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STUDY THE INFLUENCE OF SOIL MOISTURE AND PACKING INCREMENTAL LEVEL ON SOIL PHYSICAL AND HYDRAULIC PROPERTIES

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Abstract

Reconstructed soil packing is an alternative for monolithic soil columns in lysimeter studies. The excavated soil is packed in uniform layers to represent the natural soil conditions. Reconstructed soil packing alters the physical properties, including bulk density and porosity, thus can distort the hydraulic properties of the soil, so consistency of the method used is critical. Therefore, the selection of a suitable packing method is imperative. This preliminary study comes under the broad research programme: "developing and testing new fertilizer formulations in lysimeters". This work was aimed to study the effect of incremental packing methods on the hydraulic properties of soil to select the best combination for testing fertilizers. The selected soil matrix for this lysimeter study was composed of 10 cm topsoil and 30 cm washed builders' sand. For this study, four different soil packs were trialled in lysimeters with the combination of two soil moisture conditions (dry/damp and wet) and two packing depth increments (5 and 10 cm). The flow rate and saturated hydraulic conductivity were measured. Subsequently, several pore volumes of water (around 5 – 6) was allowed to pass through the soil column and the soil subsidence level was measured for each packing method. Both soil moisture condition and packing increment level have influenced the flow rate and saturated hydraulic conductivity of the soil matrix. The saturated hydraulic conductivity of the dry-5 cm, dry-10 cm, wet-5 cm and wet-10 cm packing were 3.99, 6.70, 3.56 and 6.53 cm hr^{-1}, respectively. Soil subsidence was also influenced by both the soil moisture condition and increment level. The highest soil subsidence was exhibited by dry-10 cm packing (13 mm) and lowest by wet-5 cm (2 mm) ($p<0.05$). This preliminary study showed that both moisture condition and increment level influence the soil hydraulic property and compaction level. Further study needs to be conducted to understand the influence of soil moisture and incremental level on other physical and hydraulic properties of soil packing.

Keywords: Packing increment, moisture level, reconstructed soil packing, soil hydraulic property, soil subsidence level.

Introduction

Lysimeters are classified into two major groups based on the soil column, monolithic and repacked soil column lysimeters (Lewis and Sjöstrom, 2010; Schneider *et al*., 1998). In a monolithic soil column, the excavated soil block with no, or minimum disturbances is used in the lysimeter. Whereas, in repacked soil column lysimeters, excavated soil is packed in layers to represent the natural soil conditions. Both lysimeters have their own advantages and disadvantages. The choice of the selection is based on the research question and the prevailing conditions of the study.

The monolithic soil column is preferred when the soil conditions needs to be maintained nearest to the field conditions. It resembles the natural spatial heterogeneity of the soil. However, the excavation of monoliths needs sophisticated machinery to avoid disturbances to the column and is time consuming. Repacked soil columns are an alternative to the soil monoliths. This technique needs less care during the soil excavation, however, more care is needed on repacking to maintain the uniformity throughout the soil profiles. Notwithstanding the simplicity of this method, this is usually not preferred since it causes distortion to the soil physical properties including soil structure, micro and macro flow paths and hydraulic conductivity (Lewis and Sjöstrom, 2010; Corwin, 2000). Although these disadvantages are understood for this method, repacked soil columns provide uniform soil packing which is useful for a study needing a large amount of replicated uniform soil columns (Lewis and Sjöstrom, 2010).

Dry and slurry packing are two different types of techniques used for soil column preparation. These techniques differ from each other based on the soil moisture level and way of packing. The dry packing involves packing the column with soil with a low moisture content. Air dried soil is used for this method. The packing method is undertaken by loading small discrete amounts of soil in the lysimeter followed by gentle compression. Slurry packing is undertaken with saturated soil. In this method, the saturated soil is packed in the lysimeter and stirred or vibrated to settle particles at the bottom of the column. The slurry packing produces a high density packing as the pore spaces are filled with water and soil particle compaction takes place (Lewis and Sjöstrom, 2010). Consequently, slurry packing is generally not preferred as it alters the hydraulic properties of soil and high soil density can restrict root penetration (Heilman, 1981).

The amount of soil packed in each increment was considered in relation to those that were found in literature, these range from a few millimetres (5 mm) (Corwin, 2000) to few centimetres (15 cm) (Plummer et al., 2004). A standard packing increment height for the soil column preparation is not available. Despite it consumes more time for columns with large diameter and number, packing with thin layers is preferred since it produces a more uniform soil profile (Oliveira et al., 1996; Corwin, 2000).

The uniformity of sand packing was studied with the emphasis on the impact of soil moisture and incremental level on particle segregation and bulk density changes (Oliveira et al., 1996). However, influence these soil parameters on other soil properties have not been published in literature to the best of our knowledge. Therefore, an experiment was conducted to determine the influence of soil moisture and packing increment levels on soil physical and hydraulic properties.

Materials and Methods

Packing the soil column in lysimeter

Four different lysimeter packs were undertaken using the combination of two different moisture levels; 10% (dry) and 60% (wet) and two different packing increments; 5 cm and 10 cm. All four treatments are referred as to dry- 5 cm, dry- 10 cm, wet- 5 cm and wet- 10 cm. The selected soil matrix is comprised of top soil and builders' mix sand for 10 cm and 30 cm height of the lysimeter, respectively (Figure 1). The bulk density of the top soil was 1.14 and builders' sand was 1.65 g cm^{-3}.

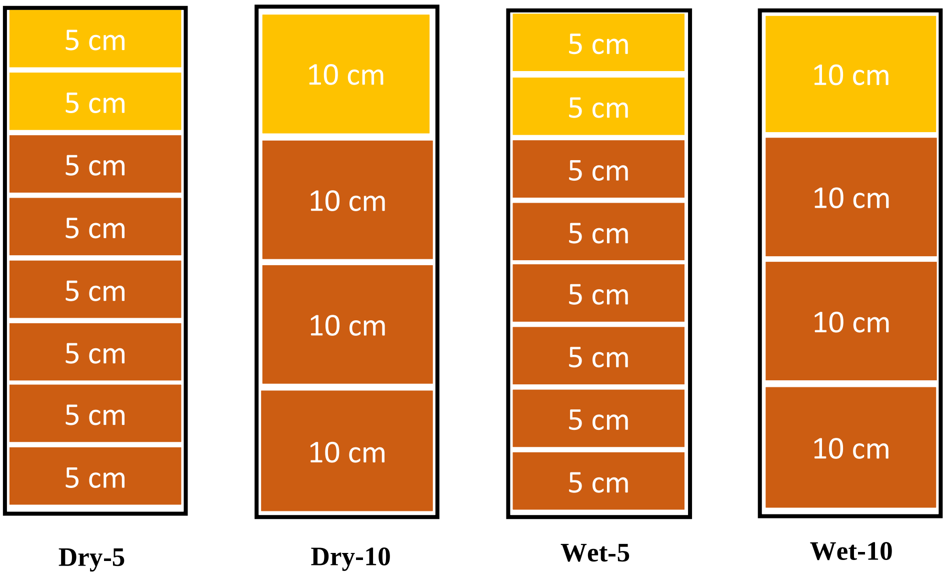

Figure 1: Different soil packing of lysimeter (Dry and wet stands for packing with 10% and 60% of moisture content, 5 and 10 stands for incremental levels in cm).

For the packing of soil, 5 cm and 10 cm levels were marked on inside wall of the lysimeter. The weight of soil corresponded to each incremental level was determined by multiplying the volume of each segments by the dry weight bulk density of the soil. This weighed soil was transferred to the lysimeter and compacted using a rammer to bring down to the marked level. The soil surface was scarified in between two consecutive incremental levels, by using a sharp needle to maintain the continuity of hydraulic conductivity.

Solute transport study

Saturated hydraulic conductivity and water flux measurement

The soil column was saturated with water and allowed to drain overnight. A 5 cm constant water head was maintained above the soil surface of the lysimeter. The leachates were collected at different time intervals and the respective volumes were measured. The water leaching rate (mL/min) was calculated by dividing the leachate volume (mL) by time (min). With these data, saturated hydraulic conductivity (K_θ) and water flux (q) of the sand-topsoil compound matrix were calculated using equation 1 and 2, respectively.

$$K\theta = \frac{q \ x \ L}{h + L} \quad (1)$$

$$q = \frac{Q}{A \ x \ t} \quad (2)$$

Surface subsidence level of soil column

The soil subsidence level was measured to study the structural stability of different packs. The initial surface level of the soil column of each pack was marked. After 4 -5 pore volumes of water were allowed to pass through the soil column, the final soil surface level was measured (Peng and Horn, 2005). The subsidence level was calculated from the difference between initial and final soil surface level.

Results and Discussion

Solute transport study

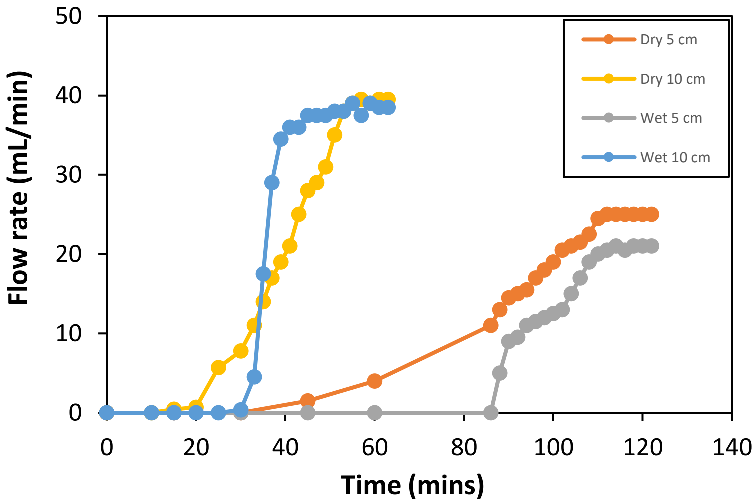

Figure 2: The change of flow rate with time for dry and wet packing methods with 5 and 10 cm packing increments.

All four packs show different flowrates with time. The time taken to reach saturation for; dry-5 cm, dry-10 cm, wet-5cm and wet-10 cm soil packing methods were 45, 15, 88 and 30 minutes, respectively (Figure 2), and the saturated flowrates for corresponding treatments were 25, 39.5, 21 and 38.5 cm^3 min^{-1}, respectively. These results clearly indicate that soil water flow was influenced by both packing method and packing increment.

Table 1: The hydraulic properties of dry and wet soil packing with 5 and 10 cm increments.

Packing method	**Flux (q) - cm/min**	**Saturated hydraulic conductivity (Kθ) - cm/hr**	**Classes**	**Texture group based on Kθ***
Dry 5 cm	0.075	3.99	Moderate	L / VFSL
Dry 10 cm	0.126	6.70	Moderately rapid	FSL
Wet 5 cm	0.067	3.56	Moderate	L/VFSL
Wet 10 cm	0.123	6.53	Moderately rapid	FSL

* L – Loam, SL – Sandy Loam, FSL – Fine Silt Loam, VFSL – Very Fine Sandy Loam.

The highest and lowest saturated hydraulic conductivity and flux were observed for dry-10 cm and wet-5 cm packing, respectively (Table 1). Reference to soil-class based hydraulic conductivity, dry-5 cm and wet-5 cm packing is classified under "moderate class" and dry-10 cm and wet-10 cm packing is classified under "moderately rapid class". These results implied that the hydraulic properties were influenced by both packing method and increment.

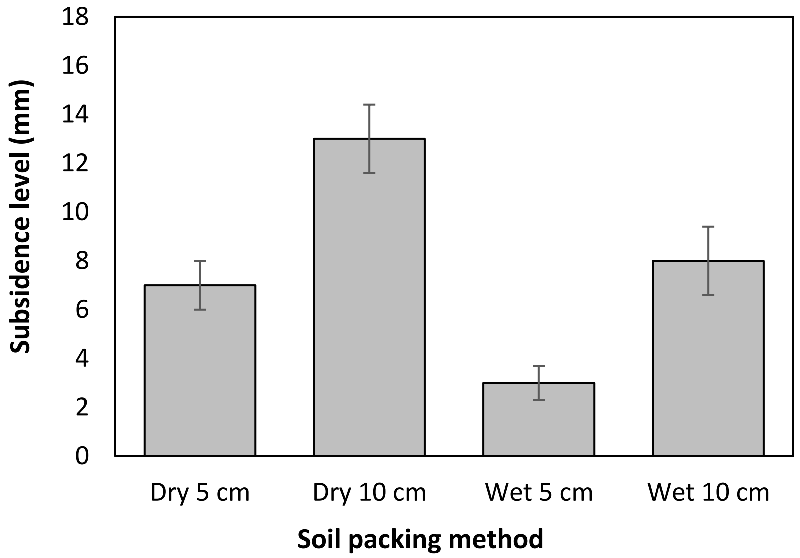

Figure 3: The subsidence level of dry and wet soil packing methods for 5 and 10 cm packing increment (error bar stands for standard deviation, n=2).

The subsidence of a soil packing takes place due to the pressure exerted by hydraulic head on the soil column (Dec et al., 2008) and the structural changes of the soil during wetting and drying (Or, 1996). The greatest soil subsidence was observed in the dry-10 cm packing method (13 mm) and the least was observed in wet-5 cm packing (2 mm) (Figure 3). Overall, wet packing showed less subsidence in comparison to the dry packing methods for the respective packing increments.

Conclusion

This preliminary study shows that soil properties such as flow rate, saturated hydraulic conductivity and soil subsidence level were influenced by moisture level and packing incremental level. Further study is recommended to confirm the strong relationship of moisture and packing incremental level on other soil physical and hydraulic properties.

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