Nitrate-N Leaching in Calcic Red-Yellow Latosol: Lysimeter Experiment and Hydrus-1d Simulation

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Abstract

Lysimeter studies are high tier studies and give additional information about leaching of fertilizers. HYDRUS -1D is a numerical model which can be used to simulate the movement of water and solutes in saturated and unsaturated soil conditions. Nitrate- N in water bodies is a serious environmental concern in Jaffna peninsula. High amount of nitrate-N in the water bodies are suspected due to the intensification of agricultural activities by adding high amount of inorganic fertilizers. In Jaffna, Carrot was cultivated around 65.7ha of arable land and public market price of carrot was reached the maximum of Rs 200 and the minimum of Rs20 in year 2011 and the fertilizer application for carrot also high. Hence a lysimeter study was carried out to evaluate the effect of different levels of fertilizer on the leaching loss of nitrate-N in calcic red yellow latosol and the possibility of using HYDRUS - 1D for the simulation of nitrate leaching. In lysimeter two levels of fertilizer application; recommended level (RT) and half of the recommended level of fertilizer (HRT) recommended by the Department of Agriculture, Sri Lanka was used with three replicates. Data from the lysimeter was statistically analyzed at 95% confidence level and the leaching was simulated by using HYDRUS-1D in a 50 cm soil column of calcic red yellow latosol. There was no significant difference found between nitrate concentrations in leachate of two treatments, but significant difference was found in leachate concentration with the days after sowing. Since the RT consist higher leave length, evaportranspiration is high. The soil nitrate-N varied as 17.3mg/100g soil and 15.3mg/100 g soil for RT and as 17.9mg/100 g and 21.1mg/100 g for HRT at 10cm and 30cm depth, respectively because of less root solute uptake in HRT. Measured nitrate-N loss by leaching was 16kgN/ha for RT and 15.2kgN/ha for HRT. In the simulation, nitrate-N leaching loss was 33kg N/ha for RT and 25.7kg N/ha for HRT. But, the percentage of loss high for HRT in both cases. Through this experiment it can be concluded that the RT has low potential to leach than the HRT and it is better to reduce the amount of fertilizer at the sowing time because of less root solute uptake.

Key words: Carrot, HYDRUS-1D, Leaching, Lysimeter, Nitrate-N

Introduction

Recent socio-economic factors adversely affect the intensive agricultural activities. The farmers go for intensification of agriculture by adding more and above the recommended level of fertilizer by the quantity and frequency. The pursuit of high crop yield has often led farmers to over apply nitrogenous fertilizer and use destructive cultivation practices that often result in excess nitrogen available for surface runoff, volatilization, and leaching beyond the root zone (Tan et al. 2002). Therefore, it plays a major role in leaching loss of nitrogen and finally reaches the water bodies through nitrogen cycle and makes hazards to biotic environment. Lysimeters and mathematical modelling are adequate experimental tools for obtaining valuable information about the impact of fertilization method on water flow and solute transport (Stumpp et al. 2011). HYDRUS-1D model numerically solves the Richard's equation for variably saturated water flow and advection-dispersion type equations for solute transport (Simunk et al. 2006). Carrot is cultivating mostly in *Maha* season, which is more vulnerable time to leachate nutrient by heavy rainfall. Therefore, this research was carried out to analyze the effect of different levels of fertilizer application on leaching of nitrate-N by comparing Lysimeter measurement and HYDRUS-1D simulation on carrot cultivation.

Materials and methods

During the research period (Dec 2011 - Mar 2012) daily meteorological data were collected and experimental soil properties were measured by using standard methods. Six Lysimeters (height 66 cm) were constructed and filled up to 50 cm by soil and known volume of water was added to each Lysimeter and the quantities drained were recorded. The treatments

were arranged in a complete randomized block design (CRD) with two treatments and three replicates. To study the effect of fertilizer dosage on nitrate leaching, a half of the recommended fertilizer (HRT-103.5kgN/ha) and the recommended fertilizer (RT-207kgN/ha) was added. All treatments were subjected to the same agronomic practices including irrigation water except the fertilizer application.

The nitrogen fertilizer was applied in the form of urea. Because of the fate of Urea, in HYDRUS, we have considered two solutes for simulation, ammonium-N (NH_4^+) and nitrate-N (NO_3^-), as those are the forms absorbed by plants. The HYDRUS-1D model was used to simulate 50 cm soil profile in one soil horizon with 10cm and 30cm observation nodes. For water flow, the upper boundary was the atmospheric boundary condition with surface layer where surface water layer increase due to precipitation or irrigation and reduce because of infiltration and evaporation and free drainage as lower boundary condition. For the solute, concentration flux as upper boundary and lower boundary was zero gradient. Initial conditions were fixed as pressure head and liquid phase concentration for water flow and solute transport respectively. HYDRUS-1D input time variable boundaries were calculated or estimated from weather and crop data. Model was validated by adjusting input parameters to obtain least residual error of water and solute in mass balance.

Results and discussion

Nitrogen leaching is the results of the interaction effect between soil-plant-environment. Excessive water in the soil column leads to the leaching loss of nitrate-N, because it does not adsorbed by the soil colloids due to the negative charge. Soil property is one of the major components influence the leaching of solute apart from the root zone. The transport and transformation processes are mainly depend on the soils hydraulic properties. An assumption was taken before the experiment that the soil is uniform and homogenous in nature and that means uniform porosity in entire soil column. Therefore, the water moves into the soil in a uniform manner.

Figure 1 shows the leachate concentration of nitrate-N with different growth stage of the carrot. There was no significant difference found between two treatments. But significant difference was found in the leachate concentration with the days after sowing. The initial periods (germination) significantly differ from other

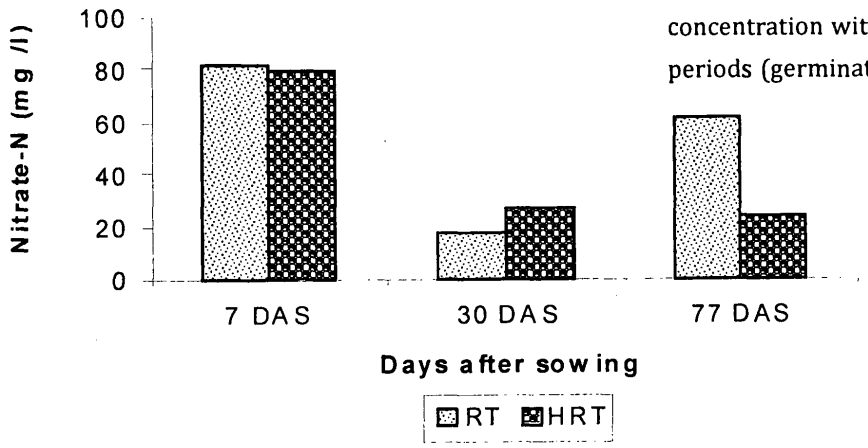

Figure : Nitrate-N concentration in leachate

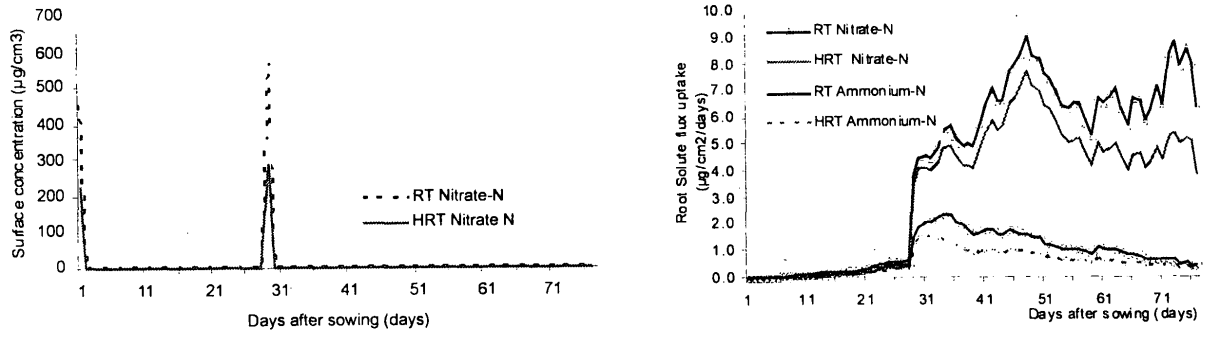

Figure : HYDRUS simulated Split application of fertilizer (left) and root solutes uptakes (right)

sampling days. And the remaining days did not significantly differ. The first application (Figure 2; left side)) was during seed sowing (seeds were germinated after four days), at that time there are no roots uptakes and after germination also it took time for root growth and during that period heavy rainfall also recorded. Therefore the potential to leach of the nitrate ions was high because of the excess water in the soil column that washes off the nitrate beyond the soil column.

The soil consisted 11mg/100g soil of nitrate-N, 2.2mg/100g soil of ammonium-N and 0.87% of organic matter at initial time. At the end of the experiment, the soil nitrate-N decreased with increasing depth in RT and increased in HRT. At 10cm and 30 cm in soil column consist 17.3mg/100g soil and 15.3mg/100g soil of nitrate-N in RT and HRT was varied as 17.9mg/100g and 21.1mg/100g of nitrate -N with increase in depth. Francaviglia et al. (2000) stated that the concentration at the bottom of the lysimeter could represent an "index of risk".

In the simulation, assumption was made that same plant growth parameters existed for both treatments. But in reality it might be varied and numerical error also occur during simulation. Therefore, correlation between HYDRUS simulated cumulative bottom flux and lysimeter measured cumulative leachate R^2 were achieved as 0.89 and 0.92 for RT and HRT respectively.

The Figure 2 left hand side shows split application of fertilizer at the time of seed sowing and 29 days after sowing and right hand side how the root solute uptakes of carrot varies with the days after sowing. It increased with increase in time. In both cases the nitrate-N uptake is high because of the high availability of nitrate-N ions in the water.

The measured fertilizer application efficiency was 98% and 97.6% for RT and HRT, respectively and it was calculated indirectly using fertilizer input and leachate output. HYDRUS simulated fertilizer use efficiency was also calculated indirectly from fertilizer input and bottom solute flux. The obtained results were 76% and 57.2% for RT and HRT, respectively. In HYDRUS, fertilizer use efficiency could be calculated directly from fertilizer input and root solute uptakes and it was 19.3% and 29.1% for RT and HRT, respectively. The measured value much differs from the simulated value. In the simulation, the soil sorption and plant absorbance were simulated separately, but in reality it was not happen.

In the lysimeter measurement, the calculation was made by using the loss from the soil leachate only. But it is necessary to measure the soil sorption by frequent sampling. In HYDRUS, the fertilizer use efficiency related to the application rate and the crop uptake. But in lysimeter the fertilizer use efficiency related to the application rate and leachate concentration. Therefore, lysimeter measurement of fertilizer application efficiency is quite over estimation. HYDRUS simulated water balance error was 0.01 mm (0.003%) and calculated water balance error was 2.18 cm, variation due to numerical error.

Conclusion

The results of the experiment show, the measured nitrate-N loss by leaching was 16kgN/ha and 15.2kgN/ha for RT and HRT, respectively. There was no significance difference in the leachate concentration (98% and 97%) and simulated root uptake was high in HRT 29%. The HYDRUS simulated nitrogen loss by leaching was 33kgN/ha and 25.7kgN/ha for RT and HRT, respectively. But simulated fertilizer application efficiency was high in HRT. Since most of the solute leaching occurred in the initial period, revaluation of first dosage of the fertilizer recommendation will helps to safe our environment and increase the economic level of farmers.

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