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ANALYSIS OF GROWING MEDIA BY MEANS OF A 1 : 1½ VOLUME EXTRACT

KEY WORDS: growing media, soil solution, aqueous extracts, salt and nutrient status.

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ABSTRACT

Analysis of the salt and nutrient status of potting composts and growing substrates with the aid of the 1 : 25 weight extract - previously used in the Netherlands - has several disadvantages. The interpretation of analytical data based on the organic matter content is not very accurate because this content does not provide a true estimation of the moisture capacity. In addition the conductivity of growing media rich in gypsum gives an unfavourable impression of the salt status.

Very good results were obtained in an investigation at the research station at Naaldwijk with a 1 : 1½ volume extract. For the preparation of this extract potting composts and growing substrates were standardised as regards moisture content, after which one part by volume was measured and mixed with 1½ parts of water. The conductivity of the extract and the contents of chloride, nitrogen, nitrate, ammonium, phosphate, potassium and magnesium were determined. The analytical results were closely correlated with those of the soil solution. The correlation coefficients were between 0.957 and 0.986. The data obtained for the 1 : 25 weight extract were not as closely correlated with those of the soil solution; the correlation coefficients varied between 0.775 and 0.980.

The weight ratio water : soil of the 1 : 1½ volume suspension was closely correlated with the moisture content at pF 1.5. In the case of growing media with low moisture capacity the ratio was about 3 : 1 and with high moisture capacity about 30 : 1.

INTRODUCTION

The determination of the salt and nutrient status of potting composts and growing substrates (together termed growing media) is carried out in the Netherlands with the aid of an extract prepared from 1 part by weight of air dry soil and 25 parts of water (1 : 25 weight extract). To give an idea of the salt status the conductivity and the chloride content are determined. The contents of nitrogen, phosphate, potash and magnesium are determined as components of the nutrient status. As a result of the fixed soil:water ratio the analytical data - with the exception of phosphate - should be interpreted in relation to the moisture capacity of the growing media. This is done by deducing the moisture capacity from the organic matter content.

The interpretation of the analytical data in relation to the organic matter content is not very accurate in the case of many of the potting composts and growing substrates in use to-day as the organic matter content does not give a true estimation of the moisture capacity. The reason for this is the increasing variability of materials used for the preparation of growing media in recent years. In the Netherlands types of peat are being used with widely varying moisture capacities, such as young peat moss, white peat and black peat. Although the organic matter content is the same for the different types of peat, young peat moss will hold two or three times as much moisture as black peat at the same matric suction. Manufactured materials such as perlite, vermiculite and styromull are also being used in the preparation of growing media. Such materials do not increase the organic matter content but they do increase the moisture capacity.

Another disadvantage of the 1 : 25 weight extract is that for growing media with a low water holding capacity the soil: water ratio of the 1 : 25 suspension is too high compared with the soil : water ratio under practical growing conditions. This has the result that if these growing media contain a lot of gypsum the conductivity reading gives an erroneous impression of the salt status. This is due to the fact that although the solubility of gypsum is low, relatively large quantities become dissolved at great dilutions.

The disadvantages of the 1 : 25 weight extract led to an investigation into an extraction method based on volume ratios. The 1 : 2 volume extract described by Sonneveld and van den Ende[1] which is successfully used for glasshouse soils, cannot be used for potting composts and growing substrates. Many of these media have a bad wettability and float on water. Preliminary investigations showed that a given 1 : 1½ volume extract might offer good prospects. The usefulness of this 1 : 1½ volume extract and of the 1 : 25 weight extract was tested by comparing their chemical composition with that of the soil solution.

METHODS

Fifty potting composts and growing substrates with widely varying chemical and physical properties were included in the investigation. The wide variation in physical properties can be illustrated by the fact that amongst the materials were Finnish peat moss, pine needles and well-decomposed low-moor peat of Dutch origin. However most of the growing media consisted of mixtures of these and other types of peat normally used in west Europe. Often some sand or clay was added to the mixtures. A few of the growing media contained 25% of manufactured materials such as perlite or styromull.

Organic matter content was established by the method of loss on ignition and expressed as a percentage of the oven-dried soil. Moisture contents were determined by drying at 105°C and expressed in grammes per 100g of dry soil (M-figure). Part of each sample was adjusted to pF 1.5 with the aid of the sand-box method of Van der Harst and Stakman[2]. The rings used in this method were filled at a pressure of 0.5 kg per cm^2 with growing medium which was first saturated with water[3].

The soil solution and the 1 : 1½ volume extract were obtained from growing medium adjusted to pF 1.5. This adjustment was based on the data got from the sand-box. The soil solution was extracted with the aid of an hydraulic press with which 25% of the moisture was pressed out. This extract is hereafter referred to as "press extract". For the preparation of the 1 : 1½ volume extract 100 ml of moist potting compost or growing substrate was measured in a ring at a pressure of 0,1 kg per cm^2 and then shaken with 150 ml of water during 15 minutes. The ring had a diameter of 5 cm and a height of 5,1 cm.

For the preparation of the 1 : 25 weight extract part of each sample was dried at 45°C. The 1 : 25 suspension was shaken during 15 minutes. The analytical results were corrected for the moisture present in the dried soil. All extracts were prepared in duplicate.

The conductivity of the extracts (mmho/cm at 25°C), the phosphate content (mg P per litre) and the contents of chloride, nitrogen, ammonium, nitrate, potassium and magnesium (me per litre) were determined. For the chemical determinations the following methods were used:

chloride - titration with mercuri nitrate,
nitrogen - distillation according to Cotte and Kahane[4],
nitrate - colorimetric method of Sijderius[5],
ammonium - distillation with MgO,
phosphate - colorimetric method of Murphy and Riley[6],
potassium - flame-photometrically,
magnesium - colorimetric method of Van Schouwenburg[7].

RESULTS

Salt and Nutrient Status

Table 1 shows the average and extreme values of the analytical results of the various extracts. The averages show that the concentration of the extracts declines in the following order: press extract, 1 : 1½ volume extract and 1 : 25 weight extract. This is the order of increasing water : soil ratio during extraction. It may be expected that for ions like chloride and nitrate which are almost completely dissolved in the soil solution the concentration is inversely proportional to the water : soil ratio. This will not be the case with other ions. If the soil solution is diluted, adsorbed cations may be dissolved by exchange which could result in the finding of relatively high

TABLE 1

Average and Extreme Values of the Analytical Data of the Different Extracts.

Determination	Press extract		1 : 1½ volume extract		1 : 25 weight extract	
	Mean	Range	Mean	Range	Mean	Range
Conductivity	4.8	0.3- 10.7	1.4	0.1- 3.8	0.8	0.1- 3.5
Chloride	4.8	0.5- 20.0	1.2	0.2- 4.2	0.6	0.1- 2.8
Nitrogen	23.6	0.6- 70.6	6.1	0.1- 21.8	3.1	0.0- 11.8
Nitrate	18.2	0.0- 56.6	4.5	0.1- 12.1	2.1	0.2- 11.2
Ammonium	5.5	0.0- 42.5	1.7	0.0- 10.4	1.1	0.0- 7.9
Phosphate	142.5	0.1-587.7	42.5	0.1-148.4	31.1	0.0-185.1
Potassium	7.5	0.1- 26.6	2.4	0.0- 9.4	1.6	0.0- 8.7
Magnesium	16.6	0.4- 47.0	4.2	0.2- 14.8	2.1	0.0- 11.8

concentrations. The latter is also the case with less soluble compounds. If present in large quantities, they may be dissolved if the soil solution is diluted. This occurs, for instance, with various phosphate compounds and with calcium sulphate. At great dilutions calcium sulphate may interfere with the true estimation of the salt concentration of the soil solution.

The analytical results have been compared by means of regression analysis. Table 2 shows the equations for the relationships between the analytical results of the press extract and the 1 : 1½ volume extract. These relationships were almost linear. It is apparent from the regression coefficients that the concentration of the various ions in

TABLE 2

Regression Equations for the Relationships between Analytical Data of Press Extract (x) and 1 : 1½ Volume Extract (y).

Determination	Regression equation	r
Conductivity	$y = 0.311\ x - 0.05$	0.969
Chloride	$y = 0.218\ x + 0.17$	0.975
Nitrogen	$y = 0.256\ x + 0.02$	0.967
Nitrate	$y = 0.239\ x + 0.18$	0.961
Ammonium	$y = 0.280\ x + 0.17$	0.986
Phosphate	$y = 0.270\ x + 4.04$	0.972
Potassium	$y = 0.302\ x + 0.17$	0.982
Magnesium	$y = 0.298\ x - 0.75$	0.957

the 1 : 1½ volume extract is between one third and one fifth of that in the press extract. The regression coefficient is lowest for chloride and nitrate. The greater regression coefficient of the other equations is a result of the exchange of adsorbed ions or the solution of less soluble salts.

The regression coefficient for phosphate is lower than was expected on the basis of other investigations. The solution of less soluble phosphate compounds usually plays such a great role that the concentration remains more or less constant if the dilution of the soil solution is not too great[1,8,9], in which case the regression coefficient is about 1. In our study the regression coefficient of phosphate is of the same order of magnitude as the other regression coefficients.

This probably results from the fact that easily soluble phosphate was used in most of the growing media which remained in solution in these very organic materials. Soukup[10] has also found that phosphate can remain in solution in strongly organic materials.

However, the phosphate concentration in the press extract was more or less the same as that in the 1 : 1½ volume extract in unfertilised peats and clayey potting composts. These materials had the lowest phosphate contents. That's why separate equations were calculated for the observations of the press extract with a phosphate content of less than 5 mg P per litre, and for the other observations. The following equations were obtained:

Phosphate content	Number	Regression equation	r
< 5 mg/l	11	$y = 0.857\,x + 0.01$	0.970
> 5 mg/l	39	$y = 0.263\,x + 6.31$	0.962

In Figure 1 the relationship between the phosphate content of the press extract and that of the 1 : 1½ volume extract is shown.

The regression equations for the relationship between the analytical results of the press extract and the 1 : 25 weight extract are shown in Table 3. With the exception of phosphate the results of the 1 : 25 weight extract have been corrected on the moisture capacity of the growing media. In practical horticultural advisory work the moisture capacity is estimated by means of the organic matter content.

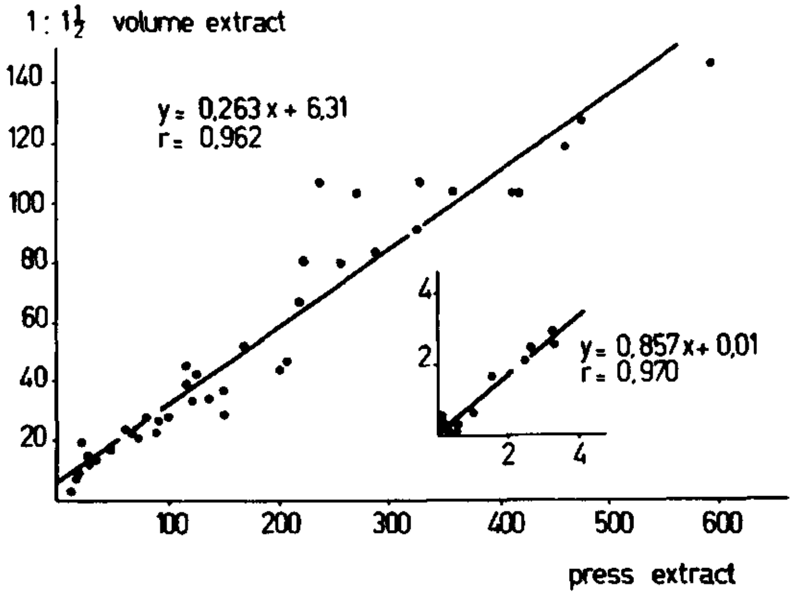

FIG. 1

The relationship between the phosphate content of press extract and 1 : 1½ volume extract.

For our investigation the estimation is best based on the equation found for the relationship between the organic matter content and the M figure at pF 1.5 (see section "Organic matter and soil moisture"). The correction factor used was :

$$p = \frac{100}{5.763\ q + 1.66}$$

in which p is the correction factor and q represents the percentage organic matter.

For all determinations the correlation between the analytical results of the press extract and the 1 : 25 weight

TABLE 3

Regression Equations for the Relationships between Analytical Data of Press Extract (x) and 1 : 25 Weight Extract (y). The Analytical Data of the 1 : 25 Weight Extract have been corrected on the Organic Matter Content.

Determination	Regression equation	r
Conductivity	$y = 0.0534\ x - 0.05$	0.775
Chloride	$y = 0.0306\ x + 0.04$	0.866
Nitrogen	$y = 0.0371\ x - 0.03$	0.936
Nitrate	$y = 0.0339\ x - 0.02$	0.855
Ammonium	$y = 0.0367\ x + 0.06$	0.924
Phosphate	$y = 0.2534\ x - 5.01$	0.952
Potassium	$y = 0.0569\ x - 0.02$	0.980
Magnesium	$y = 0.0416\ x - 0.14$	0.896

extract is lower than the correlation between the analytical results of the press extract and the 1 : 1½ volume extract. The difference is particularly great for the conductivity. This was probably caused by a high calcium sulphate content in a number of growing media. In Figure 2 the relationships are shown between the conductivities of the various extracts. The lower correlation coefficients for the other analytical data can be partly explained by the correction used for the analytical data of the 1 : 25 weight extract. The estimation of the moisture capacity by means of the organic matter content is not accurate. Apparently this had particularly an effect in the case of chloride and nitrate.

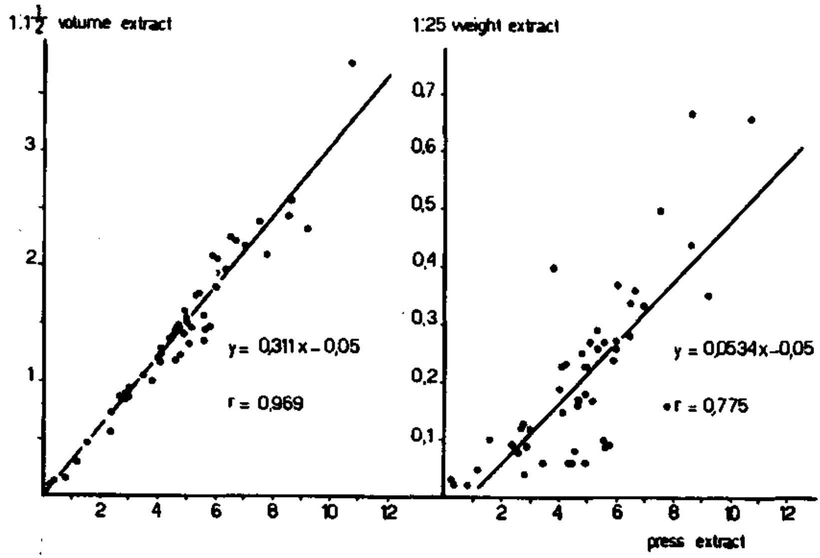

FIG. 2

The relationship between the electrical conductivity of press extract, on the one hand, and that of 1 : 1½ volume extract (left) and of 1 : 25 weight extract corrected on the organic matter content (right), on the other hand.

The high correlation for potash is noteworthy. This has probably been caused by a combination of the cation exchange capacity and the moisture absorbing capacity of the organic matter. In different types of peat with the same organic matter content one generally finds a lower M figure and a higher cation exchange capacity, the greater the degree of decomposition of the peat[11,12,13]. As a result of the dilution and valency effect[14,15] a relatively higher potassium content will therefore be found in peat with a high degree of decomposition than in peat with a low degree of decomposition when the soil solution is diluted. This is apparently compensated in the correction for the organic matter content because of over-correction in the case of highly decomposed peat and under-correction in the case of less decomposed peat.

A high correlation coefficient could also be expected for ammonium as it usually behaves in a similar way to potash as regards adsorption. However, the correlation is affected by the release of ammonium from some growing media containing ureaform during the drying of the soil for the preparation of the 1 : 25 weight extract. After the removal of the observations of these growing media a correlation coefficient of 0.984 was obtained.

The correlation coefficient for magnesium is lower. Most likely this has been caused by the solution of gypsum. It is probable that when the soil solution is diluted the exchange of magnesium is affected by the solution of gypsum.

The foregoing has shown that an important part of the phosphate in the growing media was dissolved in the soil solution. This is why a calculation was also made for the relationship between the phosphate content of the press extract and the phosphate content of the 1 : 25 weight extract which was corrected on the organic matter content. The correlation coefficient of this relationship is 0.950. This value is similar to that of the correlation coefficient for phosphate mentioned in Table 3.

Organic Matter and Soil Moisture

The relationship between organic matter content and M figure at pF 1.5 has been calculated for the growing media studied. The regression equation for this relationship is $y = 5.763\ x + 1.66 \qquad r = 0.809$
in which x is the percentage organic matter and y represents the M figure at pF 1.5.

The correlation coefficient is low. It is therefore not possible to obtain an accurate estimation of the moisture capacity with the aid of the organic matter content.

For the preparation of the press extract and the 1 : 1½ volume extract, the moisture content of the growing media has been standardised to exactly the same level as the moisture content at pF 1.5 (see section "Methods"). Besides, part of each sample was corrected to pF 1.5 by means of visual estimation in order to ascertain whether it is possible to standardise the moisture content in this way. The following relationship was found between the results of both methods:

$$y = 0.998\ x + 10.83 \qquad r = 0.983$$

in which x is the M figure after the moisture content of the growing media had been corrected exactly to the level of that at pF 1.5 and y represents the M figure after this had been done by visual estimation.

The regression coefficient differs little from 1 and the intercept 10,83 is small in relation to the high M figures. It is therefore possible to use visual estimation for the moisture content of growing media in the preparation of the 1 : 1 ½ volume extract.

It is recommended that the visual estimation is checked from time to time. This is possible by taking random samples and determining the M figure after the visual estimation and comparing it with the M figure at pF 1.5 obtained with the aid of the sandbox method of Van der Harst and Stakman. Apart from a probability of k% the difference between the two M figures may not be greater than :

$$|d| \leq \mathcal{N}_k \cdot \sigma_d$$

in which |d| is the absolute value of the difference between both M figures, $\mathcal{N}_k$ is a standard normal distributed quantity with a significance level of k% and σ_d is the standard deviation of d.

If the value of σ_d is not known this may be estimated from the data of the samples already analysed. The estimation of σ_d in this investigation was 7.6 %. If σ_d is estimated on the basis of n observations the limits for the difference become:

$$|d| \leq t_k \cdot s_d$$

in which t_k represents a student distributed quantity with n-2 degrees of freedom and a significance level of k% and s_d represents the estimation of σ_d.

During the preparation of the 1 : 1½ volume extract the weight ratio water : soil of the 1 : 1½ volume suspension was determined. As Figure 3 shows there is a linear relationship with the M figure at pF 1.5. The following equation was found

$$y = 0.0376\ x + 0.79 \qquad r = 0.968$$

in which x represents the M figure at pF 1.5 and y represents the water : soil ratio of the 1 : 1½ volume suspension.

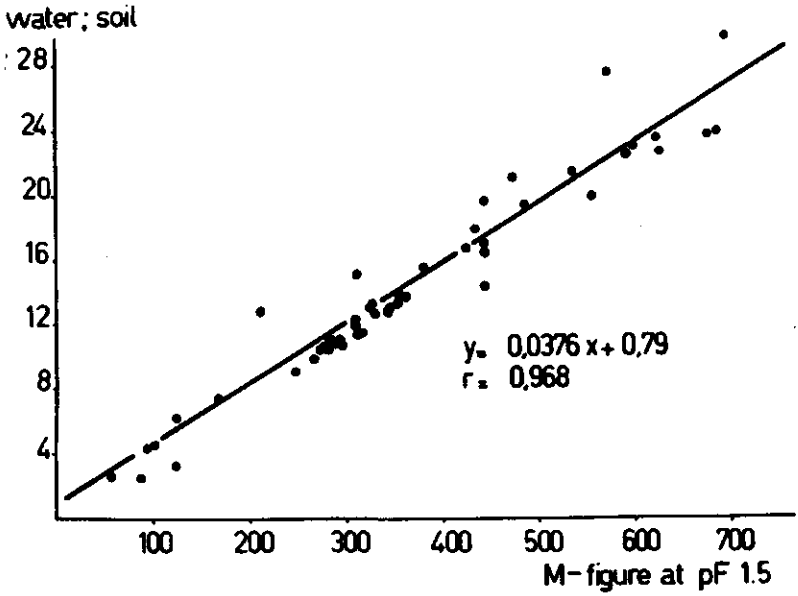

FIG. 3

The relationship between the M figure at pF 1.5 and the weight ratio water : soil of the 1 : 1½ volume suspension.

Interpretation

When using the 1 : 1½ volume extract it is necessary to have available standard values for the interpretation of the analytical data. These values can be derived from the existing standard values for the 1 : 25 weight extract with the aid of the regression equations for the relationship between the analytical results of this extract and those of the 1 : 1½ volume extract. The equations are shown in Table 4.

Boertje[16] has described the following standard values for the analytical data of potting composts obtained with the aid of the 1 : 25 weight extract :

total salts	(0.035 x % organic matter) %
chloride	(5 x % organic matter) mg NaCl/100 g
nitrogen	(1½ x % organic matter) mg N/100 g
phosphate	60 mg P_2O_5/100 g
potash	(1½ x % organic matter) mg K_2O/100 g
magnesium	(¾ x % organic matter) mg MgO /100 g

These standard values are all expressed on the basis of dry soil. They were adjusted to the relationship between the organic matter content and the M figure at pF 1.5 found in this investigation. The adjusted values were converted to the units used by us. The values thus obtained are given in the second column of Table 5. The relevant values for the 1 : 1½ volume extract are given in the last column of this Table.

TABLE 4

Regression Equations for the Relationships between Analytical Data of 1 : 25 Weight Extract (x) and 1 : 1½ Volume Extract (y). The Analytical Data of the 1 : 25 Weight Extract have been corrected on the Organic Matter Content.

Determination	Regression equation	r
Conductivity	$y = 3,761\ x + 0.67$	0.807
Chloride	$y = 5.480\ x + 0.17$	0.863
Nitrogen	$y = 6.249\ x + 0.78$	0.934
Phosphate	$y = 0.976\ x + 12.17$	0.934
Potassium	$y = 5.119\ x + 0.34$	0.969
Magnesium	$y = 6.110\ x + 0.82$	0.909

TABLE 5

Standard Values for Analytical Data of 1 : 25 Weight Extract and 1 : 1½ Volume Extract.
The Standard Values for the 1 : 25 Weight Extract have been corrected on the Organic Matter Content.

Determination		1 : 25 weight extract	1 : 1½ volume extract
Conductivity	mmho/cm (25 °C)	0.31	1.84
Chloride	me/l	0.59	3.40
Nitrogen	me/l	0.74	5.40
Phosphate	mg P/l	10.5	22.4
Potassium	me/l	0.22	1.47
Magnesium	me/l	0.26	2.41

DISCUSSION

The chemical composition of the press extract undoubtedly gives the best impression of the actual nutrient status[8]. However, a disadvantage of the press extract is that its preparation is laborious, especially for media with a low organic matter content. Another disadvantage is connected with the fact that the moisture content of the media has to be adjusted to a standardised level which is representative for growing conditions. For routine soil testing purposes this adjustment has to be carried out quickly, i.e. by visual estimation. In this estimation, however, deviations may occur. These deviations have a relatively great effect on the analytical results of the press extract because the water : soil ratio is rather low.

The 1 : 1½ volume extract does not have the above-mentioned disadvantages. With this extract a good estimation of the chemical composition of the press extract was obtained for widely varying media, even for media containing manufactured materials.

In the Netherlands the 1 : 1½ volume extract has been used in routine soil testing already a good year. Experience showed that the extraction can be performed quickly and accurately. Wetting of a growing medium and preparation of duplicate water - soil suspensions took together only a few minutes.

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