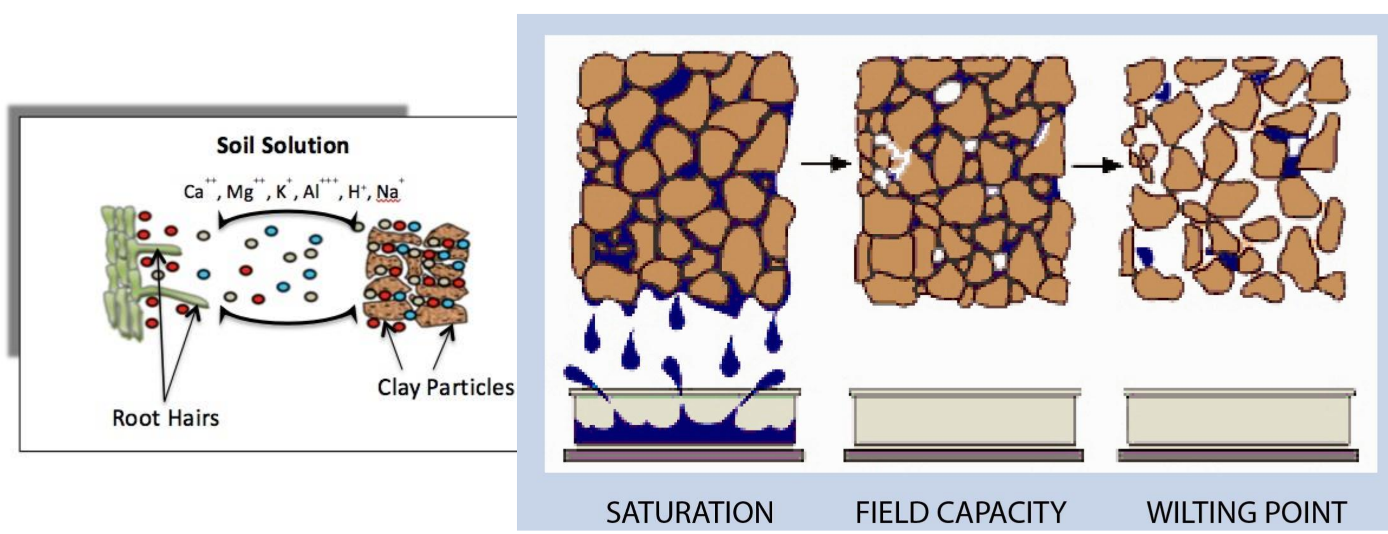
ABSORBENT METHOD FOR MEASURING SOLUTE CONCENTRATIONS IN THE AQUEOUS PHASE OF UNSATURATED SOILS IN THE PLANT AVAILABLE WATER RANGE

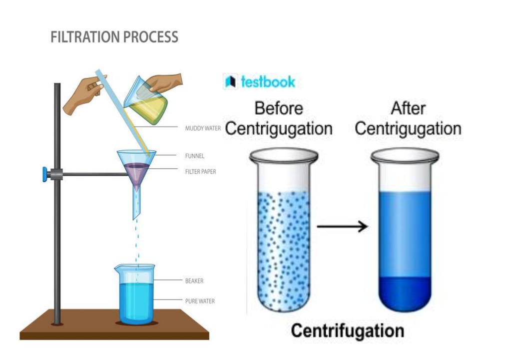
Victor A. Snyder, José A. Dumas and Priscila Casanova
Department of AgroEnvironmental Sciences
University of Puerto Rico-Mayaguez Campus

The Problem

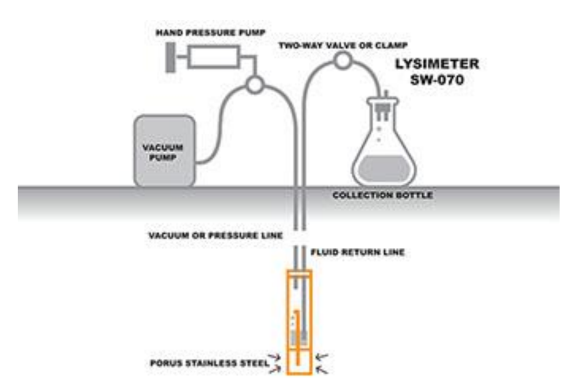
- Plant roots absorb solutes from the soil solution, at soil moisture conditions ranging from saturation to the plant wilting point near 1500 KPa (15 bars) matric suction.
- Understanding and managing plant nutrition under these moisture conditions requires ability to extract the solution phase from the soil and measure its solute composition.



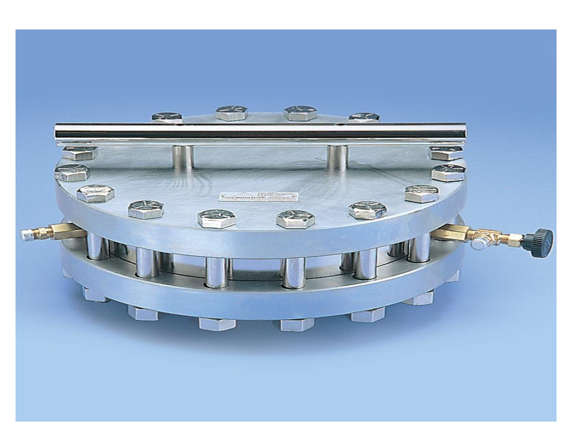
- At very high soil moisture contents (2:1, 1:1 and 1:2 water:soil suspensions), the solution phase is extracted by filtration or centrifugation and decantation.



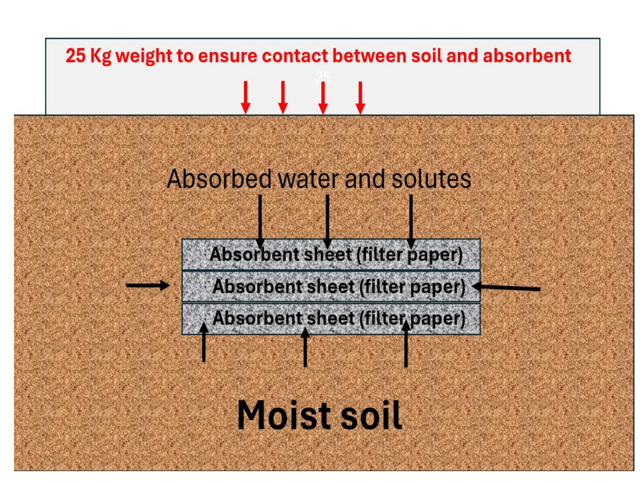
- For unsaturated soils in the 0 – 100 KPa suction range. the solution phase is usually extracted with suction lysimeters.



- For unsaturated soils in the 100 to 1500 KPa suction range, pressure membrane extractors have been used. These are costly, expensive and time consuming.



- An alternate procedure for unsaturated soils, investigated here, is the absorbent method (*Snyder et al. 1995; Keller and Hendrickx, 2002; Celejewski et al. 2014)*



Procedure in absorbent method:

1. Equilibrate soil with absorbent for 48 hrs, with periodic mixing and re-packing of soil around absorbent.
2. Weigh middle absorbent sheet (moist)
3. Oven dry absorbent sheet and determine amount of water in absorbent (m_w^{abs}) as the difference between moist and dry mass..
4. Leach solutes from absorbent with known volume (V_L) of water. Measure electrical conductivity EC_L (mS/cm) and concentrations C_L^i (mmolc/L) of individual i^{th} solutes in the leachate.
5. Estimate electrical conductivity EC_{abs} and solute concentration C_{abs}^iin the absorbent solution phase as

$$\boldsymbol{EC_{abs} = \frac{(EC_L)\,(V_L)}{m_w^{abs}}} \qquad \text{and} \qquad \boldsymbol{C_{abs}^i = \frac{(C_L^i)\,(V_L)}{m_w^{abs}}}$$

6. Assume that these values approximate those in the soil solution phase, i.e.

$$\boldsymbol{EC_{soil} \approx EC_{abs}} \qquad \text{and} \qquad \boldsymbol{C_{asoil}^i = C_{abs}^i}$$

7. Assume that the total electrolyte concentration in the soil solution ($mmol_c/L$) is related to the electrical conductivity of the soil solution (mS/cm) by

$$\boldsymbol{mmol_c/L \approx 10 \cdot EC_{soil}\,(\tfrac{mS}{cm})}$$

Experimental Application

Soil solution characterization of a Mollisol at different water:soil ratios or "gravimetric water contents" (Kg water/Kg soil) ranging from 2.0 to 0.08.

General experimental procedure

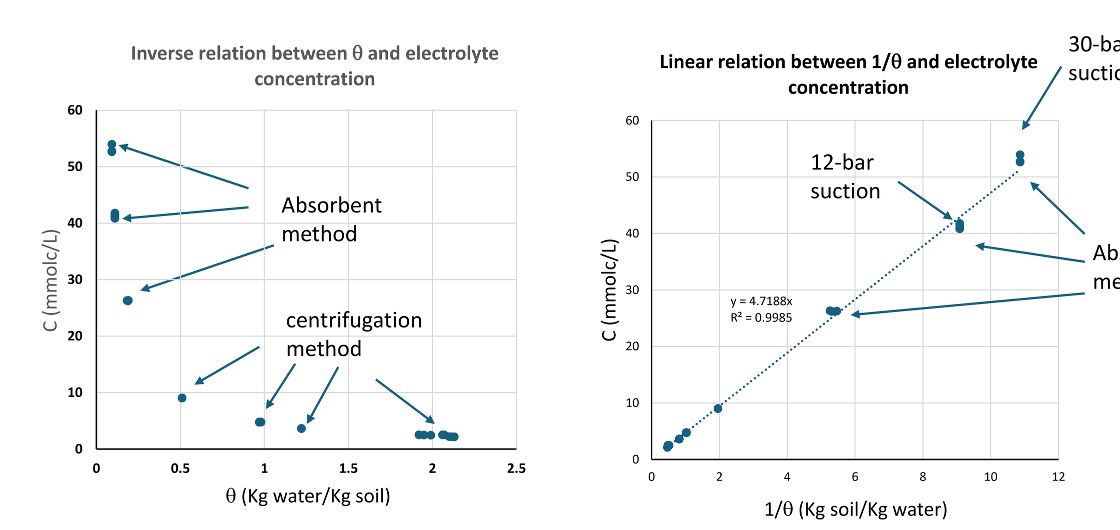
1. Saturated aqueous suspensions of sieved (< 2mm) soil were prepared at water:soil ratios of 2:1, 1:1 and 1:2, corresponding to soil water contents (θ) of 2.0, 1.0 and 0.5, respectively.
2. The suspensions were centrifuged, and electrical conductivity (EC_{soil})along with concentrations (C_{soil}^i) of cationsCa^{+2}, Mg^{+2}, K^{+} and Na^{+} were measured in the supernatant.
3. Unsaturated soil samples at water contents of 0.19 (field capacity), 0.11 (-1200 KPa suction) and 0.09 (-3000 KPa suction) were prepared by mixing water and air-dry soil in appropriate ratios.
4. Electrical conductivities EC_{soil} and concentrations C_{soil}^i of Ca^{+2}, Mg^{+2}, K^{+} and Na^{+} in the unsaturated soil solutions were determined by the absorbent method described previously.

Hypotheses tested

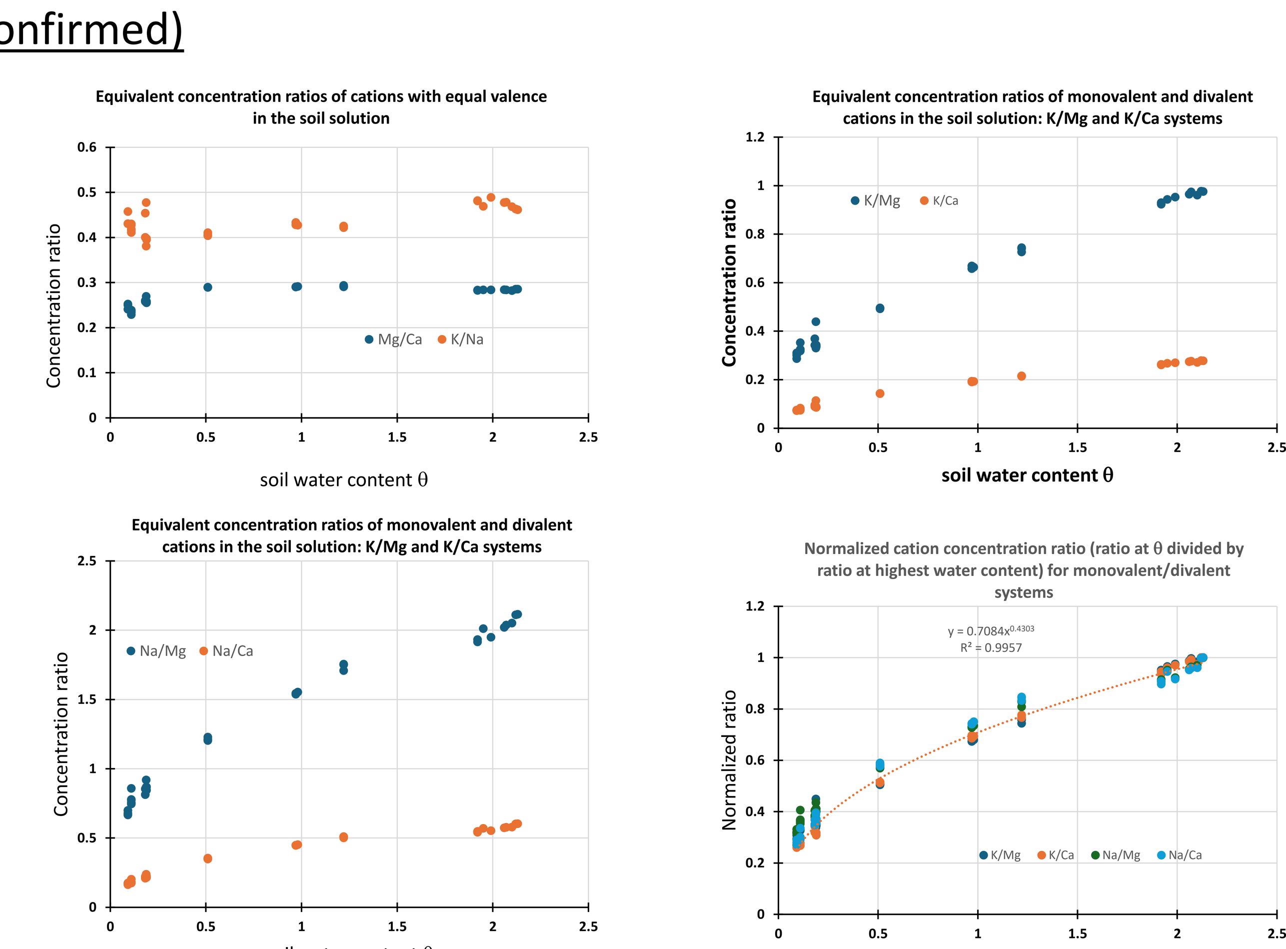
1. For a given amount of soluble electrolyte in soil, the electrolyte concentration ($mmol_c\ /Kg\ water$) should vary inversely with water content θ (Kg water/Kg soil), or linearly with 1/θ (Kg soil/Kg water). Slope of line = $mmol_c\ of\ solutes\ /Kg\ soil$.
2. A concentration valency effect should be observed, where concentration ratios of monovalent to divalent cations should decrease with decreasing soil water content due to higher solution concentration, whereas concentration ratios of cations with similar valence should remain constant.

Results of Experimental Tests of hypotheses

Hypothesis 1 (confirmed)



Hypothesis 2 (confirmed)



Conclusions

1. As hypothesized, measured total electrolyte concentration varied inversely with gravimetric soil water content.
2. As hypothesized, the concentration ratios of monovalent to divalent cations decreased with decreasing soil water content, whereas concentration ratios of cations with equal valence were relatively independent of water content.
3. Results illustrate how the absorbent method may be used in conjunction with conventional filtration or centrifugation methods to measure soil solution compositions over widely ranging soil water contents.

References:

1 Snyder, V.A., G. Martinez, M. Vazquez, L. Peña. 1995. Absorbent Method for Measuring Solute Activities in Unsaturated Soils: Thermodynamics and Preliminary Experiments. Soil Sci. Soc. Am. J. 59:1524-1531

2 Keller, C. and J. Hendrickxs. 2002. Capillary absorbers. In. Dane, J. and G.C. Topp (eds).Methods of Soil Analysis. Part 4. Physical Methods. 1308-1310. Soil Science Society of America. Madison, WI.

3 Celejewski, M; L. Scott and T. Al. 2014. An absorption method for extraction and characterization of pore water from low-permeability rocks using cellulosic sheets. Applied Geochemistry 49: 22-30.