and 0, 33 and 66 kg N.ha⁻¹ in TWW. In 1999, in order to apply the entire rate, two harvesting time were planned and done. In order to trace the fate of applied fertilizer, enriched ¹⁵N was applied as ¹⁵NH₄Cl, ¹⁵NO₃ to 1 by 1 m micro plots within each block in both years. Micro plots were located on opposite sides of each main plot and on the fourth row from the edge of each main plot border. On the way to determine the effect of application time, two ¹⁵N-microplots for each N fertilizer treatment were established. One micro plot received ¹⁵N-labelled fertilizer at rising and unlabelled N fertilizer after the first harvest; the other ¹⁵N-microplot received unlabelled N fertilizer at raising and ¹⁵N-labelled fertilizer after the first harvest. In 1997, micro plots were not confined and just surrounded with a streak made with sand. Even though, in 1999, a rigid plastic barrier, 30 cm height, was placed into the soil around the perimeter of the ¹⁵N-microplots. The plastic barriers extended 10 cm above the soil surface. A solution of ¹⁵NH₄Cl, ¹⁵NO₃ at 9.495 and 4.426 atom % ¹⁵N excess was applied in the ¹⁵N-microplots at the same rate of N fertilization as was applied to the surrounding plot, in 1997 and 1999 respectively. The isotope treatments were applied during irrigation. The soil surface were moistened with 15 liters irrigation water, after that ¹⁵N-labeled fertilizer was uniformly applied with an watering car with a sprinkler head in 2 liters of distilled water, then watering car was rinsed immediately with 1 liter of distilled water and the rinse was also applied, followed by an additional 2 liters of distilled water to wash Sudangrass foliage from deposit ¹⁵N. Plants of the surrounding plot received unlabelled-N fertilizer, applied by hand at the corresponding N rate within the same day with care to prevent any unlabelled N fertilizer from being applied to the ¹⁵N-microplots. Sudangrass (sorghum sudanense, Piper) was planted on monthly statement of May in 0.3 m row spacing at a population of 333000 plants ha⁻¹ in both years. In the micro plots population was double the density in the main plots, but plants were thinned to normal density shortly after emergence. The ¹⁵N-microplots were arranged to include four rows of sorghum with ten plants per row.

Water irrigation levels were designed to approximate the seasonal evapotranspiration (ET) minus precipitation deficit. The crop ET requirement is 630 mm per season from 15 Mai to mid-September under local conditions. According to [19], water use efficiency was estimated at 70% in field experiment, so that an additional of 30% (equal to 190 mm) excess water was applied to meet 100% of water use efficiency. Irrigation was made from May through September, consisted of a total of 30 and 32 irrigations during 1997 and 1999 respectively. Overall, the crop received a total of 870 and 820 mm of water in 1997 and 1999 respectively. ¹⁵N-microplots were irrigated at the same time as the main plots with a watering car with a sprinkler head. Two harvests were made, plants were harvested for yield and soil samples were collected after the last harvest at three depths (0-20, 20-40 and 40-60cm) from six locations in the ¹⁵N-microplots and composited. Twelve central sorghum plants were harvested and separated into different plant portions (leaf, stem, grain and roots) for estimation fertilizer N recovery (¹⁵NRF) of each part. All plant portions were dried at 70°C, and weights were recorded. The plant tissue was ground and analyzed for total N using the kjeldhal digestion method [4]. However, analysis for total N in soil was carried out using kjeldhal method modified to include nitrate, Olsen 1929 cited by [9]. The isotopic composition of nitrogen was determined by mass spectrometry (VG SIRA12. UK). To avoid cross-contamination during the steam-distillation process, the distillation unit was flushed with ethanol for 3 min between samples. The data set was statistically analyzed using SAS (1985)[22] for significance of N application levels, and of the effect of confined and unconfined ¹⁵N-microplots on ¹⁵NRF. Mean comparison
were made by protected LSD tests at 0.05 level of probability.

3. RESULTS

3.1 Plant production and nitrogen uptake

The lowest dry matter production obtained was recorded with WW irrigation with no fertilizer added and was significantly higher with TWW in both confined and unconfined micro plot. Increasing the rates of N application in TWW irrigation did not significantly increase dry matter production in the two year experiments, while plant N uptake was enhanced by a moderate fertilizer rate (50 kg.ha⁻¹) in the confined micro plot (Table 2).

Table 2: Above-ground dry matter production, nitrogen uptake and retention in soil as affected by micro plot design, fertilizer application rates and water irrigation qualities.

<table>
<thead>
<tr>
<th>Year (treatment)</th>
<th>15N labeled NH₄NO₃</th>
<th>Dry matter</th>
<th>Plant N uptake</th>
<th>Labeled N remaining in soil</th>
<th>Labeled N</th>
<th>N unaccounted for</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Labeled N</td>
<td>Total N</td>
<td>0/20cm</td>
<td>20/40cm</td>
</tr>
<tr>
<td>WW0</td>
<td>0</td>
<td>5024c</td>
<td>-</td>
<td>70b</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>WW2</td>
<td>66</td>
<td>9074ab</td>
<td>9</td>
<td>111ab</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TWW0</td>
<td>0</td>
<td>8374b</td>
<td>-</td>
<td>135a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TWW1</td>
<td>33</td>
<td>11899a</td>
<td>6</td>
<td>156a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TWW2</td>
<td>66</td>
<td>11401ab</td>
<td>11</td>
<td>154a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>LSD*</td>
<td></td>
<td>2145</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Confined micro plot 1999

| WW0             | 0                | 3647c      | -             | 54d                         | -        | -       | -       | -     |
| WW2             | 100              | 7409b      | 23b           | 107c                        | 22a      | 9a      | 7a      | 38a   |
| TWW0            | 0                | 6730b      | -             | 140b                        | -        | -       | -       | -     |
| TWW1            | 50               | 9727a      | 24b           | 182a                        | 24a      | 14a     | 11a     | 49a   |
| TWW2            | 100              | 9141a      | 36a           | 183a                        | 21a      | 7a      | 6a      | 33a   |
| LSD*            |                  | 897        | 6.98          | 13                          | 7.6      | 8.12    | 10.7    | 22.9  |

‡ Least significant difference at 0.05 level of probability.

3.2 Nitrogen derived from fertilizer

Relating to N derived from fertilizer, the Ndff% was significantly higher in the confined micro-plot and showed the same pattern of difference among all treatments as in the unconfined micro plot, regardless of plant part, water quality or nitrogen rate (Figure1).
Results showed a more marked and consistent effects of the barrier on the Ndff% in leaf, stem grain and root. On the basis of the whole plant, Ndff% values in confined micro plot were 12, 8 and 11% higher than those of unconfined micro plot for WW2, TWW1 and TWW2 respectively. This pattern was similar to fertilizer N uptake in this study; in the confined micro-plot fertilizer N uptake were 14, 18, and 25 kg 15N.ha⁻¹ higher than those of unconfined micro-plot for WW2, TWW1 and TWW2 respectively (Table 2).

The assessment of micro plot design proves a significant effect of 0.20m-deep frame in limiting lateral losses of water and fertilizer and in increasing fertilizer N uptake by Sudangrass.

3.3 Fertilizer nitrogen recovery

The differences in fertilizer N use between the different treatments and irrigation water qualities become clear when they are expressed on the percent recovery basis. Fertilizer nitrogen recovery (FNR) in Sudangrass plants was consistently higher in confined micro plot than in unconfined micro plot (Table 3).
Table 3: Fertilizer N recovery in the whole plant as estimated by isotopic method.

<table>
<thead>
<tr>
<th>Year</th>
<th>$^{15}$N-labeled NH$_4$NO$_3$</th>
<th>Fertilizer N recovery (FNR)</th>
<th>1st harvest</th>
<th>2nd harvest</th>
<th>Residual effect</th>
<th>Total recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unconfined micro plot 1997 (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WW$_2$ 66</td>
<td>15 a</td>
<td>10 b</td>
<td>1 b</td>
<td>13 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWW$_1$ 33</td>
<td>20 a</td>
<td>18 a</td>
<td>2</td>
<td>20 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWW$_2$ 66</td>
<td>21 a</td>
<td>11 b</td>
<td>2</td>
<td>17 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD‡</td>
<td>7.79</td>
<td>3.93</td>
<td>0.5</td>
<td>6.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confined micro plot 1999 (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WW$_2$ 100</td>
<td>26 b</td>
<td>16 c</td>
<td>3 b</td>
<td>22.5 c</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWW$_1$ 50</td>
<td>42 a</td>
<td>47 a</td>
<td>6 a</td>
<td>47 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TWW$_2$ 100</td>
<td>38 ab</td>
<td>29 b</td>
<td>5</td>
<td>36 b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD‡</td>
<td>12.29</td>
<td>5.43</td>
<td>1.4</td>
<td>6.48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

‡ Least significant difference at 0.05 level of probability.

3.4 Recovery of fertilizer N in soil

The atom %$^{15}$N enrichments in most soil samples were indistinguishable from natural abundance in the unconfined micro-plot (average natural abundance values of 0.3688) suggesting a greatest loss of labeled N from the micro plot. This greatest lateral or and deep movement of $^{15}$N-labeled fertilizer could be linked to the nature of our sandy soil and irrigation system. Distribution of fertilizer N in the soil profile as influenced by N rate and water qualities is presented in Table 2 and Figure 3. Nitrogen remaining in the soil after harvest seems to be height for the two qualities of water irrigation. Neither fertilizer rate nor water quality had an effect on the $^{15}$N-labeled fertilizer remaining in the 0-60 cm layer at final harvest. Residual $^{15}$N-labeled fertilizer in the soil fluctuates from 33 to 49% in the 0-60 cm layer for all rates and for both water qualities. Most of residual $^{15}$N-labeled fertilizer remaining in the soil was located in the surface 0-20 cm layer, with an average of 22% despite nitrogen rate and water irrigation qualities (Table 2). Moreover, the proportion of total $^{15}$N remaining in the top 20 cm of soil increased from 49 to 58% as the $^{15}$N-fertilizer increased in the TWW irrigation, although it was comparable for both water irrigation qualities with the same rate of $^{15}$N-fertilizer applied (Figure 2).

![Figure 2: Nitrogen derived from fertilizer in the 0-60 cm layer of soil as a proportion of the total $^{15}$N remaining in the 0-60 cm layer at final harvest.](image)
This better immobilization of nitrogen in the top layer was attributed by many authors to an important concentration of microflore biomass at the surface soil.

3.5 Fertilizer N unaccounted for

Losses of fertilizer nitrogen can be estimated from the differences between the amount of $^{15}$N recovered in the crop and the soil, and the known amount of $^{15}$N applied (Table 2). Losses estimated in this way vary significantly with the rate of nitrogen fertilizer applied with treated waste water irrigation, being 4 and 31% for an application of 50 and 100 kg N ha$^{-1}$ respectively. Conversely, losses of $^{15}$N-fertilizer was unaffected by the type of irrigation water, being 31% with wel water and 39% with treated waste water. The N unaccounted for in the soil plant system was about threefold higher when unconfined micro plot was used, regardless fertilizer N rate and water qualities. Losses of N fertilizer are significantly higher when unconfined micro plot was used, probably because the lateral movement of $^{15}$N-fertilizer outside the unconfined micro plot.

4. DISCUSSION

Dry matter production was greatly affected by nitrogen rate, either in well water or treated wastewater irrigation. Otherwise, as reported by others [5, 2, 16], treated wastewater with no fertilizer N applied significantly increased total N recovered by plant when compared to well water. Total nitrogen removed by plants increased significantly when a smallest amount of fertilizer N was supplemented with treated wastewater irrigation, notably in the confined micro plots. Furthermore, it is important to note that, at smallest N rate the entire amount seems to be absorbed by plant, but further rising in fertilizer N rates seems to be ineffective to cause additional remove in total N by plant. Similar behavior was reported by [16], who concluded that cotton yield, could be higher with the effluent particularly when supplemented with lower N rates. However, with the highest N level there was a reduction in yield obtained with the treated effluent. According to [11], a higher wheat grain yield and N use efficiency could be achieved with low application rates if the crop is irrigated with treated wastewater. Compared to well water, wastewater irrigation resulted in increases in total dry matter production. The better increases in total dry matter registered in the confined micro plots can be related to a better use efficiency of water and nitrogen compared to the unconfined micro plots. According to [11], this can also be attributed to the presence of appreciable amounts of N, P, K and some other micro-elements essential for plant growth compared with well water. Moreover, average dry matter production within the unconfined micro plots were not statistically different from dry matter production outside micro plots, while the average dry matter production within the confined micro plots were statistically higher than that of outside the micro plots (data not shown). Thus, our results don’t support the view carried by other investigations, that plant growth in confined micro plots was not different from plant growth in the rest of the main plot [28].

The percentage of N derived from labeled fertilizer ($N_{dff} \%$) was determined within the micro plot. Adequacy of the micro plot design for measuring fertilizer N uptake was evaluated by comparing $N_{dff} \%$ in different parts of plant in unconfined and confined micro plot. Any uptake of non labeled N from outside the micro plot would dilute the $^{15}$N taken up from the micro plot, resulting in lower $N_{dff} \%$ for those plants. Results showed very low $N_{dff} \%$ values obtained in the unconfined microplot compared to the confined micro plot. Regardless water qualities and fertilizer rates, less than 5%, for roots, leaves, stems and grain. These values were statistically different from those obtained in the confined micro plot. On the basis of these results, it was assumed that the possible cause of this lower $N_{dff} \%$ in 1997 was the exchange of the enriched N fertilizer vs. native soil N. This suggested that the $N_{dff} \%$ in the confined micro plots was not affected by the unlabeled N from outside the micro plots. Probably because the barriers prevented the lateral exchange of $^{15}$N labeled fertilizer outside the micro plot and unlabeled fertilizer inside the micro plot. This result is consisting with the findings of [14], who concluded that their 0.25 cm-deep frame (micro plot plastic boundary) was effective in preventing lateral movement of $^{15}$N in the upper root zone when they tested a single $^{15}$N-labeled plant in a 0.76-m by 0.23-m micro plot. [21], studied lateral movement of labeled N fertilizer in unconfined micro plots, and found that the $^{15}$N proportion in corn grain declined rapidly near the edge of micro plot. These suggestions were more consistent if $N_{dff} \%$ was examined in plants from outside the unconfined micro plot in 1997. If no labeled N was taken up by these plants, then it could be assumed that no apparent movement of labeled N out the microplot. As reported in the literature, the highest enrichment often occurred for the central plants within unconfined micro plots [8] and the lowest enrichment was found near the edge of unconfined micro plots [25].

Fertilizer nitrogen recovery as estimated by the isotopic method was very low when unconfined micro plot was used and similar to that reported in other investigations when confined micro plot was used on Sudangrass [27,10] and on maize [26, 20, 23]. Nevertheless, in unconfined micro plot, neither water quality nor fertilizer N rates had an effect on the recovery of fertilizer nitrogen by Sudangrass. About 20% of N fertilizer was recovered by Sudangrass in unconfined micro plot. [8] Note that use of $^{15}$N-labeled fertilizer in micro plots without barriers is feasible in field studies as long as minimum size and its management meet certain criteria. These are that micro plots be large enough that all roots of plants being measured are grown in soil in which $^{15}$N-fertilizer distribution is the same as it would be in a large treated area [15]. Against results obtained on
Sudangrass and conducted on lysimeters [12]. Nitrogen fertilizer efficiency in a confined micro plot was significantly higher when treated waste water was used for irrigation; about 22% and 36% of the applied fertilizer were recovered in the crop with well water and wastewater irrigation, respectively; it decreased from 47% to 36% as fertilizer N rates increased from 50 to 100 kgN ha\(^{-1}\), respectively; with is in line with previous studies [26, 23]. Residual effects measured at the second harvest were very low in the unconfined micro plot, from 1% to 2% of the nitrogen fertilizer previously applied at rising were taken by the crop in the second harvest. That labeled nitrogen expressed by the residual effect, couldn’t be originating from \(^{15}\)N fertilizer stocked in the soil and found probably him origin in the \(^{14}\)N fertilizer accumulated in the roots at the first harvest. However, when barrier was used residual effects were higher, 3 to 6% of the \(^{15}\)N-labeled fertilizer were recovered in the second harvest. This results support also the previous idea that there was probably a lateral movement of fertilizer nitrogen outside the micro plot when unconfined micro plot was used. Enrichment levels of total N in most soil samples from the unconfined micro plot were indistinguishable from natural abundance. This compares with average natural abundance values of 0.3688, as measured in micro plot without \(^{15}\)N-fertilizer, indicating a greatest lateral movement of labeled N from the micro plot. This amount unaccounted for is presumed lost by the soil plant system. This greatest lateral or and deep movement of \(^{15}\)N-labeled fertilizer could be linked to the nature of our sandy soil and irrigation system. However, in the confined micro plot nitrogen remaining in the soil after harvest seems to be height for the two qualities of water irrigation. Neither fertilizer rate nor water quality had an effect on the \(^{15}\)N-labeled fertilizer remaining in the soil at final harvest. About 33 to 49% of the nitrogen fertilizer applied was left in the 0-60 cm layer at final harvest for all rates and for both water qualities, most of them were located in the surface 0-20 cm layer, with an average of 22% despite nitrogen rate and water irrigation qualities. Studies reported in the literature [15, 18] have also concluded that most of the nitrogen remaining in the soil was in the surface layer. Moreover, the proportion of total \(^{15}\)N remaining in the top 20 cm of soil increased from 49 to 58% as the \(^{15}\)N-fertilizer increased in the treated wastewater irrigation, although it was comparable (58 vs 62%) for both water irrigation qualities with the same rate of \(^{15}\)N-fertilizer applied, which is in line with others studies [7, 12]. This better immobilization of nitrogen in the top layer suggested that this nitrogen was in the organic forms as described by [1], and on large scale it was attributed by [24] to an important concentration of microflore biomass at the surface soil. According to [6] and [17], enrichment in the apparent immobilization of \(^{15}\)N-labeled fertilizer would be the most likely explanation for the reduced crop recovery as the N fertilizer rate increased.

Losses of \(^{15}\)N-labelled fertilizer estimated from the differences between the amount of \(^{15}\)N recovered in the crop and the soil, and the known amount of \(^{14}\)N applied, was about threefold higher when unconfined micro plot was used, regardless fertilizer N rate and water qualities. It increased with application rate in treated wastewater irrigation, being 4 and 31% for an application of 50 and 100 kgN ha\(^{-1}\) respectively. This is consistent with other studies on Sudangrass where losses increased with increasing rates of fertilizer N applied [10, 12]. Conversely, losses of \(^{15}\)N-fertilizer was unaffected by the type of irrigation water, being 31% with well water and 39% with treated waste water.

5. CONCLUSION

The lower nitrogen derived from fertilizer and \(^{15}\)N recovered by sorghum plants in the unconfined micro plot can be attributed to better losses of \(^{15}\)N fertilizer through lateral movement from inside the unconfined micro plot. These results suggest that a confined micro plot can provide a reliable measure of fertilizer N recovery for sorghum plants. Finally, this study demonstrated that small micro plots (1m x 1m) can be used for \(^{15}\)N tracer studies under field conditions, if they are confined.

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REFERENCES


