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ESTIMATING ELECTRICAL CONDUCTIVITY AND SODIUM CONCENTRATION IN SOIL SOLUTION UNDER DIFFERENT SOIL SALINITY CONDITIONS IN LYSIMETERS

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ABSTRACT: TDR technique has been used as a tool for monitoring soil electrical conductivity and ion concentration in the soil. The objective of this study was to evaluate models for estimating soil solution sodium concentration based on bulk electrical conductivity (ECa) and soil water content data in lysimeters under different soil salinity conditions. Treatments regarded about leaching fraction (LF) levels (T1 – 0%, T2 – 30% and T3 – 60%), with three replications in field lysimeters. TDR probes were inserted at different distances and depths in the soil . Water samplers were inserted near each TDR probe so that soil solution could be extracted from soil and soil water content and ECa could be observed at the same time by using a TDR equipment. An empirical and parametric model adapted from the one proposed VOGELER et al. (1997) in combination to a potential model was fitted to data of ECw, ECa, soil water content (θ) and sodium concentration collected in the lysimeters. Soil solution electrical conductivity and sodium concentration of soil solution in field lysimeters was estimated reasonably by an adapted model of Vogeler et al. (1997) based upon readings of soil water content and bulk electrical conductivity. The best performance of the model corresponded to smaller salinity conditions in the soil (T1).
KEYWORDS: Soil water balance, TDR, salinity.

INTRODUCTION: The possibility for íon monitoring in the soil becomes an important tool for saline soil management or evaluation of fertirrigation (SILVA et al., 2005). Howecer, it is necessary to find ways for accomplish íon monitoring in soils under agricultural use (WRAITH & DAS, 1998). The use of water samplers is limited by the soil water content and requires additional laboratory work. Also, the use of soil samples for soil saturation extract is timing consuming, despite being time most recommended method. TDR technique has been used for soil electrical conductivity evaluation (RHOADES et al., 1976; HEIMOVAARA et al., 1995; VOGELER et al., 1996). Also, TDR technique has been used to estimate potassium concentration in the soil solution (SILVA et al., 2005; SANTANA et al., 2004), nitrate concentration (MMOLAWA & OR, 2000) . Recently, COELHO et al. (2007) evaluated the estimates of sodium and calcium in the soil solution in PVC columns with different salinity conditions. It was showed that sodium or calcium concentrationa in soil solution may be estimated by knowing soil solution electrical conductivity obtained with water samplers or bulk electrical conductivity obtained by TDR readings. Most of tropical fruit crops are expected to grow under salinity conditions in soils of electrical conductivity smaller than 2.0 dS m-1. This limit of electrical conductivity is considered as the minimum limit of a saline soil (BOHN et al., 1985). The possiblity of monitoring in the field soil electrical conductivity, soil solution electrical conductivity and ion concentration without bring samples to laboratory may be a great advance in researches about soil-water-plant relationships under salinity conditions. The objective of this study was to evaluate models for estimating soil solution sodium concentration based on bulk electrical conductivity and soil water content data in lysimeters under different soil salinity conditions.

METHODOLOGY: The work was made in an experiment about evaluation of levels of leaching fraction in lysimeters of 0.7 m^3, 0.7 m height and 1.12 m diameter installed in a experimental field of Embrapa Cassava & Tropical Fruits. The soil in the lysimeters was a Dystrophic Yellow Latossol with 590g $kg^{-1}$of total sand, 95 g kg^{-1} of silt, 315 g kg^{-1} of clay, soil bulk density of 1.33 kg dm^{-3}, soil particles of 2.50 kg dm^{-3}. Papaya at production phase (7 months-age) was the crop planted in the lysimeters. Treatments regarded about leaching fraction (LF) levels (T1 – 0%, T2 – 30% and T3 – 60%), with three replications, using saline water composed by sodium chloride and calcium chloride (3:2 proportion) with electrical conductivity of 1.5 dS m^{-1}. Twelve 0.1 m length TDR probes were inserted vertically in each lysimeter at distances from plant and depths of 0.15; 0.30 e 0.45 m. Water samplers were inserted near each TDR probe so that soil solution could be extracted from soil and soil water content and bulk dielectric conductivity could be observed at the same time by using a TDR staff. Soil solution was extracted and soil water content and bulk electrical conductivity (ECa) was observed at each depth and distance from plant during six days. Soil solution electrical conductivity (Ecw) was determined in laboratory by using a table condutivimeter. The soil solutions were also used for determination of sodium concentration by according to EMBRAPA (1997). An empirical and parametric model proposed by equation 1 (VOGELER et al., 1996) was fitted to the collected data of ECw, ECa, soil water content (θ) in nine lysimeters (three treatments and three replications).

$$EC_w = \frac{ECa - (a\theta - b)}{(c\theta - d)} \qquad (1)$$

a, b, c e d are constants obtained by minimization of square deviations between estimated and observed value of dependent variable. A potential model (equation 2) was fitted to data of ECw and sodium concentration ([Na+]).

$$CEw = \alpha' [Na^+]^\beta \qquad (2)$$

Replacing (2) in (1), a model for sodium concentration as a function of ECa and soil water content was possible to be evaluated:

$$Na = \left\{ \frac{1}{\alpha} \frac{[CEa - (a\theta - b)]}{(c\theta - d)} \right\}^{\frac{1}{\rho}} \qquad (3)$$

The evaluation of the equation 3 concerning its ability of estimating [Na+] from ECa and θ was made based upon the agreement coefficient (D), equation 4, according to WILLMONTT (1981) and based upon the goodness of fit (R2) about the function y=ax, with y being the estimated dependent variable and x the observed values of the dependent variables.

$$D = 1 - \left[\frac{\sum_{i=1}^{n} (M_i - E_i)^2}{\sum_{i=1}^{n} \left(|M_i - \overline{M}| + |E_i - \overline{M}| \right)^2} \right] \qquad (4)$$

RESULTS AND DISCUSSION: Table 1 shows the parameters of the equations 1 and 2 for estimating ECw and Na+ concentration and the evaluation parameters R^2 and D. ECw was better estimated than Na concentration, except for treatment T1 (LF=0%). ECw considers all cations in the soil solution and is strongly related to soil water content and ECa. The positive performance of models relating ECw and ECa has also been verified by others authors (Santana et al., 2006; DAS et al., 2004). Results showed that sodium concentration in the soil solution may be estimated from ECw or ECa and soil water content. These results agree to works done for bromide (MUÑOZ-CARPENA et al., 2001), nitrate (MAMOLAWA e OR, 2000) and potassium (Santana et al., 2004). The best performance of equation 3 was verified for T1 (table 1 and Figure 1) that showed larger goodness of fit and D. Also, Figure 1 shows smaller deviations between estimated and observed sodium concentration for T1 (Figure 1). The adapted model of VOGELER et al. (1996) for estimating sodium concentration in the soil solution for treatments T3 and T5 did not perform as for treatment T1, possibly due to the larger electrical conductivity of soil solution on those treatments. SANTANA et al. (2007) also verified that the increase of soil salinity is a constraint the use of this model. However, sodium concentration of soil solution may be estimated in all treatments, despite the better accuracy for T1. COELHO et al (2007) has obtained better accuracy for the model (equation 3) when working with the same soil but using PVC columns in laboratory, that may be due to the smaller sample considered, i.e., a 0.15 m height, 0.10 m diameter PVC column. These small samples were more uniform and the TDR probe was more representative for the sample than in case of lysimeters where the soil volume corresponding to a probe was much larger.

Table 1. Parameters of equation 1 for ECw and of equation 3 for sodium

		a	b	c	d	α	ρ	R^2	D
CEw	T1	29,96153	8,459321	1,576285	-0,39828			0,880785	0,965275
	T3	7,71647	2,361933	-17,2643	-6,11867			0,90128	0,970308
	T5	3,419777	1,476814	-2,48958	-1,21525			0,591103	0,836077
Na	T1	29,96153	8,459321	1,576285	-0,39828	0,002172	1,138035	0,885966	0,970089
	T3	1019,195	216,2243	-0,02958	0,136815	0,436357	1,391968	0,633567	0,828955
	T5	-57,84	-0,82358	377,6732	5,801346	0,107464	0,066989	0,707158	0,901454

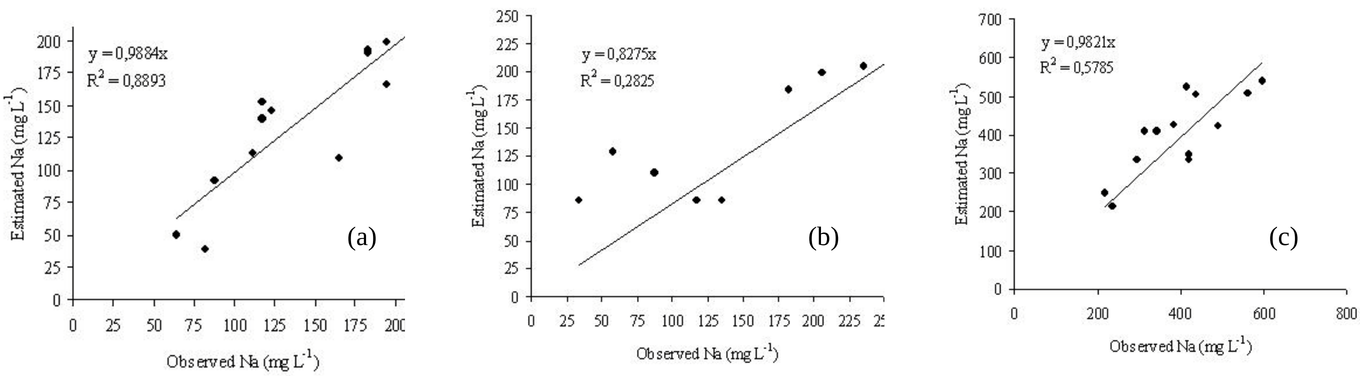

Figure 1. Sodium concentration of soil solution observed and estimated in a y=ax function.

Figure 1 shows that estimated Na concentration in soil solution was underestimated for all treatments, mainly for T3, case of smaller evaluation indexes (R^2, D). The use of models (equation 1 and 3) can help evaluate ECw or Na+ concentration using ECa and soil water content data determined by TDR technique, as showed in Figure 2 for treatments T1, T2 and T3, as average of three replications, where data were collected in lysimeters at 0.30 m from plant at 0.30 m depth.

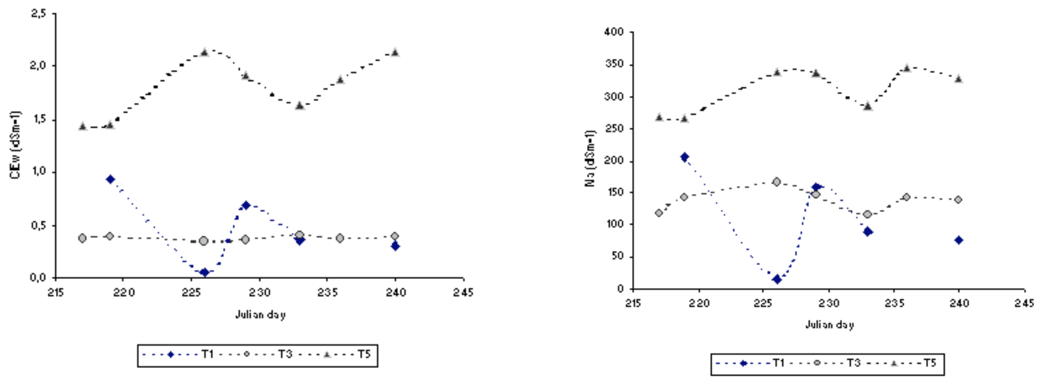

Figure 2 . Evolution of estimated ECw and Na concentration in the soil solution with time.

Values of ECw and sodium concentration (Na) verified in T5 were larger than the ones estimated for the other treatments. T5 received 60% more water and salts than T1, thus, despite more leaching, salts accumulate in the soil. Absolute values of these parameters for T1 and T3 were in the range of 0.05 to 0.92 dSm-1 and 16 to 205 mg L-1 for ECw and Na+ concentration in the soil solution, respectively.

CONCLUSIONS: Soil solution electrical conductivity and sodium concentration of soil solution in field lysimeters was estimated reasonably by an adapted model of Vogeler et al. (1996) based upon readings of soil water content and bulk electrical conductivity. The best performance of the model corresponded to smaller salinity conditions in the soil (T1). Soil solution electrical conductivity and sodium concentration estimated during a period of a month were larger for the treatment of largest leaching fraction (T5).

REFERENCES

BOHN, H. L.; McNEAL, B. L.; O'CONNOR, G. A. **Soil chemistry**. New York: John Wiley, 1985. 341p.

COELHO, E. F. ; SIMÕES, Welson L ; Veimrober Junior ; SANTOS, Delfran Batista dos . Estimativa da Concentração de Sódio na Solução do Solo com Uso de Reflectometria no Domínio do Tempo. In: XXXI Congresso Brasileiro de Ciência do Solo, 2007, Gramado. XXXI Congresso Brasileiro de Ciência do Solo. Porto ALegre : Sociedade Brasileira de Ciencia do Solo, 2007.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. Centro Nacional de Pesquisa de Solos. Manual de Métodos de Análise de Solo. 2.ed. Rio de Janeiro, 1997. 212p. (Embrapa – CNPS. **Documentos**, 1).

HEIMOVAARA, T.J., FOCKE, A.G., BOUTEN, W., VERSTRANTEN, J.M. Assessing temporal variations in soil water composition with time domain reflectometry. **Soil Science Society of America Journal**, v.59, p.689-698. 1995.

MMOLAWA, K, OR, D. Root zone solute dynamics under drip irrigation: a review. **Plant and Soil**, v. 222, p. 163-190, 2000.

MUÑOZ-CARPENA, R.; REGALADO, C.M.; ALVAREZ-BENEDÍ, J.; SOCORRO, A.R.; PÉREZ, N. Determinación simultánea mediante TDR del transporte de agua y un soluto salino en el suelo. In: López, J.J.; Quemada, M. ed. V, Temas de Investigación en Zona no Saturada. Pamplona: Universidade Pública de Navarra, 2001, p.1-7.

RHOADES, J.D., RAATS, P.A., PRATHER, R.J. Effects of liquid phase electrical conductivity, water content, and surface conductivity on bulk soil electrical conductivity**. Soil Science Society of America Journal**, v.40, p.651–655. 1976

SANTANA, G.S., COELHO, E.F., SILVA, T.S.M., RAMOS, M.M., COELHO FILHO, M.A. estimativa do teor de potássio na solução do solo a partir da condutividade elétrica da solução do solo. In XXXIII congresso brasileiro de Engenharia Agrícola – CONBEA 2004, CD-ROM.

SILVA, Tibério S M ; PAZ, Vital Pedro da Silva ; COELHO, E. F. ; SANTANA, Gessionei Silva . Condutividade elétrica da solução da solução de solo em função da condutividade elétrica aparente e da umidade do solo sob aplicação do cloreto de potássio com uso da reflectometria no dominío tempo. **Irriga**, Botucatu, v. 10, n. 2, p. 174-183, 2005.

VOGELER, I.; CLOTHIER, B.E.; GREEN, S.R. TDR estimation of the resident concentration of electrolyte in the soil solution. **Australian Journal Soil Researches**, v.35, p.515-526, 1997.

VOGELER, I.; CLOTHIER, B.E.; GREEN, S.R.; SCOTTER, D.R.; TILLMAN, R.W. Characterizing water and solute movement by TDR and disk permeametry. **Soil Science Society of America Journal**, Madison, v.60, n.1, p.5-12, 1996.

WILLMONTT, C.J. **On the validation of models**. Physical Geography, New York, v.2, p.184-194, 1981.