Porous cup shape and installation mode influencing determinations of matric potential by tensiometers

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Abstract – The objective of this work was to determine the measurement accuracy of the soil water matric potential (ψ_m) by puncture tensiometers with either rounded or pointed porous cups, installed with or without "soil mud", and to compare the performance of these tensiometers with that of tensiometers equipped with mercury manometers. The experiment was conducted in a Ultisol, in a randomized complete block design, in a factorial arrangement with five replicates. Puncture tensiometers with rounded porous cups, installed with "soil mud", present more elevated accuracy for ψ_m determination in a wider measurement range, resembling tensiometers equipped with mercury manometers in drying soil.

Index terms: puncture tensiometers, rounded porous cup, soil mud.

Formato de cápsula e modo de instalação influenciando determinações do potencial mátrico por tensiômetros

Resumo – O objetivo deste trabalho foi determinar a acurácia em medidas do potencial mátrico da água no solo (ψ_m) por tensiômetros de punção com cápsulas arredondadas ou pontiagudas, instalados com ou sem "lama de solo", e comparar o desempenho destes tensiômetros com o de tensiômetros com manômetros de mercúrio. O experimento foi conduzido em Argissolo Vermelho-Amarelo distrófico, em delineamento experimental de blocos ao acaso, em arranjo fatorial, com cinco repetições. Tensiômetros de punção com cápsulas arredondadas, instalados com "lama de solo", apresentam maior acurácia nas determinações do ψ_m em uma faixa mais ampla de medidas, assemelhando-se aos tensiômetros com manômetros de mercúrio com o secamento do solo.

Termos para indexação: tensiômetros de punção, cápsula arredondada, lama de solo.

Tensiometers are instruments used to measure the state of energy in which water is retained by the soil solid fraction (Young & Sisson, 2002), commonly referred to as soil water matric potential (ψ_m). By providing a direct and accurate measure of ψ_m (Brito et al., 2009), these apparatus have been used, for instance, in studies related to soil physical-hydraulic properties (Libardi et al., 2015), soil erosion (Bolte et al., 2011), and solute transportation in the soil (Ghiberto et al., 2015).

Although some tensiometer models are currently presenting materials and modifications that enable their utilization in a wider range of ψ_m (Kandelous et al., 2015), conventional tensiometers, such as those with mercury manometers, are still being used due to their notable accuracy and sensitiveness, serving as standard equipment for measuring other tensiometer models (Brito et al., 2009; Beraldo et al., 2012). In contrast, this conventional equipment has a drawback in that mercury represents a toxic metal of elevated risk to human health and the environment (Braga & Calgaro, 2010). Therefore, puncture tensiometers are presented as an alternative apparatus to determine ψ_m, since these are also considered reliable to monitor ψ_m in field conditions (Beraldo et al., 2012).

Despite the reliability of tensiometers with mercury manometers or puncture tensiometers, special attention should be given to these equipment when installed by

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a hand auger, since any failure in the contact between porous cup and soil could result in an error in ψ_m determination. Intending to reduce this error, a rounded porous cup with similar geometry to that of conventional hand auger models and the use of a type of "soil mud" (Young & Sisson, 2002; Braga & Calgaro, 2010) are suggested to enhance the porous cup contact with the soil. However, the effect of porous cup shape and "soil mud" on ψ_m measured through puncture tensiometers is not yet known.

The objective of this work was to determine the measurement accuracy of ψ_m by puncture tensiometers with either rounded or pointed porous cup, installed with or without "soil mud", and to compare the performance of these tensiometers with that of conventional tensiometers equipped with mercury manometers.

The experiment was conducted in 2014, in an area located in Escola Superior de Agricultura Luiz de Queiroz, in the municipality of Piracicaba, in the state of São Paulo, Brazil (22°42'41"S, 47°37'17"W). The soil was classified as an Argissolo Vermelho-Amarelo distrófico (Ultisol), with 658 g kg^{-1} sand, 90 g kg^{-1} silt, and 252 g kg^{-1} clay, belonging to the textural class defined as sandy clay loam, and presenting average soil bulk density equal to 1.52 Mg m^{-3} at the 0–0.2 m layer depth.

The experimental design was a randomized complete block, in a 2x2+1 factorial arrangement (either rounded or pointed porous cup shape x with or without "soil mud" + additional control treatment) with five replicates. Each block was composed of the following treatments: puncture tensiometer with rounded porous cup without using "soil mud" in the installation process (R-SM); puncture tensiometer with rounded porous cup using "soil mud" in the installation process (R+SM); puncture tensiometer with pointed porous cup without "soil mud" in the installation process (P-SM); puncture tensiometer with pointed porous cup using "soil mud" in the installation process (P+SM); and tensiometer with both rounded porous cup and mercury manometer using "soil mud" in the installation process (Standard), which was considered the control treatment.

The tensiometers were subjected to hydraulic conductance tests of porous cups, as well as to bubbling pressure assays, before their installation in the field. During tensiometer installation, the soil removed by the hand auger was sieved in a mesh of $1.18x10^{-3}$ m. This experimental technique was adapted from the methodology proposed by Young & Sisson (2002). Then, the soil was incorporated into 0.015 L distilled water to generate "soil mud". Tensiometers were installed in the center of the soil layer (0.0–0.2 m). Afterwards, the soil of experimental area was saturated with 7 m^3 of water.

From June to August 2014, six temporal readings of ψ_m were performed on 6/26, 7/1, 8/6, 8/10, 8/21, and 8/25, following soil drying of the experimental area, which are presented in this work as readings 1, 2, 3, 4, 5, and 6, respectively. To determine ψ_m in the puncture tensiometers, the A-6410 tensimeter with a pressure transducer (Brumat Digital, Telfs, Tyrol, Austria) previously calibrated was used. The procedures to determine ψ_m in both puncture tensiometers and mercury manometers apparatus were executed according to Brito et al. (2009). Readings of ψ_m were accomplished between 6:15 and 7:00 a.m.

The ψ_m data were subjected to the analysis of variance after satisfying the basic assumption homogeneity of variance by Hartley's test, at 5% probability. Significant effects were detected by the F-test of the analysis of variance, at 5% probability, and the means were compared by Dunnett's test, also at 5% probability. Moreover, linear regression models were fitted between the ψ_m obtained in tensiometers with mercury manometers and puncture tensiometers.

The R+SM treatment presented greater accuracy in ψ_m determination than R-SM, P-SM, and P+SM, indicated by the higher proximity between the trend line and line 1:1 (Figure 1). In general, all treatments have shown detachment in major or minor magnitude when comparing the trend line and line 1:1 over soil drying. Brito et al. (2009), when working with a ψ_m range between 0 and -14 kPa, have verified similar behavior to ψ_m determination in 0.2-m soil depth. They attributed this detachment to more elevated variations of edaphoclimatic conditions near soil surface, which were associated with soil drying and moistening, as well as with temperature variations. Despite the effects these external factors, those authors have obtained a coefficient of determination equal to 0.91, which was similar to values obtained for R+SM in the present study.

No statistically significant interaction was observed between the porous cup shape and "soil mud", and these factors were individually significant ($p<0.05$). Puncture tensiometers presented smaller ψ_m values than the control treatment in both first and second readings (Figure 2), which could be related to the higher sensibility of the mercury manometer in registering ψ_m under little pressure variations inside the apparatus, indicated by the inferior confidence intervals when compared with other readings in this treatment. However, R+SM has denoted ψ_m determinations close to the control treatment for the other readings, not differing statistically from this treatment. Thus, it can be concluded that puncture tensiometers with rounded porous cup, installed with "soil mud", have superior accuracy for ψ_m determination in a wider measurement range, resembling tensiometers equipped with mercury manometers in drying soil.

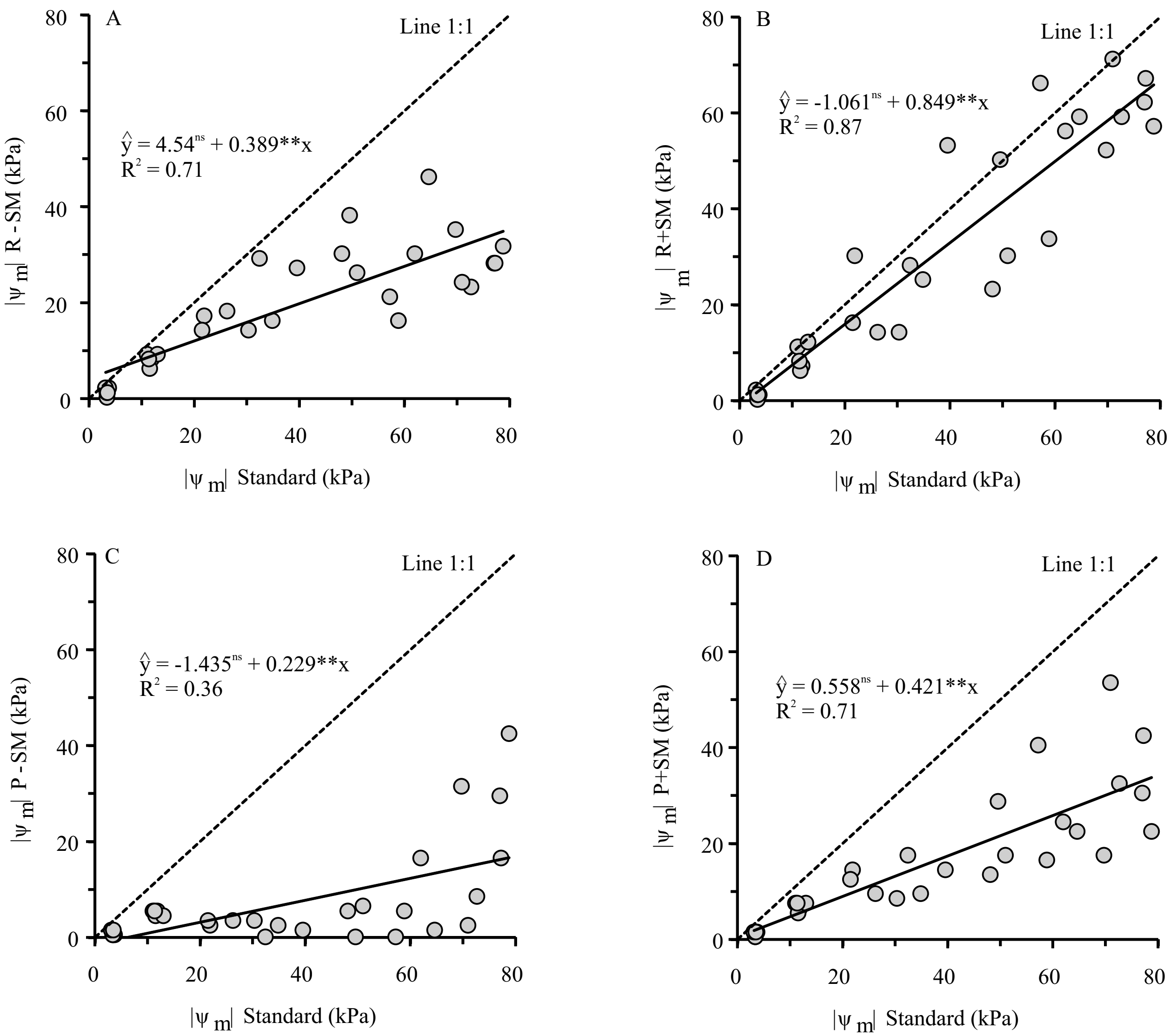

Figure 1. Linear regressions between soil water matric potential (ψ_m), in modules, measured in the control treatment, and ψ_m, in modules, calculated in the other treatments: A, standard x R-SM; B, standard x R+SM; C, standard x P-SM; and D, standard x P+SM. * and **Significant by the t-test, at 5 and 1% probability, respectively. nsNonsignificant. R-SM, puncture tensiometer with rounded porous cup without using "soil mud" in the installation process; R+SM, puncture tensiometer with rounded porous cup using "soil mud" in the installation process; P-SM, puncture tensiometer with pointed porous cup without using "soil mud" in the installation process; P+SM, puncture tensiometer with pointed porous cup using "soil mud" in the installation process; and standard (control), tensiometer with both rounded porous cup and mercury manometer using "soil mud" in the installation process.

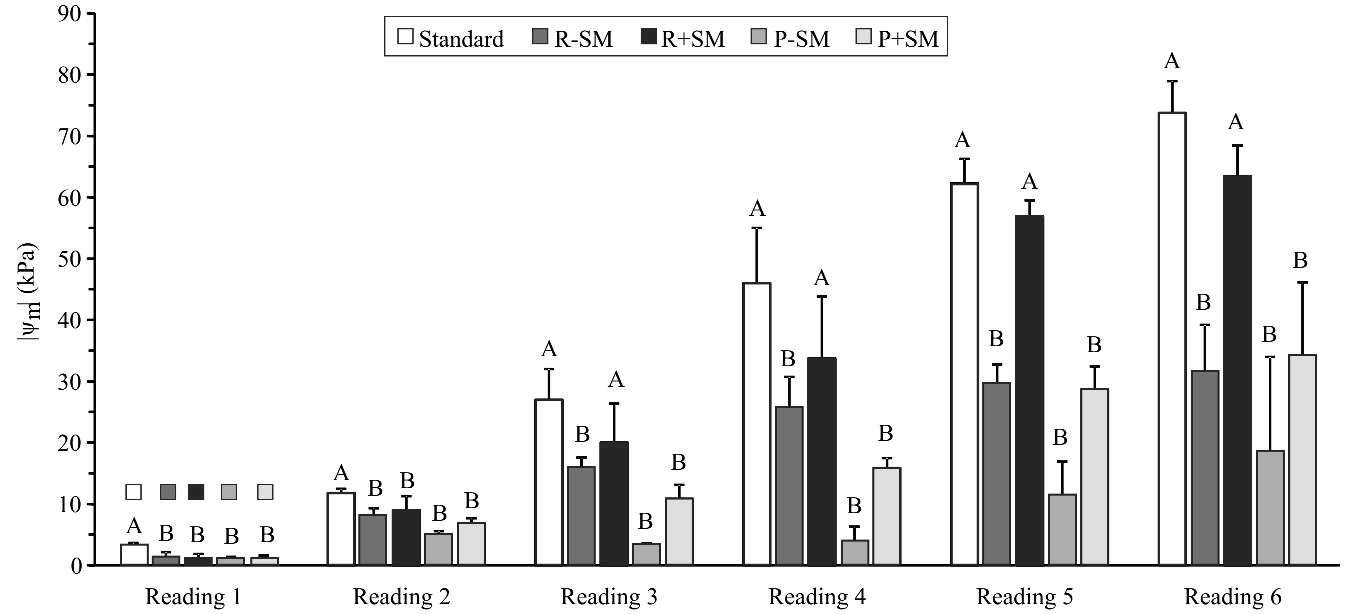

Figure 2. Means of soil water matric potential (ψ_m), in modules, measured in the experiment in function of soil drying. Letters equal to the control treatment (standard) within the same readings did not differ according to Dunnett's test, at 5% probability. R-SM, puncture tensiometer with rounded porous cup without using "soil mud" in the installation process; R+SM, puncture tensiometer with rounded porous cup using "soil mud" in the installation process; P-SM, puncture tensiometer with pointed porous cup without using "soil mud" in the installation process; P+SM, puncture tensiometer with pointed porous cup using "soil mud" in the installation process; and standard (control), tensiometer with both rounded porous cup and mercury manometer using "soil mud" in the installation process.

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