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Analytical Methods for Growing Media – Challenges and Perspectives

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Abstract

Production methods in modern horticulture demand an equivalent choice of suitable substrates. Starting with rather simple systems, today growing media are complex mixtures with a still growing number of possible constituents. Analytical methods to characterize growing media in terms of plant response were initially derived from soil analysis. Nowadays, it is a separate field with a high degree of specialization, as a sufficient characterization of the matrix is a basic requirement for the successful use of growing media.

In the beginning, substrate analysis has focussed on several key parameters like bulk density, pore space, pH, salt content or soluble nutrients. The development of new matrices increases the number of essential methodologies like detailed physical characterization or biological properties.

According to local demands, individual approaches with varying focus have been developed for equal or similar properties. Moreover, certain groups have also differing demands to be met: substrate producers are in need of tools for quality control, trade and inspection require well standardized and comparable methods and for the growers, the surveillance of the plant production is of main importance.

Therefore, depending on the purpose or simply on the national methods for one and the same feature may differ to quite a large extent. To assure comparability, work has to be done not only to develop and verify new methods but also to define general standards especially for the key parameters. Furthermore, these standard methods have to be calibrated on the basis of the corresponding "old" approaches to guarantee continuity of control or recommendation systems.

Activities of the Centre Européen de Normalisation (CEN) or the EU-funded project "HORIZONTAL" can be seen as a second starting point. Although all EU countries have accepted and implemented some of the so far established EN-standards, other nationally or otherwise established methods are still in use as there are still disadvantages for routine analysis and consulting work. ISHS can serve as a basis to improve this situation.

INTRODUCTION

Since the beginning of horticultural science, the analysis of the substrates in use has been a valuable tool for the researchers – but never the aim in itself. The main point of interest is still the correlation with the plant response. Nevertheless, substrate analysis is essential for better characterizing substrates in terms of explaining or predicting plant response. Furthermore, data obtained should serve as a basis for the development of models, thus reducing the analytical work and improving the accuracy of interpretations.

Substrate analysis was initially derived from methods developed for soil analysis. The main difference, however, is the limited rooting space within containers. But in comparison to soil, growing media might be referred to as equivalent to the rhizosphere zone, as the rooting density is very high. Therefore, the characteristics of the substrate have a much more direct influence on the plant than similar parameters determined for soil. As the "buffer capacity" of soil is lacking, methodology has to be focussed on immediate consequences for roots and plants.

SUBSTRATES OF MODERN HORTICULTURE

Since the development of industrial substrates, the complexity of the media due to various constituents has been growing permanently, especially during the last 20 years. Starting with rather simple peat-based mixtures like the John Innes compost or the media developed by Fruhstorfer or Penningsfeld, the variety of possible substrates has been increasing permanently. In Table 1, a selection of substrate constituents is listed. Apart from materials for improving or changing substrate characteristics, a number of products derived from waste management is gaining more and more importance - on the one hand to improve the utilization of these materials, on the other hand to find substitutes for or amendments to peat.

Parallel to this, also production methods have improved to a large extent, thus causing the necessity for more precise and accurate analytical methods to guarantee a proper management of the production process.

TARGET GROUPS FOR ANALYSIS

Due to the complex process, starting from the preparation of the substrate constituents and the substrate production to trade regulations, the horticultural production itself and finally the consumer, a clear scope has to be defined regarding the target groups of substrate analysis. Whereas for the producer questions of quality control are of main importance, at the level of the grower the demands for effective consulting work have to be added. Trade itself is regulated for example by national or community law (like in the EU), demanding well standardized procedures for the characterization of substrates. For the consumer, both advisory work and supervision are relevant. Science therefore not only has to provide methodology for basic scientific work but also for the different demands and targets groups mentioned above (Fig. 1).

In the past, the scientific work was strongly related to individual researchers or research groups, often due to certain thematic fields or simply reasons of nationality (e.g., VDLUFA, 1997; van Pol, 1984; Gysi and van Almen, 1984). Thus, the transfer of data or the interpretation and prediction of characteristics was or – in several cases – still is limited. Regarding the need of the target groups, that have to be supplied with sound interpretations based on value ranges, thresholds and practical applications derived from these data, efforts have still to be made to meet these demands. Of course, scientific work may not be limited by a fixed methodology, but at least for certain basic parameters it should be tried to find comparable approaches.

ANALYTICAL METHODS

Regarding substrate physics, a lot of work has been done recently (Bohne and Wrede, 2005), especially in characterizing hydraulic properties (e.g., Wever et al., 2004; Caron and Elrick, 2005; Naasz et al., 2005). Fortunately, in this field of research work, method descriptions are precise as most of the publications can be regarded as "first step approaches" – to prepare and validate methodology for further practical use. However, if we have a look at rather simple, "basic" methodology, the picture gets more and more diverse. For the determination of the bulk density, at least 5 different methods – even on a normative scale – can be found to characterize one and the same parameter. Taking into account that several chemical parameters refer to the bulk density, it becomes clear that we are facing a possible source of misinterpretation.

For chemical parameters, the situation seems to be even worse, since most of these are no more in the status of a first step approach but well established. There is practically no publication that does not refer to pH, EC or nutrient contents – but unfortunately in most of the cases with regard to different methodologies. Starting with such a basic parameter as the pH, there are several possibilities – e.g., measuring in water (EN 13037) or salt solution (ÖNORM S 2021), leading to completely different results. Moreover, for the determination of the salt content, you not only find different extraction ratios – ranging from saturation extract to 1 +10 – based on M/M, M/V or V/V, but also a set of different dimensions: from $\mu S \cdot cm^{-1}$ to $g\ KCl \cdot L^{-1}$ (e.g., Sonneveld and van Elderen, 1994; Fischer et al., 1991).

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Similarly, for the contents of soluble nutrients, methodology differs with regard to the extraction ratio, extraction basis (mass or volume), the extractant itself (e.g., water, solutions of neutral salts, acidic solutions, chelating agents, combinations of extracting agents), the reference basis and the dimension. Table 2 gives the characteristics of selected methodologies. As a consequence, reference tables for the interpretation of analytical data are available – but not comparable between one working group/nationality and the other (Tables 3, 4 and 5). So it is left to the reader to work out means of comparing the work done by different authors.

CHALLENGES FOR METHODOLOGY

Coming back to the actual needs, what parameters are demanded? According to Moore (2005), only a rather simple set of attributes is of interest for optimal plant growth: Sufficient aeration and drainage, stability and – regarding the chemical attributes – no phytotoxicity (e.g., caused by pH, salt or phenolics), sufficient nutrient availability and sufficient buffering capacity. At least for these attributes, methods with the possibility of a comparable interpretation should be available.

For chemical characterization, several methods derived from soil analysis are applicable with only slight modification like e.g., pH, TOM, N_{tot}, lime content, aqua regia extractable elements or some nutrient extractions (e.g., Schüller, 1969). Especially in this field, with regard to the "rhizosphere aspect", additional methodologies have been developed (Alt and Peters, 1993; Sonneveld and van Elderen, 1994). Not only the extractant, but also the extraction procedure has been modified. Furthermore, some parameters like cation exchange capacity are often quoted and analytical results are given, nevertheless there is no common methodology available that is sufficiently described yet.

Regarding the physical parameters, the applicability of the methodology used for soil seems to be limited due to the obvious differences in particle size and pore structure. Whereas the principles of measurement are often the same (e.g., sand bed methods, TDR, FD or tensiometers for characterizing hydraulic properties), the actual methodology differs to a more or less large extent. Furthermore, several methods had to be developed completely new - like the determination of the bulk density, the shrinkage or the particle size distribution. Which methods are missing still, probably the next years of scientific research will show.

A rather new field of methodology is derived from the (micro)biological properties of growing media. Originally, microbial activity in substrates was objectionable because of the possibility of lacking "stability", due to a loss of structure (e.g., Prasad and Maher, 2004) and nutritional problems resulting from immobilization processes (Carlile, 2004). As the use of waste products in modern growing media increases, further, this time beneficial characteristics like the possible suppression of pathogens or the increase of nutrient availability due to the "rhizosphere effect" come into focus. Therefore, a new set of parameters such as the traditional classification of microorganisms or the measurement of the microbial activity (respiration, enzyme activity), is being developed (Carlile and Dickinson, 2004).

Furthermore, biological tests for assessing the possible phytotoxicity or the number of viable weeds have to be taken into account.

CONCLUSION

Summarizing, we are facing several problems in interpreting substrate analysis data due to various differences in the methodology. As a consequence, these problems are extended to the fields of quality control, standardization, product declaration and, finally, legislation as well. According to this, several approaches have started to harmonize key methodology, like on the level of European Standardization (CEN) or in scientific projects (EU-sponsored project "HORIZONTAL"). However, up to now no real effect is visible on a large scale. Although CEN-methods are adopted as national methods of all CEN-Member States and contradictory methods once published by national standardization institutes withdrawn, the implementation of these methods is still limited.

This is mainly due to the different national legislation, which is often based on traditional and still existing methods not published by national standard bodies. It may also be due to some methodological problems, as especially the physical methods are rather time consuming. On the other hand, work still has to be done to convert existing threshold ranges based on the former routine analysis into the new methods (Baumgarten, 2004).

Within project HORIZONTAL, it is still not clear if growing media are covered by the scope of the project, thus limiting harmonization. As has been said earlier, it should be the aim to agree upon a set of parameters to serve as a common basis for a general characterization of growing media. Of course, the set of methods has to be chosen with regard to the material tested. But even then, conventions can be fixed to get a uniform approach with no regard to the scientist or the performing laboratory. Perhaps ISHS can serve as a basis for this kind of work to improve the applicability of analytical data for horticulture.

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Tables

Table 1. Substrate constitu

Natural resources
Peat
"Primary" Waste materia
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Coconut prc
Husks
Others
"Secondary" Waste mater
Compost
Charcoal
Mineral or synthetic mate
Soil
Sand
Clay (pure c
Mineral woc
Perlite, Zeol
Cellular glas
Synthetic fit
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Wever, G., Nowak, J.S., de S. Oliveira, O.M. and van Winkel, A. 2004. Determination of hydraulic conductivity in growing media. Acta Hort. 648:135–143.

Tables

Table 1. Substrate constituents according to their origin.

Natural resources		
	Peat	
"Primary" Waste materials - used with no or mechanical processing		
	Wood-based materials	
		Fibres, chips, sawdust, bark, leaf litter, …
	Coconut products	
		Fibres, coir, husk
	Husks	
		Rice, groundnut, almond, coffee, …
	Others	
		Orange peel, grape mark, cork residue, river waste, bovine bones, municipal solid waste and sewage sludge, paper, cotton, …
"Secondary" Waste materials - used after chemical and/or biological processing		
	Compost	
		e.g., Barnyard manure, green waste, bark, municipal waste municipal sewage sludge, biosolids, seaweed, *Miscanthus*
	Charcoal	
Mineral or synthetic materials		
	Soil	
	Sand	
	Clay (pure or processed)	
	Mineral wool	
	Perlite, Zeolite	
	Cellular glass foam	
	Synthetic fibres	
	Organic polymeres (hydrophilic properties)	

Table 2. Characteristics of different methods for the determination of plant available nutrients.

Method	Matrix	Extraction ratio	Extractant	Elements	Dimension
EN 13652	"inert" substrates	1 + 5, V/V	water	main nutrients	mg element · L^{-1}
EN 13651	substrates with high CEC, high buffer capacity	1 + 5, V/V	$CaCl_2$/DTPA (CAT)	main nutrients, trace elements	mg element · L^{-1}
ON 2021	all substrates	1 + 10, M/V	Calcium Acetate Lactate (CAL)	P, K	mg oxide · L^{-1}
ON 2021	all substrates	1 + 10, M/V	$CaCl_2$	Mg	mg element · L^{-1}
Alt and Peters (1993)	all substrates	1 + 8, M/V	$CaCl_2$/DTPA (CAT)	all nutrients	mg oxide · L^{-1} or mg element · L^{-1}
Sonneveld and van Elderen (1994)	peaty substrates	saturation extract, 1 + 1.5 (V/V), 1 + 2 (V/V)	water	main nutrients, Na, Cl, SO_4	mmol · L^{-1} extract

Table 3. Thresholds according to ÖNORM S 2021 (referred to in the Austrian fertilizer law).

Parameter	Substrate group		
	I	II	III
pH	5–6.5	5–6.5	4–5
salt content (g/L)	< 1.5	< 3	< 1
"available" nutrients			
N (mg/L)	50–300	200–500	50–150
P_2O_5 (mg/L)	80–300	200–500	40–150
K_2O (mg/L)	80–400	300–600 (1000)	50–150

Table 4. Thresholds according

Parameter	S
pH	5
salt content (g/L)	(
"available" nutrients	
N (mg/L)	7
P_2O_5 (mg/L)	5
K_2O (mg/L)	1(

Table 5. Guide values (mmo various authors).

	Po
	1 + 1.5 extra
EC (mS/cm)	0.4–0.9
NO_3	1.5–6.0
P	0.3–0.5
K	1.0–2.5
Ca	0.8–1.4
Mg	0.3–0.6
Na	1.7–3.5
Cl	1.7–3.5
SO_4	0.4–1.4

the determination of plant available

...nt	Elements	Dimension
	main nutrients	mg element · L^{-1}
...PA	main nutrients, trace elements	mg element · L^{-1}
...etate ...AL)	P, K	mg oxide · L^{-1}
	Mg	mg element · L^{-1}
...PA	all nutrients	mg oxide · L^{-1} or mg element · L^{-1}
	main nutrients, Na, Cl, SO_4	mmol · L^{-1} extract

...eferred to in the Austrian fertilizer

III
4–5
< 1
50–150
40–150
50–150

Table 4. Thresholds according to VDLUFA (1997).

Parameter	Nutrient demand		
	Small	Medium	High
pH	5.5–6.5	5.5–6.5	5.5–6.5
salt content (g/L)	0.5–1	1–2	2–3
"available" nutrients			
N (mg/L)	70–140	140–280	280–420
P_2O_5 (mg/L)	50–100	100–200	200–300
K_2O (mg/L)	100–200	200–400	400–600

Table 5. Guide values (mmol · L^{-1} extract) of water extraction methods (according to various authors).

	Pot plants		Vegetables, cut flowers	
	1 + 1.5 extract	saturation extract	1 + 1.5 extract	saturation extract
EC (mS/cm)	0.4–0.9	1.1–2.3	0.8–1.5	2.1–3.8
NO_3	1.5–6.0	4.8–17.3	4.0–6.0	11.8–17.3
P	0.3–0.5	0.9–1.4	0.3–1.0	0.9–2.6
K	1.0–2.5	2.4–6.2	1.9–3.5	4.6–8.7
Ca	0.8–1.4	2.8–4.4	1.7–3.0	5.3–8.8
Mg	0.3–0.6	1.3–2.1	0.7–1.5	2.4–4.4
Na	1.7–3.5	4.3–8.8	2.0–3.5	5.0–8.8
Cl	1.7–3.5	4.6–9.6	2.0–3.5	5.4–9.6
SO_4	0.4–1.4	1.5–3.8	1.1–2.0	3.1–5.3

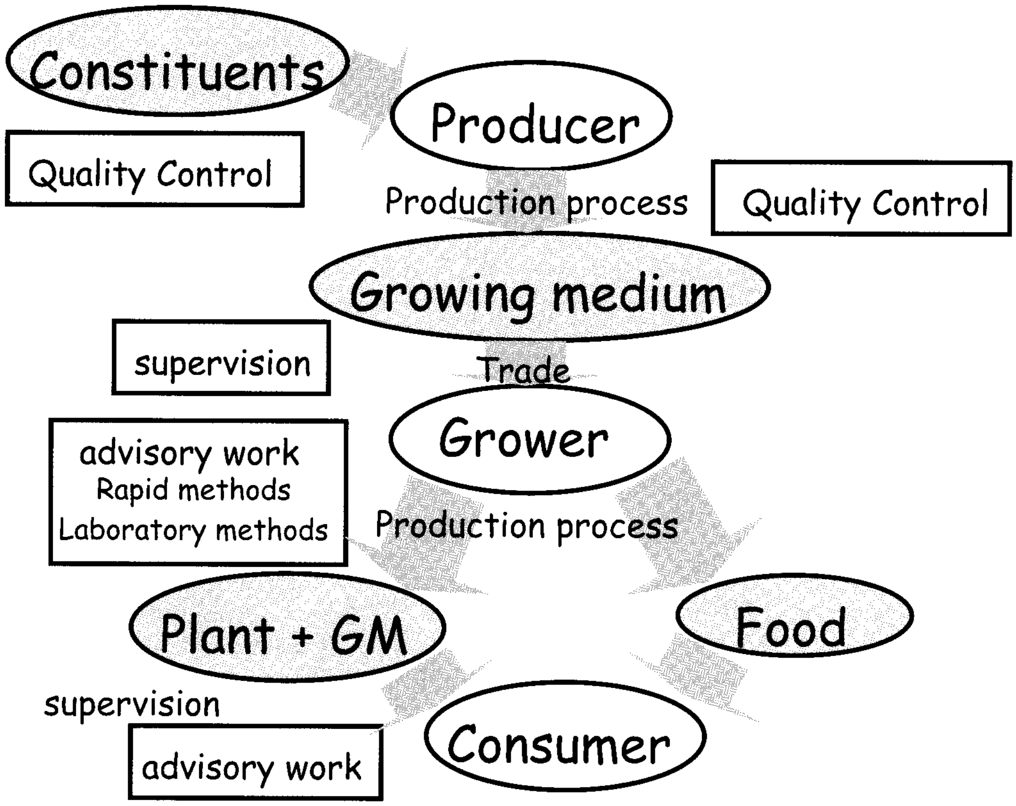

Fig. 1. Target groups and functions of substrate analysis in modern horticulture.

Development of Mo
Substrates

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Keywords: lime require
$CaCl_2$, 1 M KCl, SMP

Abstract

**Several compone
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process of neutralizatio
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ment which will permit
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ingredients on $pH_{w(e)}$ a
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models were developed
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were selected to initiate
were tested such as 0.01
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relationship between ins
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$pH_{w(e)}$ values were 0.90
and 0.87 for the model o
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INTRODUCTION

Media solution pH
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of pH for most crops gro
al., 2005a). In this range,
becoming too soluble as
take several days before
moistened (Bailey et al.
various factors such as r

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