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A Quick Method for the Determination of the Water Capacity of Substrates

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Summary

The results of a quick method for the determination of the water capacity of substrates are compared with those from DIN EN 13041. The results of the quick method have a good correlation to those from DIN EN 13041 when the substrate is filled into the cylinder of the quick method with a volume weight determined according to VDLUFA (2002b). Using the quick method the water capacity is slightly underestimated. If the air capacity is calculated from the total pore space and the water capacity, the air capacity is overestimated.

Zusammenfassung

Schnellmethode zur Bestimmung der Wasserkapazität von Substraten. Die Ergebnisse einer Schnellmethode zur Bestimmung der Wasserkapazität von Substraten werden mit denen der Methode DIN EN 13041 verglichen. Die Ergebnisse der Schnellmethode korrelieren gut mit denen der Methode DIN EN 13041, wenn das Substrat mit einem Volumengewicht in den Zylinder der Schnellmethode gefüllt wird, das nach der Methodenvorschrift des VDLUFA (2002b) ermittelt wurde. Mit der Schnellmethode wird die Wasserkapazität der Substrate geringfügig unterschätzt. Wird der Wert für die Berechnung der Luftkapazität verwendet, wird diese überschätzt.

Key words. Air capacity – water

Introduction

Declarations of substrate properties have to be reproducible. For this reason the European Committee for Standardization (CEN) introduced standards for the chemical and physical analysis of growing media. Concerning physical properties these are DIN EN 13040 (sample preparing prior to chemical and physical analysis) and 13041 (dry bulk density, water capacity, air volume, shrinkage value, total pore space). DIN EN 13039 describes the determination of organic matter and ash content, which is necessary for the calculation of the total pore space. Specially DIN EN 13041 is time consuming and needs specific laboratory equipment, which makes it difficult to carry out the investigation directly at the production plant of the substrate producer. Therefore it was desirable to have a method, which is easy and quick. Of course, this method has to give results, which are comparable to the DIN EN method.

Since many years there is a quick method for the determination of the water capacity of soils (SCHLICHTING and BLUME 1966). This method was further developed for substrates, concerning the time of saturation the sample with water and drainage time (BOHNE et al. 1998). The quick method was introduced into the VDLUFA methods (VDLUFA 2002a). It was investigated if the results for the water capacity obtained by this method are comparable to those from the DIN EN method.

Since the volume weight at the end of the drainage influences the results it was also investigated if the volume weight at the beginning of the investigation has an effect on the volume weight after drainage. This was necessary because the DIN EN method does not work with a defined volume weight for saturation and drainage.

Materials and Methods

Determination of the volume weight

The volume weight was determined according to VDLUFA (2002b). Additionally, the determination was carried out with 15 and 5 instead of 10 falling events. This is referred to as "VDLUFA +5" and "VDLUFA–5", the original as "VDLUFA" in the text. All treatments were carried out with three replications.

Quick method

The sample was filled into a cylinder of 10 cm height with a defined volume weight, which was "VDLUFA", "VDLUFA+5", and "VDLUFA–5" (see above). Then the sample was placed on a grate in a water basin and saturated for 16 hours. Doing this in the afternoon it was possible to continue with the next step the other morning.

After 16 hours the sample was placed on a saturated sand layer of 4 cm height in a box with a perforated bottom (measuring box). The measuring box stood in the saturation box, a box without perforated bottom, which is slightly bigger than the measuring box. Having

checked that there was a good contact between the sample in the cylinder and the sand in the measuring box, this box was taken out of the saturation box and placed on a grate above a water basin or directly above a drainpipe on the floor.

Free drainage is essential. Drainage time was 8 hours. The negative pressure head at the bottom of the cylinder was –4 hPa, at the top of the cylinder –14 hPa. This resulted for the middle of the cylinder in a negative pressure head of –9 hPa. This was taken equivalent to the –10 hPa in DIN EN 13041, hence –10 hPa is used in the following.

After 8 hours, shrinkage and settlement of the sample in the cylinder were measured. These data were used for the calculation of the volume weight at the end of the drainage (Vw_{end}, kg m^{-3}). Then the cylinder was weighed and dried at 105 °C to constant mass (24–48 hours, depending on the substrate). The water capacity (W_v, %, v/v) at –10 hPa was calculated as a product of the gravimetric water content (W_m, %, m/m) at –10 hPa and the volume weight at the end of the drainage:

$$W_m = \frac{m_2 - m_3}{m_3} \times 100$$

m_2 = mass in grams of the wet sample at –10 hPa pressure head minus mass of cylinder (m_1)

m_3 = mass in grams of the dried sample minus mass of cylinder (m_1)

$$W_v = W_m \times Vw_{end}$$

In most cases the determinations were carried out with 4 replications.

A detailed description of the quick method is given by WREDE (2001) and by VDLUFA (2002a).

DIN EN 13041

The sample prepared according to DIN EN 13040 was saturated with water for 12 hours, then filled into plastic tubes and drained on a special sand box at a negative pressure head of –50 hPa for 48 hours.

After this, the sample was mixed carefully and filled into special double rings (diameter 10 cm, height 5 cm for each ring), saturated again for 24 hours and then drained on the sand box at a negative pressure head of –10 hPa for 48 to 72 hours depending on the substrate. The negative pressure head was measured from half the height of the lower ring. This means that there was an average negative pressure head for the sample of –10 hPa.

After drainage, the double rings were separated carefully with a vertical movement. With a knife or straight edge the material was struck off carefully level with the top of the lower sample ring. The lower ring with the sample was weighed and dried at 105 °C to constant mass (24 to 48 hours depending on the substrate).

The water capacity was calculated using the following equation:

$$W_v = \frac{m_2 - m_3}{V} \times 100$$

W_v = water capacity expressed as a percentage by volume (% v/v), wet sample at –10 hPa pressure head

V = volume of the sample ring in cm^3

m_2 = mass in grams of the wet sample plus sample ring (m_1) at –10 hPa pressure head

m_3 = mass in grams of the dried sample plus sample ring (m_1)

The measurements were carried out with four replications.

A detailed description of the method is given in DIN EN 13041 and by WREDE (2001).

When the organic matter content is determined for both the quick method and the DIN EN 13041 method, calculation of total pore space and air capacity is possible.

Substrates

The measurements were carried out with 36 different substrates. 13 of them were commercially available substrates. The main components of these substrates were white peat (different grades) and black peat, followed by peat fibres, clay, composted bark, cocofibres, rice hulls. The other substrates were mixes of white peat with different amounts of each black peat-fine, black peat-coarse, clay, coco fibres, and composted bark.

Statistics

The results for the volume weight determined with the methods VDLUFA, VDLUFA+5, VDLUFA–5 were tested according to Tukey. These were the volume weights when starting the quick method. The volume weights at the end of the quick method (after drainage) were tested according to Tukey-Kramer. In this case Tukey-Kramer was used, because the number of replications was different for the substrates due to lack of substrate.

The Student T-test was used to evaluate if the two methods (quick method and DIN EN 13041) differed in their effect on the water capacity of the substrates investigated.

Results

The determination of the water capacity with both methods for all substrates took several months. Presumably for this reason the wettability of the substrates decreased. This was specially the case for self-mixed substrates containing clay. The clay sucked off water from the peat and decreased its wettability. When this was obvious during saturation of the substrates, these results were omitted. Hence the data presented here do not always include all 36 substrates.

For the determination of the water capacity with the quick method the substrates were filled into the cylinder with the volume weight resulting from the different treatments for the determination of the volume weight (VDLUFA, VDLUFA+5, VDLUFA–5). The results for the volume weight according to VDLUFA, VDLUFA+5, VDLUFA–5 (= before drainage) and those after drainage were significant at $\alpha = 0.05$ (Tukey and Tukey-Kramer). Table 1 shows the regression equations for the volume weights before and after drainage at –10 hPa. For "VDLUFA+5" there is the closest correlation between the volume weight before and after drainage. The difference between the volume weight

Table 1. Correlation between the volume weight at the beginning and at the end of the drainage. The volume weight at the beginning was defined by "VDLUFA", "VDLUFA+5", and "VDLUFA–5".

Treatment	x = volume weight$_{beginning}$ y = volume weight$_{end}$
VDLUFA (10 falling events)	y = 1.1173 x + 3.4995 r^2 = 0.934, r = 0.966
VDLUFA+5 (15 falling events)	y = 1.145 x – 0.5659 r^2 = 0.966, r = 0.983
VDLUFA–5 (5 falling events)	y = 1.0483 x + 19.94 r^2 = 0.952, r = 0.976

Table 2. Correlation between the volume weight of the quick method and of DIN EN 13041 at the end of the drainage. The volume weight at the beginning was defined by "VDLUFA", "VDLUFA+5", and "VDLUFA–5".

Treatment	x = volume weight$_{end}$ DIN EN 13041 y = volume weight$_{end}$ quick method
VDLUFA (10 falling events)	y = 1.0436 x – 6.2414 r^2 = 0.988, r = 0.994
VDLUFA+5 (15 falling events)	y = 1.0715 x – 6.3926 r^2 = 0.968, r = 0.984
VDLUFA–5 (5 falling events)	y = 0.9545 x + 11.175 r^2 = 0.962, r = 0.981

before and after drainage is highest for the treatment "VDLUFA–5" and smallest for the treatment "VDLUFA+5".

DIN EN 13041 does not work with a defined volume weight when filling the sample rings. But, of course, due to drainage at –10 hPa a certain volume weight will result at the end of the measurement. Fig. 1 and Table 2 show the relationship between this volume weight and those of the different treatments for the quick method at the end of drainage. The best relationship was determined for the treatment "VDLUFA". This means, if the substrate investigated by the quick method is filled into the cylinder with a volume weight resulting from ten falling events according to the method of VDLUFA (2002b), there will be a close relation to the volume weight resulting from DIN EN 13041 at the end of the drainage.

Relating water capacity at –10 hPa determined with DIN EN 13041 to the water capacity resulting from the quick method again the highest correlation was found for the treatment "VDLUFA" of the quick method (Fig. 2 and Table 3). The relation was:

Water capacity-quick method = (1.0019 x Water capacity-DIN EN13041) – 5.337

The correlation coefficients were tested with the Student-t-test for $\alpha = 0.05$ and are significant.

Discussion

Working with DIN EN 13041, the substrate is filled into the sample rings randomly without compaction. Drainage at –10 hPa leads to settlement and shrinkage and hence to a certain volume weight at the end of the drainage. Since this volume weight is part of the calculation of the water capacity it is important to know how the volume weight at the beginning affects the one at the end. This was investigated with the different treatments for the quick method. It turned out that producing a volume weight with 15 falling events (VDLUFA+5) and filling the cylinder for the determination of the water capacity with this volume weight increases the volume weight at the end of drainage at –10 hPa to the smallest degree. 5 falling events (VDLUFA–5),

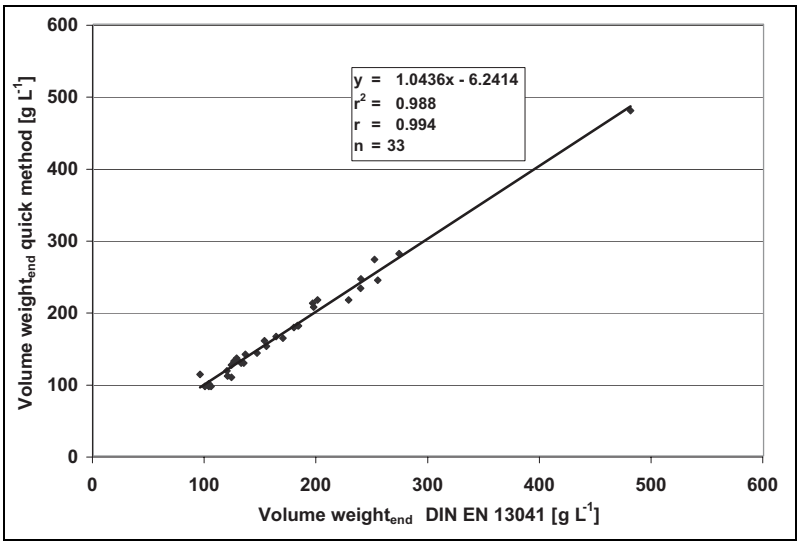


Fig. 1. Volume weight at the end of drainage at –10 hPa: DIN EN 13041 in relation to the quick method (treatment VDLUFA).

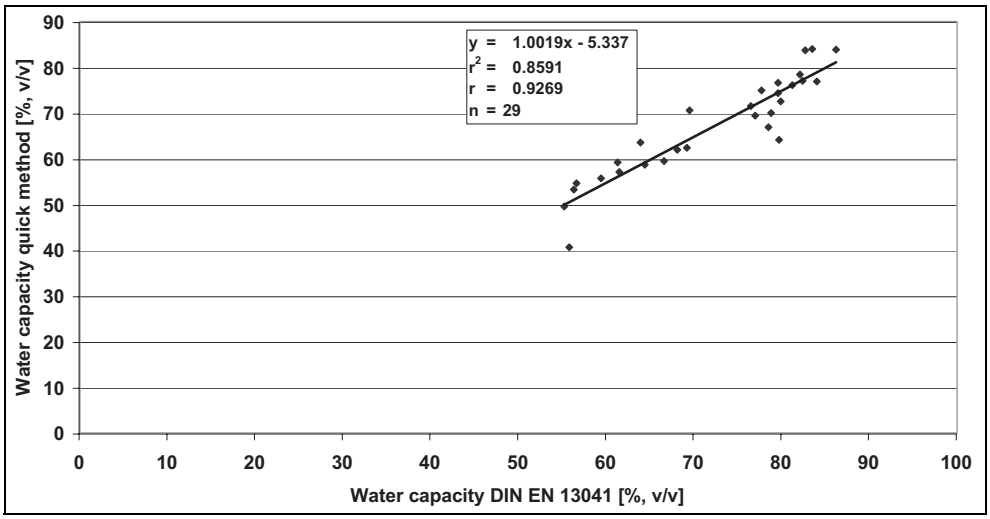


Fig. 2. Water capacity of the quick method (treatment VDLUFA) in relation to the water capacity of DIN EN 13041.

Table 3. Correlation between the water capacity determined by DIN EN 13041 and by the quick method and its treatments "VDLUFA", "VDLUFA+5", and "VDLUFA–5".

Treatment	x = water volume from DIN EN 13041 y = water capacity from the quick method
VDLUFA (10 falling events)	y = 1.0019 x – 5.337 r^2 = 0.8591, r = 0.9269
VDLUFA+5 (15 falling events)	y = 1.055 x – 6.7935 r^2 = 0.8111, r = 0.9006
VDLUFA–5 (5 falling events)	y = 0.9814 x – 1.3301 r^2 = 0.7595, r = 0.8715

which mean a less compacted substrate, resulted in the biggest increase of the volume weight after drainage. This means the smaller the degree of compaction before drainage the higher is the increase in volume weight as a consequence of the drainage. Drainage exerts a force on the substrate particles due to the effect of the negative pressure head on the water menisci. This force will lead to settlement and shrinkage until an equilibrium with the packing of the particles is reached. The less dense the packing is before drainage the higher are settlement and shrinkage until the equilibrium with the negative pressure is reached.

Although the difference between the volume weight before and after drainage is higher for the treatment "VDLUFA" (10 falling events) of the quick method, this treatment results in the highest correlation with the volume weight at the end of the drainage of DIN EN 13041. Presumably the filling of the sample rings for DIN EN 13041 produces a similar volume weight as the VDLUFA method. Consequently, the water capacity determined with the volume weight from "VDLUFA" correlated the best with the water capacity from DIN EN 13041. The correlation shows that the results for the water capacity obtained from the quick method are slightly lower than those from DIN EN 13041. These differences are significant for $\alpha = 0.05$ (Student t-test). From this it is possible to use the quick method for a rapid determination of the water capacity. This is an advantage for substrate producers. However, one should be aware of the underestimation of the water capacity determined by the quick method or transform W_V of the quick method to W_V of DIN EN 13041 by the correlation given here. This has to be specified.

When using the method for the determination of the total pore space and calculation of air capacity it has to be kept in mind that the results for the air capacity will be slightly higher compared to those obtained from DIN EN 13041, because air capacity is calculated as the difference between total pore space and water capacity.

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