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APPROACH FOR NITRATE BALANCE IN THE SOIL SOLUTION UNDER FERTIRRIGATION

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ABSTRACT: The use of fertirrigation brings inputs to soil solution that affect solute dynamics and nutrient balance in the soil wetted volume. This work has as objective to present an approach for nitrate balance in the soil wetted volume under drip irrigation from readings of electrical conductivity and soil water content using TDR technique. The approach uses a balance for nitrate in the soil solution, based upon the fact that the transport of nitrate is solely convective. Ion concentration is determined based on a combination of an empircal model for estimating soil solution electrical conductivity (ECw) and a potential model that relates ECw and nitrate concentration in the soil solution. The approach has given satisfactory results, although the absolute values of the estimated dependent variables of the model may not stands for the real values in the soil. However, it can be used for analyzing different components of the nitrate balance in the soil (uptake, leaching, infiltration) among fertirrigation events.
KEYWORDS: Mass balance, TDR, fertirrigation management, nitrate.

INTRODUCTION: The inadequate use of fertirrigation may result in several environmental hazards such as reduction of yields, degradation of chemical and physical soil characteristics, contamination of water resources (surface water and groundwater). Therefore, the adequate fertirrigation management and evaluation of chemical soil characteristics are important tasks and requires knowledge about ion soil dynamics. All nitrogen sources become nitrate after reactions in the soil solution under conditions of nitrification. Nitrate leaching is considered the main loss of nitrogen in the soil and is influenced by conditions that determine soil water flow and by nitrate concentration in the soil solution. Nitrate leaching contributes to groundwater contamination. The use of fertirrigation brings inputs to soil solution that affect solute dynamics and nutrient balance in the wetted volume. Leaching is one component of the balance of concern, since efficiency of nutrient use depends on it. Nutrient balance has been done using several methodologies (citar autores), but all ones follow basic mass balance, where a mass variation in a control volume depends upon inputs and outputs of mass. Nitrate transport in the soil is basically convective,i.e., diffusion may be disregarded. This allows to connect nitrate transport to water transport and to evaluate nitrate balance according to water balance. TDR technique has been used for ion distribution and monitoring with time by using models to estimate ion concentration as a function of electrical conductivity and soil water content (SANTANA et al.,2007). Percolation may be evaluated at any depth of the soil by the flow obtained from soil water content variation at very small time range. Soil water balance has been done using TDR data successfully (SILVA et al, 2005) and as well there is good possibility of using it for nutrient balance. This work has as objective to present an approach for nitrate balance in the soil wetted volume under drip irrigation from readings of electrical conductivity and soil water content using TDR technique.

METHODOLOGY: The approach is based upon the fact that nitrate concentration at a location of the wetted soil volume may be estimated from soil electrical conductivity (ECa) and soil water content by using models adapted from VOGELER et al. (1996) and evaluated by SANTANA et al. (2007). These works have demonstrated that soil solution electrical conductivity (ECw) may be related to nitrate concentration by a potential model (SILVA et al., 2005). This approach does not take in account physical chemical and biological phenomena which are involved in solute dynamics in the wetted volume, therefore, it requires calibration according to soil conditions. Nitrate ion considered is in soil solution and this is the reason for a strong relation to soil solution electrical conductivity (ECw) that is also strongly related to Eca and soil water content (HEIMOVAARA et al.,1995). If nitrate concentration may be estimated from ECw, it is possible to proceed a nitrate balance in the soil following a water balance scheme. Figure 1 ilustrate the control volume limited by 0.675 m depth and horizontal distance from plant along plant row in which 0.10 m -TDR probes were inserted horizontally.

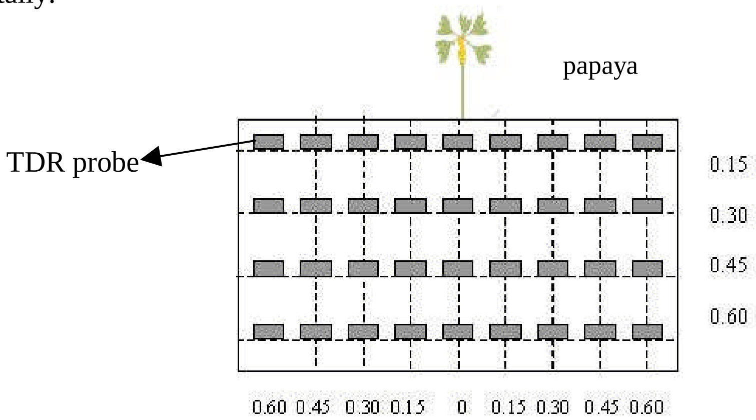

Figure 1. Distribution of TDR probes in the control volume for obtaining ECa and soil water content.

The balance considers the initial time t_o, immediately before fertirrigation event, t_1, the time after fertirrigation and time t_2, immediately before next irrigation. The balance takes into account $NO_{3,0}(x,z)$, $NO_{3,f}(x,z)$, $NO_{3,e}(x,z)$ and $NO_{3,2}(x,z)$, where (x,z) stands for the location (horizontal distance and depth), 0, f, e and 2 indicate NO_3 at time before fertirrigation, NO_3 applied to the control volume, NO_3 extracted from the control volume and NO_3 remaining in the control volume before next fertirrigation or irrigation, respectively. The balance can be described as:

$$NO_{32}(x,z) = NO_{30}(x,z) + NO_{3f}(x,z) - NO_{3e}(x,z) \quad (1)$$

$NO_{3,f}(x,z)$ may be determined by the difference between amount immediately after fertirrigation ($NO_{3,1}(x,z)$) and before it ($NO_{3,0}(x,z)$). $NO_{3,e}(x,z) = NO_{3,1}(x,z) - NO_{3,2}(x,z)$ and $NO_{3,e}(x,z) = NO_{3,u}(x,z) + NO_{3,L}(x,z)$, where $NO_{3,u}(x,z)$ corresponds to the uptake amount and $NO_{3L}(x,z)$ the

$$NO_{3L} = \int_{t0}^{t2} [NO_3']dt \quad (2)$$

leaching. $NO_{3L}(x,z)$ was determined by the mass flow integration (NO3') between two fertirrigations from to to t2 at the effective root depth (Ze), i.e., that one of most of nitrate leaching. In this work it was assumed 0.45 m as the effective root depth. The numerical integration was done considering nitrate mass flow at one-hour interval. The uptake nitrate was given by:

$$NO_{3,u}(x,z) = NO_{3,e}(x,z) - NO_{3,L}(x,z) \quad (3)$$

The balance was evaluated at the same conditions reported by SILVA et al. (2005) in a Distrophyc Yellow Latossol of a clay loam texture. Papaya (*Carica papaya L.*) was being grown at 3.5 x 1.5 m. Ureia wa used as source of nitrogen in fertirrigation in three treatments as frequency of fertirrigation (1, 3 and 7 days). TDR probes were installed as in Figure 1. Bulk soil electrical condutvity (ECa) and soil water content were monitored in all (x, z) locations by na acquisition data system (TDR and datalogger and multiplexers) during three irrigation cycles, considering the fertirrigation at overlaping the first irrigation. ECa data were corrected to 25^{o}C according to U. S. SALINITY LABORATORY STAFF (1954). The corrected ECa data and soil water content were used to estimate nitrate concentration based in a model adapted from a combination of an empirical model for estimating ECw (VOGELER et al., 1996) as a function of ECa and soil water content with a potential model to estimate ECw as function of nitrate concentration proposed and evaluated by SILVA et al. (2006).

$$NO_3 = \left[\frac{CE_{a-}(0{,}7690\theta + 0{,}0173)}{0{,}0012(3{,}6836 - 0{,}5360\theta)} \right]^{\frac{1}{1{,}1038}} \qquad (4)$$

where CEw and CEa have units of dS m^{-1} and nitrate concentration are given in mgL^{-1}.

RESULTS AND DISCUSSION: Figure 2 shows that ECw varies inversely with soil water content, i.e., during fertirrigation, since water content increases, ECw reduces due to reduction in ion concentration, but after fertirrigation ECw gets larger values that decrease until next event event. The amount of nitrate in the soil solution for 7 day-fertirrigation frequency was larger than the amounts for 1 and 3 day frequencies (Table1). Leaching nitrate for 1 day-frequency was the largest one followed by 3 day and 7 day frequencies. Despite the fact that the reduction in fertirrigation frequency implicates in larger amount of fertilizer applied at one time, leaching did not increase due to that.

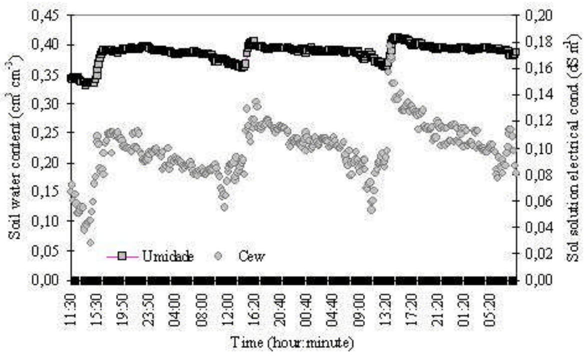

Figure 2. Evolution of soil water content and soil solution electrical conductivity at the location (0,15m; 0,30m) in the wetted volume under drip irrigation.

The depth of water applied at each fertirrigation event follows water needs, therefore it is expected larger concentration in the soil solution for smaller fertirrigation frequencies, but the potential gradients that move down the solution is near to those corresponding to higher fertirrigation frequencies (1 and 2 day- frequencies). This explains the larger values of $NO_{3,0}$ for 7 day-frequency. Nitrate uptake was smaller for 3 day fertirrigation frequency and larger for 7 day-frequency. The larger nitrate availability around roots possibly induced larger uptake for 7 day frequency. Small amount of the total nitrate in the soil solution was leached (less than 0.14%). The 7 day frequency was the one of smallest leaching (0.06%) corresponding to 44% of leaching of the others treatments (Figure 3). The percentage of total nitrate in the soil solution after fertigation that was uptaken by roots varied from 10.09% (3 day frequency) to 21.82% (1 day frequency). Uptake for 7 day fertirrigation frequency was very close to that one for 1 day frequency, i.e., about 20% of the total nitrate in soil solution after fertirrigation.

Table 1. Nitrate balance components of the control volume

Frequency	$NO_{3,0}$	$NO_{3,1}$	$NO_{3,2}$ (mg)	$NO_{3,L}$	$NO_{3,u}$
1	1286,36	1526,86	1191,16	2,03	333,67
3	1184,21	1300,60	1165,32	1,83	133,44
7	1951,66	2295,71	1837,46	1,44	456,82

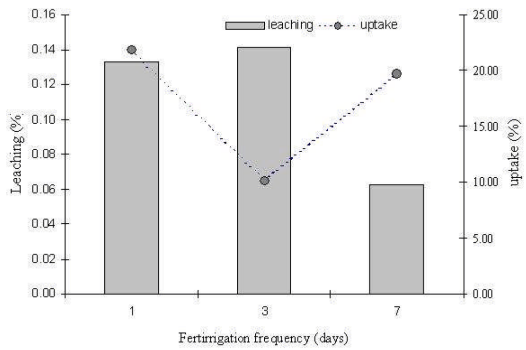

Figure 3. Percentage of total nitrate in the soil solution after fertirrigation extracted as leaching and uptake.

CONCLUSIONS: The approach has given satisfactory results, although the absolute values of the estimated dependent variables of the model may not stands for the real values in the soil. However, it can be used for analyzing different components of the nitrate balance in the soil (uptake, leaching, infiltration) among fertirrigation events. Seven day frequency of fertirrigation resulted in large nitrate storage in soil solution and smaller leaching. Root uptake was larger for fertirrigation frequencies of 1 and 7 days.

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