SATURATION PERCENTAGE

Robert O. Miller, Colorado State University

Scope and Application

This method quantifies the soil water content of a saturated soil. At saturation all soil pore space is occupied by water and no free water collects on the soil surface. Salinity crop tolerance data; the relationships between cation solution concentrations and soil exchangeable cations (i.e. SAR); and soluble soil boron,are based on the saturation paste extract (U.S. Salinity Laboratory Staff, 1954 and Robbins, 1990). From the saturation paste, soil pH may be determined directly on the paste.. By extracting the liquid phase of the saturation paste under partial vacuum estimates of: electrical conductivity, EC_e (soluble salts); solution concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HBO_3, NO_3^-, SO_4^{2-}, SeO_4^{2-}, HCO_3^-, CO_3^{2-}; and SAR can be determined. Estimates of soil water holding capacity, wilting point and texture can be made from the saturated moisture content. The method is generally reproducible within ± 12%, dependent on the soil textural class (Klages, 1984).

Equipment

1. Analytical balance: 500 g capacity, resolution ± 0.1 g
2. 500 mL container and cap (polypropylene container or 16 oz waxed paper cups).
3. Spatula
4. Buchner filter assembly (preferably plastic) and vacuum system (capable of - 90 kPa).
5. Whatman No. 5 filter paper, or equivalent highly retentive filter paper.
6. Test tube or vial, 50 mL, polypropylene with cap.

Reagents

1. Deionized water, ASTM Type I grade.

Procedure

1. Weigh 200 ± 0.5 g air-dry soil pulverized to pass 10 mesh sieve (< 2 mm) of known water content (P_w, %), into a 500 mL container and record total weight (See Comments #1 and #2).
2. Gradually add deionized water and mix uniformly (free of partially wetted clumps) until a saturated paste is obtained (See Comments #3 and #4). At saturation, the soil paste:
   - i. Does not have free standing water on the surface of the paste.
   - ii. Slides freely and cleanly off a spatula (does not apply to high clay soils, > 40% clay).
   - iii. Will flow slightly when the container is tipped to a 45 degree angle from horizontal.
   - iv. Glistens as it reflects light.
   - v. Consolidates easily by tapping after a trench is formed in the paste with the flat side of a spatula (may not apply to sandy soils >70% sand).
3. Record weight, cap container and let stand for four (4) hours. Check saturation characteristics again and add soil or water as needed to obtain the desired characteristics (See Comment #5).
4. Record the mass of the soil (g) and total water (g) added.

5. After equilibration, thoroughly remix samples and determine soil pH, Method S - 1.10 (See Comment #6).

6. Transfer soil saturation paste to buchner funnel filter paper and spread evenly over surface. Apply -80 KPa vacuum and collect filtrate in test tube. Discontinue vacuum when cracks appear in soil paste. Refilter if filtrate is turbid. Determine EC_e, HCO_3^- and CO_3^{2-} with in five (5) minutes (Methods S - 1.20 and S - 1.30). Cap and retain filtrate for additional analysis (See Comments #7, #8 and #9).

Calculations

$$SP\ \% = \frac{(\text{Amount of water (g), added}) \times 100}{(\text{mass of air dry soil (g)} \times ((100 - P_w)/100)}$$

[equ. S-1.0-1]

Report saturation percentage (SP) to the nearest 0.1% (See Comment #10).

Comments

1. Soil samples should not be oven-dried above 70 °C prior to extracting for soluble salts.

2. For organic soils (>16% organic matter) it is advisable to start with a 150 mL of water and add soil.

3. Fine textured soils (> 40% clay) may puddle easily. To minimize puddling and obtain a more definite endpoint with fine-textured soils, water should be added with a minimum amount of stirring, especially in the earlier stages of wetting. Peat soils (>16% organic matter) will require soaking for twenty-four (24) hours. The method can be used assess greenhouse potting media.

4. Some fine textured soils swell considerably upon addition of water. In these cases, steps 2 and 3 must be repeated until the paste characteristics are stable. For salinity appraisal the paste can be extracted after four (4) hours; however, for sodic soil samples it should stand sixteen (16) or more hours. For the assessment of soil soluble boron, twenty-four (24) hours of paste equilibration is required.

5. Coarse textured soils, sandy loam and loamy sand with less than 15% clay, may not exhibit saturated paste characteristics of finer textured soils. For these soil types the relative accuracy of the method declines and should be noted when making soil comparisons.

6. If calcium carbonate precipitates are noted in the extract, dilute samples 1:1 with deionized water and note dilution in subsequent analysis. Samples may be refrigerated (4 °C) for storage (do not allow to freeze) for 30 days. Small quantities (200 uL) of thymol or toluene may be added to minimize the influence of microbial activity while samples are refrigerated (Carlson et al., 1971).

7. Determining saturated paste percentage alternative: take a 30 - 50 g sub sample of the paste, weigh, oven dry at 105 °C for four (4) hours, reweigh and calculate saturation percentage. Oven dry moisture values will be slightly higher than the direct method as air dry soil will retain 3-5% moisture, dependent on clay and salt content.

8. Extraction consistency is best achieved using a vacuum of -60 to -80 KPa (-0.6 to -0.8 bars) applied for thirty (30) minutes (Jacober and Sandoval, 1970). Soils maybe centrifuged.

9. Approximately one-quarter to one-third of the water added in making the saturated paste can be recovered as a solution extract (Loveday, 1974).

10. Soil Field Capacity (FC, 33 kPa) can be estimated from the saturation percentage as follows: SP × 0.5 = FC. Soil water potential Permanent Wilting Point (PWP, 1500 kPa) can be estimated as follows: SP × 0.25 = PWP. Saturation percentage is related to soil texture as follows (based on organic matter contents less than 3%):

SP (%)	Soil Texture
0 < 20	sand or loamy sand
20 - 35	sandy loam
35 - 50	loam or silt loam
50 - 65	clay loam
65 - 135	clay
> 81	organic soils

For fine-textured soils and those high in sodium (SAR > 10), SP cannot be used to estimate FC and PWP values (Reeves et al. 1954).

Literature

Carlson R.M., R. Overstreet, and D.J. Naylor. 1971. Effect of microbial activity on saturation extract composition. Hilgardia. 40:553-564.

Jacober, F. And F. Sandoval. 1971. Effect of grinding, suction and extraction time on salt concentration of saturated paste extracts. Soil Sci. 112, 263-266.

Klages, M.G. 1984. Reproducibility of saturation percentage of soils. Proc. Mont. Acad. Sci. 44: 6769.

Loveday, J. (Ed.) 1974. Methods of analysis of irrigated soils. Tech Communication #54. Commonwealth Agriculture Bureaux, Wilke and Company. Clayton, Victoria, Australia.

Reeves, R.C., L.E. Allison and D.F. Peterson Jr. 1948. Reclamation of saline-alkali soils by leaching. Utah Agr. Expt. Sta. Bull. 335.

Rhoades, J.D. and M. Clark. 1978. Sampling procedures and chemical methods in use at the U.S. Salinity laboratory for characterizing salt-affected soils and waters. U.S. Salinity Laboratory USDA, Riverside CA. pp 11-12.

Rhoades, J.D. 1996. Salinity: Electrical conductivity and total dissolved solids. p. 417-435. *In:* J.M. Bartels et al. (ed.) Methods of soil analysis: Part 3 Chemical methods. 3rd ed. ASA and SSSA, Madison, WI. Book Series no. 5

Rhoades, J.D. and S. Miyamoto. 1990. Testing soils for salinity. p. 299-336. *In*: R.L. Westerman (ed.) Soil Testing and Plant Analysis. 3rd ed. SSSA, Madison, WI.

Robbins, C.W. and C.L. Wiegand. 1990. Field and laboratory measurements. p. 201-219. *In*: K.K. Tanji (ed.) ASCE manuals and reports No. 71, Agricultural salinity, assessment, and management. American Society of Civil Engineers, 245 E. 47th St., New York.

U.S. Salinity Laboratory Staff. 1954. Saturated soil paste. Diagnosis and improvement of saline and alkali soils. Agr. Handbook 60, USDA, Washington, D.C.