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Determining saturated hydraulic conductivity of a repacked loam soil by the simplified falling-head technique: impact of sieving duration and scraping of exposed surfaces

Abstract: Many methods are used in laboratory for packing sieved soil. Determination of soil properties is expected to vary with the applied packing method. The objective of this investigation was to test the impact of initial soil sieving duration and scraping of exposed soil surfaces on saturated hydraulic conductivity, K_s, of an initially air-dry loam soil determined by the simplified falling-head technique. Two sieving durations (5 and 30 min) were considered. A brush was used to scrape exposed surfaces for half of the tested soil columns. A long sieving yielded a finer soil than a short sieving and 9-22% smaller values of K_s. Scraping the exposed soil surfaces yielded 4-17% smaller K_s values than those obtained on the not scraped columns. None of the observed differences was statistically significant. Therefore, sieving duration and treatment of the exposed soil surfaces were minor factors influencing determination of K_s. Reaching general conclusions about sieving duration and scraping effects requires testing these factors with other soils, initial soil water conditions and K_s measurement techniques.

Keywords: Soil column preparation method; saturated soil hydraulic conductivity; undispersed particle size distribution; hydraulic continuity.

INTRODUCTION

Determining the saturated hydraulic conductivity, K_s, of undisturbed field soils is necessary for many agronomic, engineering and environmental activities, such as understanding and predicting water movement or seepage in soils, that can also be expected to depend on the flow direction (Nam et al., 2021; Woessner et al., 2020). Obtaining appropriate K_s values for an intended use is very difficult since this parameter is extremely sensitive to sample size, flow geometry, sample collection procedures and various soil physical-hydrological characteristics (Reynolds et al. 2000). Repacked soil does not represent an alternative to undisturbed soil since repacking alters the characteristics of the porous medium. Nevertheless, saturated conductivity of sieved and repacked soil columns is determined for many reasons such as testing theories (Reynolds & Elrick 1987) or establishing the effects of wastewater (Viviani & Iovino 2004), organic amendment (Bondì et al. 2024), wildfire (Šurda et al. 2023) or rock fragments (Wu et al. 2021) on the soil hydrodynamic behavior as well as serving as input data for numerical simulations (Ghazouani et al. 2015). Working with homogeneous soil columns favors reproducibility of the experiment and hence it makes collaboration between different research teams easier. Despite at least 300 years of experience in the use of soil columns, no standardization of experimental methods has occurred, which complicates comparison between investigations (Lewis & Sjöstrom 2010). Moving towards standardized methods requires considering that many factors could influence experimental results. Sieving duration of an air-dry soil mass and treatment of any exposed soil surface before performing the K_s experiment are two of these factors.

Before preparing a soil column, the porous medium is generally passed through a sieve to include in the sample particles smaller than a given size, frequently fixed at 2 mm, but mechanical sieving duration is rarely reported in scientific papers. The lack of this information is justified if sieving duration does not influence the particle size distribution of the soil used for the experiment. However, Díaz-Zorita et al. (2007) reported that the probability of discriminating between soils increased with a longer sieving duration. According to Bartley et al. (2019), sieving duration influences the probability of a particle to pass through a given sieve. Fomin et al. (2021) suggested that sieving duration is a factor to be considered to define an optimal sieving method. Therefore, it is still necessary to verify if sieving duration is a practically negligible experimental factor.

In some investigations it is explicitly reported that, when the soil sample is prepared by layers, the interface is, and should be, scraped before addition of another soil mass to ensure hydraulic connectivity between the layers since, after compaction, the exposed soil surface could act as a layer with different properties from those of the other portion of the soil column (Lewis & Sjöstrom 2010). We did not find in the literature specific laboratory comparisons between K_s values of scraped and not scraped soil columns. However, the effects of even a thin smeared or compacted soil layer on hydrological processes (Assouline & Mualem, 2006) or field measurement of K_s (Bagarello 1997) are documented. Therefore, scraping impact on laboratory K_s determination should be investigated.

The saturated hydraulic conductivity of an initially unsaturated repacked soil column can be determined in the laboratory from an early-time falling-head infiltration process with the simplified falling-head (SFH) technique, which is also usable in the field (Bagarello et al. 2004). Recently, the dependence of the K_s values obtained by this technique on several factors related with laboratory preparation of an initially air-dry soil column was tested. Investigations were mainly performed on loamy soils and the tested factors included the applied manual method for packing the soil (Bagarello et al. 2022), the reuse of the same soil mass for repeated determinations of K_s (Bagarello et al. 2024), and the relationship between K_s and the dissipated soil compaction energy by a simple laboratory apparatus (Autovino et al. 2024), also taking into account that K_s of repacked soil samples is expected to decrease with increasing bulk density as a response of the smaller volume of coarse pores (Dec et al., 2008). Testing other factors is necessary to better predict the impact of the laboratory preparation method of an initially air-dry soil column on determination of K_s by the SFH technique. This information could also represent a reference for investigations with other soils, initial soil water conditions and K_s measurement techniques.

The general objective of this investigation was to determine how different choices that can be made when a soil column has to be prepared influence determination of saturated hydraulic conductivity of an initially air-dry loam soil with the simplified falling-head technique. The specific objectives were to test dependence of the measured K_s values on i) duration of mechanical sieving; and ii) scraping of exposed soil surfaces during preparation of the soil column.

MATERIALS AND METHODS

Soil

The soil was collected at the orchard of the Department of Agricultural, Food and Forest Sciences of the University of Palermo (Italy, 38°06’24’’ N, 13°21’06’’ E). The soil organic carbon content, determined with the Walkley-Black method, was of 27.1 g/kg. According to the USDA classification system, the sand, silt and clay percentages were equal to 50.7%, 30.3% and 19.0%, respectively, and the soil was classified as loam (Bagarello et al. 2024). A soil mass of nearly 80 kg was collected in the field and it was transported to the laboratory and spread on plastic sheets and manually stirred every two or three days for nearly one month to facilitate natural drying. The gravimetric water content, w (g/g), of this soil was periodically measured. The experiment started as w stabilized at the air-dry value, w_i (g/g). Fresh soil, that is a soil mass never used for other K_s determinations, was used to prepare each soil column in this investigation. A 30 cm diameter and 7 cm high sieve filled with 2-3 kg of air-dry soil was used for sieving the air-dry soil.

Soil compaction apparatus

The soil compaction apparatus by Autovino et al. (2024) was used to prepare a soil column. The apparatus consists of a Teflon pestle sliding inside a Plexiglas guide cylinder and an underlying Plexiglas cylinder containing the soil. The pestle has a diameter of 5 cm, a height of 30 cm and a mass, m_p = 0.89 kg. At its upper end, a screw eyelet connects a rope with a handle. The rope slides through a fixed pulley. The guide cylinder, having an internal diameter, d_c, of 5.3 cm and a height of 50 cm, is aligned with the pulley and secured by metal supports. The container cylinder, also having d_c = 5.3 cm and a height of 25 cm, aligned with the guide cylinder, is equipped at the bottom with a sock and a mesh fixed with a metal band. Compaction involves repeated drops of the pestle from a given height, HF (m). The gravitational potential energy, E_p, dissipated to prepare the soil column is calculated since both the mass of the pestle and the height of fall are known. In particular, for a single blow, E_p (J/m^2) is equal to $m_p \times g \times HF/A$, g (m/s^2) being the acceleration due to gravity and A (m^2) the exposed surface of the soil sample.

Saturated soil hydraulic conductivity

The saturated hydraulic conductivity, K_s (L/T), of a soil column was determined by the simplified falling-head (SFH) technique (Bagarello et al. 2004). A fixed water volume was used for each K_s test. The infiltration time, t_a (T), was determined as the time from water application to the instant when all free water disappeared from the soil surface. The following equation was used to calculate K_s:

$$K_s = \frac{\Delta\theta}{t_a(1-\Delta\theta)}\left[\frac{D}{\Delta\theta} - \frac{\left(D+\frac{1}{\alpha^*}\right)}{1-\Delta\theta} ln\left(1+\frac{(1-\Delta\theta)D}{\Delta\theta\left(D+\frac{1}{\alpha^*}\right)}\right)\right] \tag{1}$$

in which $\Delta\theta$ (L^3/L^3) is the difference between the saturated (θ_s) and the initial (θ_i) volumetric soil water content, $D = V/A$ (L) is the height of the ponded head of water at t = 0, V (L^3) is the applied water volume, A (L^2) is the infiltration surface, and α^* (1/L) is a soil texture/structure parameter that was fixed at 0.012 1/mm (Elrick & Reynolds 1992). In this investigation, θ_i and θ_s were determined using the gravimetric soil water content of the air-dry soil, w_i (g/g), and the dry soil bulk density, ρ_b (g/cm^3), assuming that θ_s coincided with the porosity. Since the soil used to fill the cylinder was air-dry and not oven-dry, ρ_b was determined by the following relationship:

$$\rho_b = \frac{m_s}{V_t} = \frac{m_{ad}}{V_t(1+w_i)} \quad (2)$$

where m_s (g) is the mass of the dry soil, V_t (cm^3) is the bulk volume of the soil sample, and m_{ad} (g) is the mass of the air-dry soil.

Sieving duration

The soil mass was passed through a 2 mm mechanical sieve. Sieving duration, *SD* (T), was equal to 5 min for a part of the soil and 30 min for another part. The particle size distribution, PSD, of the undispersed soil passing through the sieve was determined without initially treating the soil with H_2O_2 or sodium hexametaphosphate to verify if the different sieving durations had a detectable effect on the fine (< 2 mm) soil particle content. At this aim, the percentages by weight of particles of 2-0.86, 0.86-0.425, 0.425-0.25, 0.25-0.106, 0.106-0.075 and < 0.075 mm were determined. For a given *SD* value, the PSD of *N* = 8 soil samples was determined.

The soil passing through the sieve was used to prepare the soil columns for the SFH runs. A column was prepared with a one-step procedure using 580 g of air-dry soil. The soil was poured in the cylinder and then it was compacted by an established number of blows of the pestle, *NB*, falling from a fixed height, *HF*. In particular, three combinations between *NB* and *HF* were used, that is 10 (*NB*) × 0.10 m (*HF*), 30 × 0.30 m and 50 × 0.50 m. The corresponding E_p values were equal to 4.1 (low, L, compaction energy), 37.0 (intermediate, I, energy) and 102.8 kJ/m^2 (high, H, energy), respectively. The final height, h_f (L), of the soil samples varied on average from 21.5 cm for E_p = 4.1 kJ/m^2 to 20.1 cm for E_p = 102.8 kJ/m^2 for a soil sieved for 5 min and from 20.9 cm (E_p = 4.1 kJ/m^2) to 19.6 (E_p = 102.8 kJ/m^2) with *SD* = 30 min. Taking into account that the SFH technique requires establishing a one-dimensional infiltration process, free water should not appear at the bottom of the column by the end of the run. For this reason, a water volume, V_w (cm^3), equal to the empty pore volume in the upper 75% of the soil column was used to perform each SFH run:

$$V_w = 0.75\, h_f \times \pi \times \frac{d_c^2}{4} \times (\theta_s - \theta_i) \quad (3)$$

The V_w values varied from 142 to 172 cm^3, depending on the soil sample, for *SD* = 5 min and from 127 to 154 cm^3 for *SD* = 30 min. Four different soil columns were prepared for each E_p

and *SD* value. Therefore, a dataset of N = 24 individual determinations of ρ_b and K_s was obtained (3 E_p values × 2 *SD* values × 4 replicates).

The one-step soil column preparation method was adopted to avoid the risk to introduce, in the developed dataset, some noise due to a possible hydraulic discontinuity in the case of a preparation by layers. The experiment was repeated with three E_p values to recognize a possible effect of the dissipated energy on the differences between the two sieving durations.

Scraping

In this experiment, the soil mass passing through a 2 mm mechanical sieve for 5 min was used to prepare the soil columns for the SFH runs. A total of 12 soil columns were prepared with a one-step procedure using 580 g of air-dry soil for each column. The soil was poured in the cylinder and then it was compacted by blowing the pestle 48 times from a height of 0.48 m. Consequently, E_p was equal to 94.7 kJ/m^2. After compaction, the exposed soil surface of six randomly chosen columns was scraped by sliding over the surface a small rigid brush, prepared by sticking several needles into a cork connected to a rod. Other 12 soil columns were prepared with a three-step procedure using 193.3 g of air-dry soil at each step. Each of the three layers was compacted by blowing the pestle 16 times from a height of 0.48 m in order not to change the total dissipated energy for a soil column (E_p = 94.7 kJ/m^2). Also in this case, the exposed soil surfaces of six randomly chosen columns were scraped by the brush. In particular, scraping preceded addition of any new soil mass. Even in this case, eq.(3) was used to determine V_w for each infiltration run. The final height of the 24 soil samples was equal on average to 19.9 cm (coefficient of variation, *CV* = 1.1%) and the mean V_w value was equal to 142 cm^3 (*CV* = 2.4%).

A three-step procedure was also used in this experiment to verify if the differences between scraped and not scraped soil columns depended on the number of scraped surfaces in a sample.

Statistical analysis

F and two-tailed t tests at P = 0.05 were applied in this investigation to establish comparisons between two datasets with reference to both dry soil bulk density and saturated soil hydraulic conductivity.

RESULTS AND DISCUSSION

Sieving duration

Undispersed particles having an equivalent diameter > 0.25 mm represented the 66.5% of all particles when the soil was sieved for 5 min and the 63.6% with *SD* = 30 min (Figure 1).

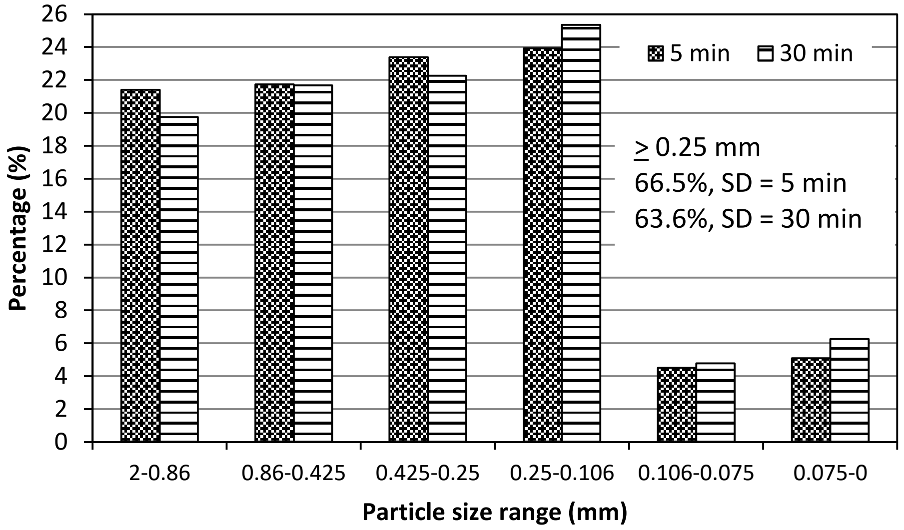

Figure 1. Percentage by weight of soil particles of a given size range for a sieving duration of 5 and 30 min (each percentage is the mean of eight values)

Therefore, the content of coarse particles was smaller by 2.9 percentage units with a longer sieving. More in detail, sieving duration did not influence appreciably the percentages of 0.86-0.425 and 0.106-0.075 mm particles, since two corresponding percentages differed at the most by 0.3 units. With *SD* = 5 min, there were more particles of 2-0.86 mm (by 1.7 units) and 0.425-0.25 mm (by 1.1 units) and less particles of 0.25-0.106 mm (by 1.4 units) and 0.075-0 mm (by 1.2 units) as compared with *SD* = 30 min. Therefore, coarseness of the soil decreased as *SD* increased. The effect of a longer sieving on the undispersed PSD was similar to that detected as a consequence of using repeatedly the same soil mass for preparing soil columns (Bagarello et al. 2024).

Regardless of *SD*, the dry soil bulk density, ρ_b, increased as expected (Dec et al., 2008; Shafiq et al. 1994; Autovino et al. 2024) as E_p increased from a L to a H value (Table 1 and Figure 2). The increase was similar for the two *SD* values (6.6% and 6.0% with *SD* = 5 and 30 min, respectively). For *SD* = 5 min, the largest energy dissipated in this experiment yielded a significantly more compacted soil than that obtained with a small and an intermediate energy but, in this range of relatively small E_p values ($4 \leq E_p \leq 37$ kJ/m^2), the applied energy did not influence significantly ρ_b (Table 1). For SD = 30 min, all differences between two means were significant. Regardless of E_p, the ρ_b value obtained with SD = 30 min was greater than that obtained with SD = 5 min by a percentage varying from 1.0% to 1.9%, depending on E_p. However, the differences between the two SD values were not significant.

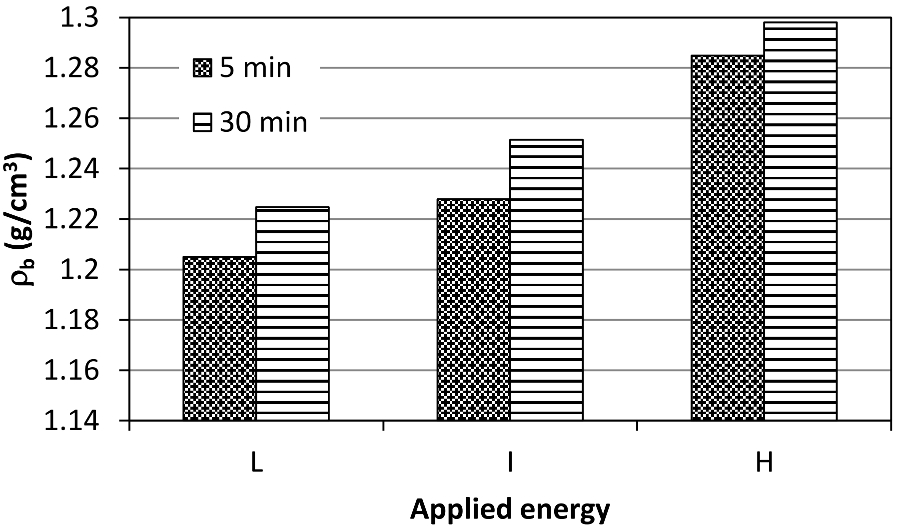

Figure 2. Mean values of the dry soil bulk density, ρ_b, for two sieving durations, SD, and three levels of the applied soil compaction energy, E_p (low, L; intermediate, I; high, H; sample size, N = 4 for each SD and E_p value)

Table 1. Summary statistics of the dry soil bulk density, ρ_b, and saturated soil hydraulic conductivity, K_s, values obtained for each applied compaction energy, E_p, on soil samples prepared after two different sieving durations (sample size, N = 4 for each energy, variable and sieving duration)

E_p	**Statistic**	**ρ_b (g/cm^3)**		**K_s (mm/h)**	
		5 min	**30 min**	**5 min**	**30 min**
Low, L (4 kJ/m^2)	Min	1.18	1.21	62.4	44.7
	Max	1.22	1.25	90.0	67.0
	Mean	1.21 a A (B)	1.22 a (A) (B)	73.4 a (A) (B)	57.5 a (A) (B)

	CV (%)	1.4	1.34	18.1	18.1
Intermediate, I (37 kJ/m^2)	Min	1.21	1.24	38.6	34.8
	Max	1.25	1.26	44.1	43.0
	Mean	1.23 a A (C)	1.25 a (A) (C)	41.4 a (A) (C)	37.7 a (A) (C)
	CV (%)	1.5	0.6	6.6	10.0
High, H (103 kJ/m^2)	Min	1.26	1.28	25.5	23.3
	Max	1.29	1.32	30.2	25.9
	Mean	1.28 a (B) (C)	1.30 a (B) (C)	27.6 a (B) (C)	24.8 a (B) (C)
	CV (%)	1.2	1.2	7.5	4.9

For given compacting energy and variable, values in a row followed by the same lower case letter not enclosed in parenthesis were not significantly different according to an F test and a two-tailed t test at $P = 0.05$. For given variable and sieving duration, values in a column followed by the same upper case letter not enclosed in parenthesis were not significantly different according to an F test and a two-tailed t test at $P = 0.05$. Values followed by the same upper case letter enclosed in parenthesis were significantly different.

The saturated soil hydraulic conductivity, K_s, decreased as E_p increased from L to H for both $SD = 5$ and 30 min (Table 1 and Figure 3). In particular, K_s decreased by 62% with $SD = 5$ min and by 57% with $SD = 30$ min. For a given SD value, all differences between two means of K_s were significant. Regardless of E_p, the K_s value obtained with $SD = 30$ min was smaller than that obtained with $SD = 5$ min by a percentage varying with E_p between 9% and 22%. However, differences between two corresponding means of K_s were not significant.

Differences between the ρ_b and K_s values obtained with the two sieving durations were not so large to be statistically significant. However, sieving duration did not appear to have a totally negligible effect on the tested soil properties since a long sieving yielded numerically larger ρ_b values and smaller K_s values than a short sieving for all applied energies. This last circumstance suggested that the detected differences between the two sieving durations, although small, had a physical explanation and they were not only obtained by chance. A longer sieving implies a larger content of fine particles in the soil used for the experiment (Figure 1). Therefore, there is a greater probability that small particles occupy the empty spaces at the contact zones between the coarser particles. A soil column prepared with a given soil mass will then have a smaller bulk volume and hence a greater ρ_b value (Figure 2). The presence of these small particles makes the pores overall narrower and it induces flow to be more tortuous with the consequence that K_s decreases (Figure 3).

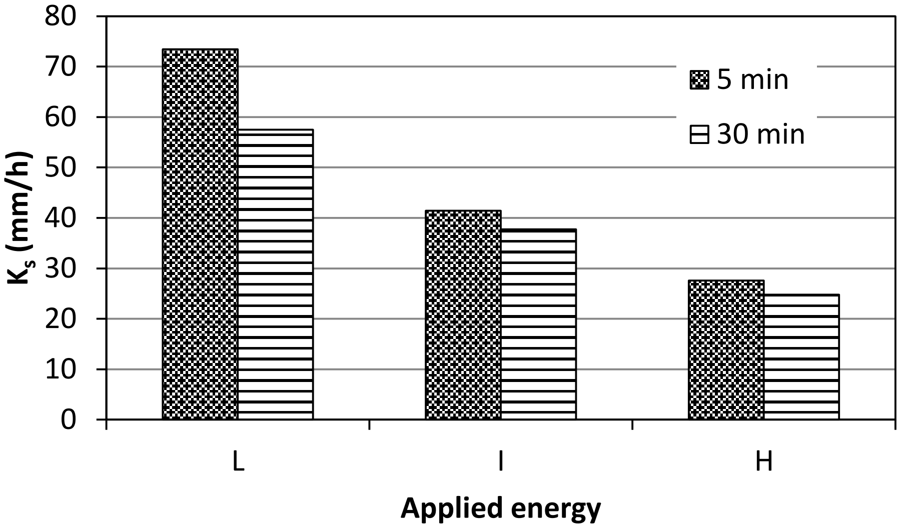

Figure 3. Mean values of the saturated soil hydraulic conductivity, K_s, for two sieving durations, *SD*, and three levels of the applied soil compaction energy, E_p (low, L; intermediate, I; high, H; sample size, $N = 4$ for each *SD* and E_p value)

According to this investigation, sieving duration was a minor and statistically negligible factor influencing the ρ_b and K_s data. Consequently, two datasets obtained under identical conditions only differing by sieving duration can be considered drawn from the same population. However, the existence of some small differences between the two *SD* values having a plausible physical explanation also suggests that more appreciable effects of sieving duration could be detected in other experimental conditions. In this case, a longer sieving could likely imply preparing a more compacted and less conductive soil column. Sieving duration should be reported in scientific papers (Díaz-Zorita et al. 2007). Two investigations performed with similar sieving durations are comparable with more confidence than two investigations differing appreciably by sieving duration.

Scraping

There was not any statistically significant difference between the ρ_b values obtained on the scraped (SC) and the not scraped (NSC) soil columns, regardless of whether the sample was prepared in one or three steps (Table 2). In particular, the percentage difference between two corresponding means, Δ, was equal to 0.6% for the columns prepared in one step and to 0.1% for those prepared in three steps. The SC and NSC columns also yielded statistically similar K_s values for both sample preparation methods. However, the SC and NSC soil columns prepared by a three-step method yielded more similar K_s values than those prepared by a one-step method since Δ was equal to 3.6% in the former case and 16.9% in the latter one.

Regardless of the treatment of the exposed soil surfaces (SC, NSC), preparing the soil sample in three steps yielded significantly higher ρ_b values as compared with those obtained by the one-step method (Δ = 1.5% for the SC columns and 1.0% for the NSC ones). Even K_s was greater with the three- than the one-step method. However, with the SC columns, the difference between the two corresponding means was equal to 26.6% and it was statistically significant. With the NSC columns, the difference was smaller (Δ = 12.2%) and not significant.

The established SC vs. NSC comparisons, yielding not statistically significant and also small differences between corresponding datasets for both sample preparation methods ($\Delta \leq 0.6\%$ for ρ_b and $\Delta \leq 17\%$ for K_s), suggested that scraping the exposed surfaces or not was irrelevant in this investigation. According to this result, two investigations performed on a relatively coarse soil having an initially low water content can be expected to be comparable even if the exposed soil surfaces are scraped in a case but not in the other case.

Table 2. Summary statistics of the dry soil bulk density, ρ_b, and saturated soil hydraulic conductivity, K_s, values obtained by preparing the soil sample in one or three steps and scraping (SC columns) or not scraping (NSC columns) any exposed soil surface (sample size, N = 6 for each step number, variable and scraping treatment)

Steps	**Columns**	**Statistic**	**ρ_b (g/cm^3)**	**K_s (mm/h)**
1	SC	Min	1.27	19.6
		Max	1.31	27.6
		Mean	1.29 a(c)	24.4 a(c)
		CV (%)	1.3	10.8

	NSC	Min	1.30	21.6
		Max	1.31	32.8
		Mean	1.30 a(d)	28.5 ad
		CV (%)	0.3	13.4
3	SC	Min	1.30	26.9
		Max	1.32	33.9
		Mean	1.31 b(c)	30.9 b(c)
		CV (%)	0.8	10.4
	NSC	Min	1.29	28.8
		Max	1.32	34.8
		Mean	1.31 b(d)	32.0 bd
		CV (%)	0.9	7.7

For a given variable, values in a column followed by the same lower case letter not enclosed in parenthesis were not significantly different according to an F test and a two-tailed t test at $P = 0.05$. Values followed by the same lower case letter enclosed in parenthesis were significantly different.

However, for both preparation methods (one- and three-step), the minimum, maximum and mean values of K_s were numerically smaller in the scraped columns than in those in which the soil surface was left intact after compaction. Therefore, scraping appeared to induce a decrease of K_s, although not at a statistically relevant level. Scraping was performed by sliding some needles over the exposed surface. It was unlikely that this operation implied a soil compaction additional to that performed with the compaction apparatus. More likely, sliding the needles induced some mixing of the soil particles at the exposed surface. A consequence of this mixing was that small particles were moved over this surface and they blocked some of the larger pores. This occlusion contributed to impede infiltration through the treated surface. In other terms, scraping the soil surface, rather than favoring hydraulic continuity, hindered it. In any case, the consequences of this phenomenon on K_s determination were small and not statistically significant.

The three-step sample preparation method yielded higher values of both ρ_b and K_s than the one-step method (Table 2). Differences between two datasets were not large ($\Delta \leq 1.5\%$ for ρ_b and $\leq 27\%$ for K_s) even if most of them were statistically significant. Therefore, this investigation also suggested that using, for a given value of total compaction energy, a three-step packing method instead of a one-step method increased global compaction of the soil column (larger ρ_b value) and yielded a larger K_s value. This result, that could appear unexpected (Assouline, 2006), was likely due to the fact that all energy was dissipated on the exposed soil surface with the one-step method whereas it was more evenly distributed along the vertical with the three-step method. Dissipating less energy at the infiltration surface likely produced a vertically more homogeneous soil sample (Oliviera et al. 1996) and it made water entry into the soil easier. This circumstance, determining a smaller t_a value, implied obtaining a larger K_s value. Characterizing in some detail the properties of the top soil layer appears advisable in future research to independently verify the soundness of the suggested explanation with reference to packing method effects on K_s.

CONCLUSIONS

Sieving duration and scraping of exposed surfaces could be expected not to have a statistically relevant effect on saturated hydraulic conductivity, K_s, of a repacked column prepared with an initially air-dry loam soil and determined by the simplified falling-head technique. Therefore, these two factors can be considered as having no more than a minor effect on preparation of these columns. The practical implication is that two datasets only differing by sieving duration or the applied treatment of the exposed surfaces during preparation of the soil column could be considered as belonging to the same population of measurements.

This conclusion is only valid for a specific experiment and it cannot be considered to have a general validity. Therefore, sieving duration and treatment of exposed surfaces effects should be tested in other experimental conditions, that is considering other soils, initial soil water conditions and K_s measurement techniques. In light of the data obtained in this investigation, a prediction that can be made is that a longer sieving duration and the scraping of the exposed surfaces during soil column preparation could yield smaller K_s values.

In the perspective to move towards standardized methods to prepare a repacked soil column, an optimal sieving duration could be the minimum duration beyond which the undispersed particle size distribution does not change further. As regards scraping, an alternative method to the one applied in this investigation could be positioning, and then lifting, a film of adhesive material on the exposed surface of the soil.

Finding an acceptable compromise between complexity of the soil column preparation method and homogeneity of the soil sample requires additional investigations. In particular, it seems necessary trying to support results for some tested factors, such as number of applied layers, soil compaction method or soil water content, in more general contexts and with reference to different soils. In addition, it appears advisable to also consider other factors less or not investigated at all, such as the duration of the storage period before performing the experiment, the operator that prepares the sample, or the actual inner diameter of cylinders having a given nominal diameter.

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