Determination of volume weight and water content of wood fiber substrates with different methods

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1 Introduction

Wood fiber substrates have been introduced for several years in horticulture. Their use in seedling and transplant production is still not very popular. The most frequently applied mixtures are based on peat (GRUDA, 1999). To evaluate wood fiber substrates for their suitability for plant production physical, chemical and biological characteristics are usually determined. Chemical-biological characteristics of wood fiber substrates (N-immobilization) have been reported by GRUDA and SCHNITZLER (1997; 1999).

The physical characterization of substrates gives important information on numerous parameters but particularly on the water/air relation in the substrate. This information is necessary for the correct control of water supply (BOHNE and GÜNTHER, 1997). The physical characteristics of substrates are important since they cannot be changed during the culture (VERDONCK, 1983).

The determination of volume weight (VW) or bulk density is a precondition for calculating nutrient contents of substrates. In contrast, other physical properties of substrates are rarely analyzed, although, with such data available recommendations for vegetable growth and production can be improved. Consideration has to be due to higher expenditures for physical compared to chemical analyses. In addition, different equipment in the laboratories and the application of different methods makes the transfer of data and information more difficult.

The ISHS method (**I**nternational **S**ociety for **H**orticultural **S**cience) can serve as an international standard of investigations for the physical properties of substrates as suggested by VERDONCK and GABRIELS (1992). The LUFA method provided by the **V**erband **D**eutscher **L**andwirtschaftlicher **U**ntersuchungs- und **F**orschungs-**A**nstalten (German Association of Agricultural Laboratory Research Institutes) is considered as standard for the investigation of the VW of horticultural substrates in Germany. The disadvantage of the ISHS method is the relatively large amount of time for analysis. The advantage is that VW is determined at a defined volumetric water content (WC) of the substrates (pF = 1,0). Whereas with LUFA method, the water content is not adjusted by an objective measurement.

The condition established for the determination for VW of a substrate according to ISHS and LUFA method does not reflect the condition in the pot during cultivation. This needs to be considered when the mineral nutrient content in a pot is calculated and when the WC of a substrate in pots is determined.

The standard method for determination of volumetric WC at pF = 1-2 and other derived parameters for physical characterization of substrates is the original ISHS method which is based on non-compacted substrates. For the determination of the WC in substrates under pot

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conditions a modified ISHS method was suggested by BOHNE and GÜNTHER (1997). In addition, some laboratories use the same techniques as for soil analysis (BRÜCKNER, 1997).

The aim of this study is to investigate the comparability of the available methods for determination of volume weight and water content in organic substrates.

2 Material and methods

Volume weight and volumetric water content at three different water potentials were determined with 'Toresa nova' (Tn), a wood fiber substrate with a finer texture and 'Toresa + brown coal' (TnBk), a mixture both from Intertoresa AG (Switzerland) as well as the peat substrate 'Statohum' from Gebr. Patzer GmbH & Co. KG (Germany).

Volume weight (VW)

The VW of substrates was determined by three procedures: a) LUFA method, b) ISHS method and c) pot method. For all three methods the VW was determined by the ratio of dry weight at 105 °C of substrate (g) and substrate volume (cm^3).

a) LUFA method

Transparent plastic cylinders (250 ml) were filled up to the edge with the substrate. The required water content of the substrate was adjusted before by observation. It must be moist enough to be adhesive after pressing (when tightly compacted in a fist, it must have a moist touch but no water may exude). The cylinder was successively dropped ten times from 10 cm height. The volume and the dry matter of the compressed substrate was then determined (VDLUFA, 1991).

b) ISHS method

According to VERDONCK and GABRIELS (1992) the substrate must be saturated with water first: fill slowly with water until the level reaches up to 1 cm under the top of the container. After this remove the container and leave for 48 h on the sandbox, applying a suction of 50 cm (pF = 1.7). Mix the sample, fill rings with a big spoon in increments of approximately 100 ml without causing compaction and fill up to the top of the removable ring. Transfer the filled double rings into laboratory water bath and after repeated moistening for 24 hours place them immediately to the sand boxes. The rings are slightly pressed for good contact with the sand surface. Cover the sand boxes and apply the suction from 10 cm (pF = 1.0) for 48 hours. Take the double rings from the sand box and remove the upper ring slowly, exposing the uppermost part of material. Using a sharp knife strike off the material level with the top of the test ring without causing compaction. Volume and dry matter as well as the VW of the substrate of the lower ring was then determined.

c) Pot method

The VW of the substrates or substrate mixtures for 4x4x4 cm press pots and for plug trays (77 pots) was determined after pressing and filling respectively. Only one substrate (Toresa nova) was examined in the plug trays. The substrate's volume as well as substrate dry matter was determined by using 2x10 pots for each treatment. Consequently, the VW corresponded with the conditions which prevailed in the pot.

Volumetric water content (WC) at different water potentials

The volumetric WC of substrates was determined using three procedures: a) modified ISHS method, b) positive pressure method and c) negative pressure method. Principle of measurement of all three methods is the saturation of the substrate sample with water and a further drainage to certain levels of water potential, i.e. at each level of water potential all water has left the substrate sample which is held back at less tension than the applied water potential.

The amount of water left in the sample at each level was measured and changes noted for calculation of water content (HARTGE and HORN 1992).

Measurements of the water content by positive and negative pressure method were done in 100 cm^3 metal rings according to HARTGE and HORN (1992), while in modified ISHS method 415 cm^3 rings were used. For all three methods it was ensured to simulate the real conditions in a pot by filling the rings with a defined VW. The substrate samples were filled in the rings with the substrate surface ending at the ring's upper edge. That was ensured by accurately squeezing the substrate with two ring covers. After removing the covers the rings were placed on filter paper on top of the water source for 24 hours to allow for saturation. In the second test series of the negative pressure method, the samples were placed in the system for 48 hours, in the modified ISHS method for 74 hours.

Water content of samples was determined at water potentials of pF = 1.0, 1.7 and 2.0 for all methods. Measurements according to modified ISHS method were carried out in two replications, for the other methods in six replications for all treatments.

a) Modified ISHS method

This method is also basically a negative pressure method. For modified ISHS method only the lower of the two ring (415 cm^3) used in the original ISHS method was used and filled up with substrate. The VW was adjusted specifically to pot condition for each substrate (BOHNE and GÜNTHER, 1997).

b) Positive pressure method

Samples were set on paper filters on top of porous ceramic disks. Samples on their ceramic beds were placed in a pressure chamber. At each level of water potential this chamber was pressurized until all water was drained. Excess water was drained of the chamber via a hose.

c) Negative pressure method

This method is based on suction applied from the bottom side of the substrate sample. Measurements were taken with equipment of Ejkelkamp company, Equipment for Soil Research B.V. Giesbeek, Holland. The samples were set on a layer of fine sand to avoid direct suction on substrate particles. A water column was "hanged" to the bottom end of the sample. Different levels of water potential were obtained by changing the height of the water column.

3 Results

Volume weight

As presented in Figure 1, only slight differences in VW resulted from the application of the LUFA method compared to the ISHS method. The pot method also gives comparable values for 'Toresa nova' in the plug tray. However pressing the substrates for press pots clearly resulted in higher VW-s. In the press pots, the VW for substrate 'Toresa + brown coal' increased from 0.16 g cm^{-3} to 0.20 g cm^{-3} and for Statohum from 0.14-0.15 g cm^{-3} to 0.21 g cm^{-3}.

The calculation of N_{min}-contents based on the volume weights determined with the LUFA method, ISHS method and pot method is presented in Table 1. This example shows that the difference of N_{min} in the tested substrates is minimal if VW was measured by LUFA or ISHS method (10 mg N L^{-1} with Toresa nova and 5 mg N L^{-1} with Statohum). Accordingly, there was no difference between the mentioned methods and the pot method for Toresa nova in plug trays (77 pots). Calculating N_{min} on the base of the pot method-VW resulted in a higher content (157 mg N L^{-1}) in Toresa nova in press pots compared to plug trays. Higher N_{min} contents were found in the three substrates when calculated with the actual VW (pot method) in press pots compared to LUFA and ISHS method. Consequently, higher N_{min} content per pot

were found (10.6, 6.8 and 6.7 mg pot^{-1} in 'Toresa nova', 'Toresa nova + brown coal' and 'Statohum' respectively) due to more substrate in the press pot.

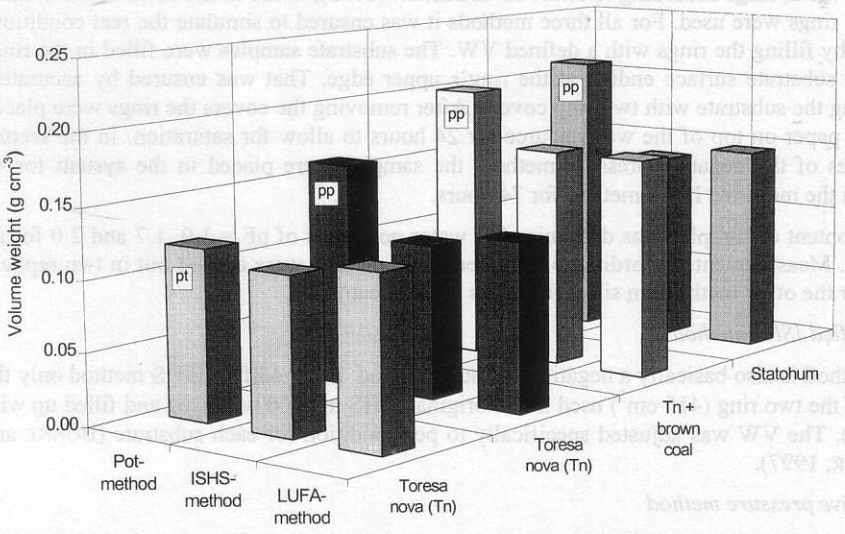

Figure 1: Volume weight (g cm^{-3}) of the substrates. Comparison of the three applied methods.
Abbildung 1: Volumengewicht (g cm^{-3}) der Substrate. Vergleich der drei angewandten Methoden.

Table 1: Calculated N_{min}-content of substrates in pots based on volume weights obtained by different methods.
Tabelle 1: Berechnete N_{min}-Gehalte von Substraten mit nach drei verschiedenen Methoden ermittelten Volumengewichten.

Substrate	LUFA method		ISHS method		Pot method	
	mg L^{-1}	mg pot^{-1}	mg L^{-1}	mg pot^{-1}	mg L^{-1}	mg pot^{-1}
Toresa nova (Tn)	118	6.6	108	6.0	118 (pt)	6.6 (pt)
Toresa nova (Tn)	118	6.6	108	6.0	157 (pp)	10.6 (pp)
Tn + brown coal	86	5.5	86	5.5	107 (pp)	6.8 (pp)
Statohum	76	4.9	71	4.5	106 (pp)	6.7 (pp)

pt = plug trays (77 pots), pp = press pot.

Volumetric water content at different water potentials

Figure 2 shows the correlation between the modified ISHS method compared to the positive and negative pressure method based on the measurement of volumetric water contents at pF = 1.0, 1.7 and 2.0. Both methods are closely related to the modified ISHS method (r^2 = 0.94). At lower water contents, the positive and negative pressure method indicated slightly higher values than determined with the modified ISHS method. Thus, a water content of 30 Vol. % determined by the modified ISHS method equals a water content of 33.6 Vol. % measured by the positive pressure method and a water content of 35 Vol. % determined by the negative pressure method.

Water contents of 80 Vol. % after the modified ISHS method showed somewhat lower values in comparison with 73.4 Vol. % both for positive and for negative pressure method. All three methods provided similar values at the measured water content of 50 Vol. % (Figure 2).

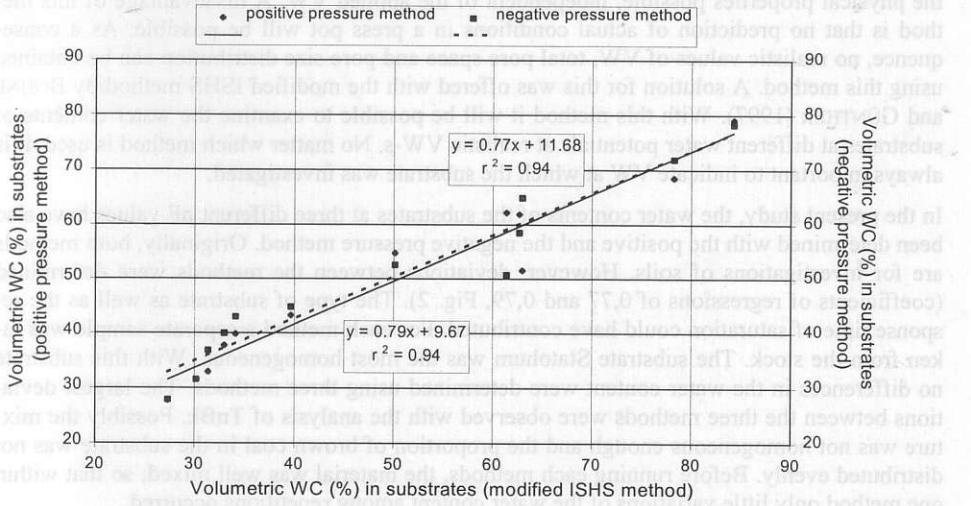

Figure 2: Comparison of the volumetric water content (WC) in substrates at pF = 1.0, 1.7 and 2.0. determined with the positive and negative pressure methods in comparison to the modified ISHS method.

Abbildung 2: Wassergehalte der Substrate bei pF = 1,0, 1,7 und 2,0 bestimmt mit der Über- und Unterdruckmethode im Vergleich zur veränderten ISHS-Methode.

4 Discussion

Volume weight

Applying the ISHS and LUFA methods, the same results were obtained concerning the VW for the examined substrates. This shows that the VW of organic substrate measured with the LUFA method can directly be compared with results from the ISHS and *vice versa*. The advantages of the LUFA method are (i) lower costs - only one transparent plastic cylinder with a stand is needed, (ii) reduced time for analyses. BOHNE and DIENSBERG (1996) even suggested to examine soils by this method since very good correlations between a modified LUFA method (20 cm height, 25 drop-downs) and soil core method for soil investigation were found. In their investigations the VW was not influenced by the soil moisture contents.

However neither of the two methods can be applied to determine the VW of the substrate under practical conditions in a pot. In this case only the pot method can be used. When producing press pots the VW has to be determined right after the pressing.

A different VW will influence further calculations of mineral nutrient contents in the substrate. Table 1 shows higher N_{min} contents in press pots than in plug trays, when calculated with VW determined with the pot method. This plays a role if the plants will not be periodically supplied with additional nutrients. In this case, it is necessary to know exactly how much nutrients are available in a pot in order to adjust the necessary nutrient level. Therefore the growers are recommended to determine the VW in their pots to calculate the actual mineral nutrients available.