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EXTRACTION METHODS FOR THE DETERMINATION OF MAJOR ELEMENTS IN GREENHOUSE SOILS AND POTTING - AND CULTURE MEDIA

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Introduction

For many crops grown in greenhouses, the levels of nutrients in the soil should be rather high. The nutrients, however, must not be overdosed as otherwise the growth of the crops is reduced by a too high salt concentration of the soil solution. For these reasons, it is important to analyse greenhouse soils regular. In some areas, regular soil testing is also necessary because of saline irrigation water.
Practically all laboratories engaged in routine testing of greenhouse soils employ one or another water-extraction technique. The equeous extracts are primarily used to determine the salinity level of the soils by means of measuring the electrical conductivity. Some laboratories use aqueous extracts also for the determination of nutrient levels. Most laboratories, however, extract the nutrients with other extractants, like diluted acids and buffer solutions. As compared with water, such extractants generally extract larger amounts of nutrients.
From research work at Naaldwijk, the conclusion can be drawn that aqueous extracts are most suited for the determination of the nutrient levels of greenhouse soils. I want to give some resukts of this work.
The analytical results of these extracts were closely correlated. For potting - and culture media, there are problems in the interpretation of the analytical results of aqueous

weight extracts as the organic-matter content of these media does not give an accurate estimate of their water-holding capacity. There are indications that a water-extraction method in which volume samples of the media are measured in a standardized manner will offer good possibilities.

Mass flow of nutrients

One of the investigations was carried out on 75 soil samples which were taken in as many greenhouse used for tomato growing. The following soil types were equally represented: loamy sand, sandy loam, loam, peaty clay, and clayey peat. The tomato crops were in the picking period during the sampling.
The moisture content of the field-moist soil samples were approximately equal to the moisture contents at pF 1.8.
From the field-moist samples, press extracts were obtained by means of an hydraulic press. It was show that the electrical conductivities of the press extracts equalled those of the soil solutions [2]. The same was shown for the potassium-, magnesium-, calcium-, sodium-, nitrate-, sulphate-, and chloride contents but not for the phosphate contents.
It is likely that the phosphate contents of the press extracts were in most cases considerably lower than those of the soil solutions.
The average values of the analytical data of the press extracts are listed in Table 1. From the data of this table

Table 1. Average values of the results of analysis made on the press extracts.

Calcium	49.9 me/l	Phosphate	6.4 mg P_2O_5/l
Sulphate	45.7 "		
Nitrate	20.7 "	Electrical conductivity	6.7 mmho/cm (25°C)
Magnesium	18.7 "		
Chloride	16.2 "	Osmotic pressure	2.2 atm (0°C)
Sodium	13.6 "		
Potassium	6.4 "		
Ammonium	1.0 "		
Bicarbonate	0.4 "		

and some data which were given by Spithost [9] and van der Post et al. [5], conclusions can be drawn with respect to the supply of nutrients to the root surface.
Spithost determined the amounts of major elements which were taken up by a high-yielding tomato crop. His data are given in the column "uptake" of Table 2. Van der Post et al. calculated that the tomato crop in question has taken up about 300 mm of water.

Table 2. Amounts of nutrients taken up by a high-yielding tomato crop in comparison with calculated values for the amounts supplied to the root surface by mass flow of the soil solution.

	Uptake (kg/are)	Supply (kg/are)	Supply/Uptake
Na_2O	0.5	12.6	25.2
MgO	1.5	11.3	7.5
CaO	6.8	41.9	6.2
K_2O	7.5	9.0	1.2
SO_3	5.0	54.8	11.0
Cl	3.0	17.3	5.8
N	4.0	9.1	2.3
P_2O_5	1.4	0.19	0.14

This amount of water has been transported to the roots by mass flow of the soil solution. If the data of Table 1 are considered to be representive for the chemical composition of the soil solution, then the mass flow mentioned should have supplied an amount of nutrients to the roots which is given in the column "supply"" of Table 2.
This table shows that in tomato cultures in the Netherlands the amounts of sodium, magnesium, calcium, sulphate, and chloride transported to the roots by mass flow are on the average much larger than the amounts taken up by the roots. The amounts of nitrogen and potassium supplied by mass flow are relatively much smaller. However, they are large enough to meet the nitrogen- and potassium requirements of the crop, at least if the levels of nitrogen and potassium

in the soil are not lower than the levels which are usual for tomato growing.

The amount of phosphate that reaches the roots by mass flow is on the average larger than the amount given in Table 2. The latter amount is too small as the phosphate contents of the press extracts were lower than those of the soil solutions. Probably, the phosphate content of a saturation extract does agree with that of the soil solution. From saturation extracts, the amount of phosphate supplied by mass flow was assessed at 0.45 kg P_2O_5 per are. This amount is only about one third of the amount of phosphate taken up by the crop. So, a great part of the phosphate uptake must reach the roots by interception or diffusion.

Experiences gained in routine testing of greenhouse soils and data obtained in several investigations indicate that with most crops the ratios "supply/uptake" are not much smaller than those found for the tomato. Therefore, the conclusion can be drawn that in the soil testing in behalf of greenhouse cultures it is not necessary to extract larger amounts of nutrients from the soil than the amounts which are present in the soil solution, phosphate leaved out of consideration. So, for instance, it is not necessary to determine exchangeable cations. Consequently, extraction methods developed for the determination of exchangeable cations are not preferable, the more so as the interpretation of the amounts of exchangeable cations is rather difficult. The interpretation of the amounts of nutrients in the soil solution is comparatively very simple. For the analysis of greenhouse soils, therefore, those extraction methods are preferable with which a good estimation of the chemical composition of the soil solution can be obtained. As far as I know, water-extraction methods only are suited to this purpose.

<u>Saturation-and 1:5 extracts</u>

The Research Station at Naaldwijk has used a water-extraction technique for many years. The soil : water ratio employed is 1:5 by weight. In the 1:5 extracts, the electrical conductivity and the chloride-, nitrogen-, phosphate-, potassium-, and magnesium contents are determined. The analytical data, with the exception of those for phosphate, are adjusted to soil-moisture level, for which they are multiplied by $\frac{500}{F}$ F being the moisture content of the soil at field capacity. This moisture content is estimated by means of the organic-matter content of the soil. The way upon which this is done has been described previously [2]. For soils with an organic-matter content between 3 and 40 per cent, it proved very accurate.

In the above-mentioned investigation on 75 greenhouse soils, analytical data of 1:5 extracts, after adjustment so soil-moisture level, were compared with analytical data of press extracts, for which coefficients of correlation were calculated. The correlation coefficients found are given in the second column of Table 3. The correlation coefficients for nitrate, chloride, and potassium are high. Those for magnesium and electrical conductivity are lower. It is likely that the poorer correlation for electrical conductivity was caused primarily by varying quantities of grypsum dissolved in the 1:5 suspensions due to variations in grypsum contents of the soils examined. For this reason, the coefficient of multiple correlation was calculated for (a) values of the electrical conductivity of press extracts and (b) adjusted values of the electrical conductivity and the sulphate content of 1:5 extracts. As in consequence of dissolution of gypsum, adsorbed magnesium will be exchanged by calcium, such a multiple-correlation coefficient was also calculated for magnesium. The multiple-correlation coefficients found are given in the third column of Table 3.

Saturation extracts were also included in the investigation Coefficients of correlation between analytical data of saturation extracts and those of press extracts are listed in the fourth column of Table 3.

Table 3. Coefficients of correlation between analytical data of press extracts, on the one hand, and those of saturation extracts and of 1:5 extracts adjusted to soil-moisture level, on the other hand.

	Press extracts and 1:5 extracts[x]		Press extracts and saturation extracts
	r	R[xx]	r
Nitrate	0.940		0.931
Chloride	0.965		0.957
Potassium	0.927		0.965
Magnesium	0.820	0.873	0.908
Electrical conductivity	0.752	0.884	0.890

[x] analytical data adjusted to soil-moisture level.
[xx] multiple-correlation coefficients with as extra variable the sulphate content of 1:5 extracts adjusted to soil-moisture level.

From the data of this table and from data mentioned before, the conclusion can be drawn that the electrical conductivity and the nitrate-, chloride-, potassium-, and magnesium contens of the soil solution can be estimated satisfactorily with both the saturation- and the 1:5 extract. Both extracts have advantages and disadvantages. The 1:5 extract has the advantage that its preparation is simple. This advantage is very important for routine soil-testing purposes. Disadvantages of the use of the 1:5 extract are that the soil needs to be dried and that organic matter and sulphate need to be determined. These disadvantages do not occur in the use of the saturation extract. However, the saturation extract has the disadvantage that its preparation is very laborious. For this reason, most laboratories do not use the saturation extract for routine soil-testing purposes.

On the other hand, the saturation extract is often used for research purposes. The reason of this is that the relationship between the chemical composition of the saturation extract and that of the soil solution is rather simple. However, this relationship is more complicated than sometimes described. Some of the regression equations which I found for the relationship mentioned are given in Table 4. The intercepts

Table 4. Regression equations for the relationships between analytical data of press extracts and those of saturation extracts.

	Regression equations
Nitrate	$y = 0.556\,x + 0.6$
Chloride	$y = 0.526\,x - 0.3$
Potassium	$y = 0.705\,x + 0.4$
Magnesium	$y = 0.546\,x + 0.3$
Electrical conductivity	$y = 0.619\,x + 0.2$

x = analytical data of press extracts
y = analytical data of saturation extracts

of these equations are small. Therefore, the regression coefficients only are important. One of the conclusions which can be drawn from the regression coefficients is that the potassium: magnesium ratio in the saturation extract differs considerably from that in the soil solution.

2 + 1 extracts

Sonneveld and van den Ende [8] studied still another water-extraction technique. The extract employed will be termed 2 + 1 extract. It is prepared by filtration of a suspension obtained by adding sufficient soil to two parts of water so that the total volume is increased by one part.
In an investigation on different soil types, like loamy sand, loam and clayey peat, analytical data of 2 + 1 extracts were compared with analytical data of saturation extracts, for which coefficients of correlation were calculated. The correlation coefficients found are listed in Table 5. All of them are high.
From these correlation coefficients and from data mentioned before, the conclusion can be drawn that the 2 + 1 extract

Table 5. Coefficients of correlation between analytical data of saturation extracts and those of 2 + 1 extracts.

	Correlation coefficients (r)
Nitrogen	0.982
Chloride	0.976
Phosphate	0.943
Potassium	0.965
Magnesium	0.960
Electrical conductivity	0.948

offers good possibilities for the estimation of the electrical conductivity and the nitrate-, chloride-, potassium-, and magnesium contents of the soil solution. The 2 : 1 extract lacks the disadvantages of the 1:5 extract. So, the soil needs not be dried and organic matter and sulphate need not be determined. For these reasons, the 2 + 1 extract could be a good substitute for the 1 : 5 extract. For routine soil-testing purposes, however, the preparation of the 2 + 1 extract gives still some difficulties. It is worth trying to overcome these difficulties.

Phosphate

In the foregoing, the phosphate contents of the extracts were not discussed. The reason of this is that the behaviour of phosphate differs considerably from the behaviour of the other major elements.
With increasing water : soil ratio the concentration of phosphate in solution tends to be more or less constant as a result of the large reserves in the soil and their low solubility. Only if the water : soil ratio is raised to a high value can a significant decrease in concentration be expected.
In our investigations, in which the water : soil ratio varied from 0.3 up to 5, such a decrease in phosphate concentration did nearly not occur. For almost each soil examined, the phosphate concentrations in the saturation-,

1 : 5 -, and 2 + 1 extracts were more or less equal. It is likely that these phosphate concentrations more or less equalled the phosphate concentration in the soil solution. In experiments with lettuce, Roorda van Eysinga [6] investigated the suitability which a number of extraction methods has for the determination of the phosphate level of greenhouse soils.

Different extractants, like water, citric acid, and buffer solutions, were included in the investigation and the extractant water was tested in different soil : water ratios including the 1 : 5 ratio. There was a close relationship between the phosphate content of the crop and the phosphate level of the soil. For the various extraction methods, the relationship was almost equally stringent. This is easy to understand as the analytical data found with the various methods were mutually highly correlated.

Evidently, many extraction methods can be used for the determination of the phosphate level of greenhouse soils. For routine testing of the phosphate level, it is a matter of course to use an extraction method which is used also for routine testing of the levels of other major elements.

Volume extracts

Several laboratories use water-extraction methods in which soil and water are measured by volume. The extracts obtained by means of these methods will be termed volume extracts. A few volume extracts employed are the 1 : 2.5 - and 1 : 5 volume extracts (soil : water ratios expressed in v/v). Volume extracts are used especially for the determination of the salinity level of soils. At first, it was thought that the electrical conductivity of volume extracts is a precise standard for the salinity level. However, this is not the case because the various soil types have different water-holding capacities. Therefore, it is necessary to correct the electrical conductivity of volume extracts. Besides on the water-holding capacity, the correction can be based

also on quantities which are closely related to this capacity. Thus Drews [1] and Massey and Winsor [4] found that the correction can be carried out by means of the bulk density. Some laboratories employ volume extracts also for the determination of nutrient levels. Except the phosphate level, these levels need to be corrected just as well.
Undoubtedly, volume extracts offer good passibilities for the estimation of the electrical conductivity and the nitrate-, chloride-, phosphate-, potassium-, and magnesium contents of the soil solution. They have the advantage that the soil needs not be dried. However, a disadvantage is that the water-holding capacity or the bulk density need to be determined. Moreover, it is difficult to measure a volume of peat exactly. For peat soils, it is necessary to standardize the method of volume measurement very precisely as otherwise erratic analytical results may be obtained [3].

Potting -and culture media

Analysis of growth media, like potting soils and culture substrata, gives more difficulties than analysis of greenhouse soils. The cause of this is that the composition of the growth media mentioned differs strongly. Some of media consist of different types of peat. Others contain in addition to peat also sand, clay or artificial materials, like perlite, vermiculite, and polyether flocks.
The growth media used in greenhouse cultures have nutrient levels which are comparable with the nutrient levels of greenhouse soils. So, it is likely that the ratio between supply and uptake of nutrients for crops grown in these media more or less equals that for crops grown in greenhouse soils. For this reason, the Research Station at Naaldwijk uses water-extraction methods for the analysis of potting soils and culture substrata. For purposes of routine analysis, the soil : water ratio employed is 1:25 by weight. This wide ratio is necessary in connection with the graat water-holding capacity of many media.

In the 1 : 25 extracts, the electrical conductivity and the chloride-, nitrogen-, phosphate-, potassium-, and magnesium contents are determined. The analytical data, with the exception of those for phosphate, are adjusted to the moisture content at pF 1.5, for which they are multiplied by $\frac{2500}{5P}$, P being the organic-matter percentage (5 P = estimate of the moisture content at pF 1.5). The adjustment is rather correct for growth media which have an organic-matter percentage below 50 and do not contain artificial materials. For other media, it is not reliable. This was shown by Sonneveld [7] in an investigation on growth media of very different compositions: different types of peat; mixtures of peat and sand; and mixtures of peat, sand, and perlite or vermiculite.

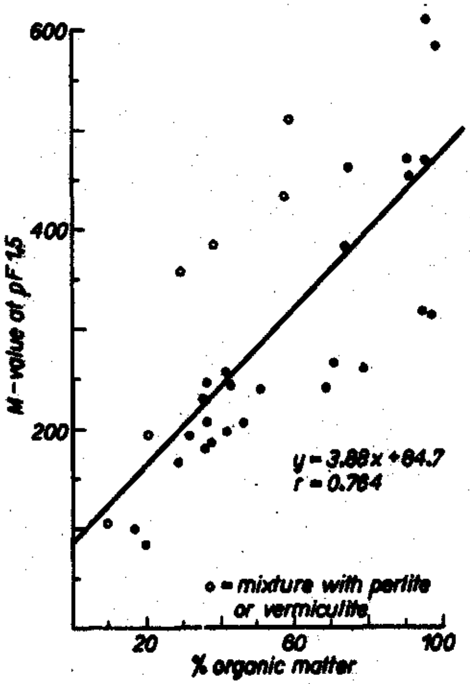

Fig. 1. The relationship between organic-matter content and M-value at pF 1.5 for growth media of various compositions (M-value = moisture content in grammes per 100 g dry matter)

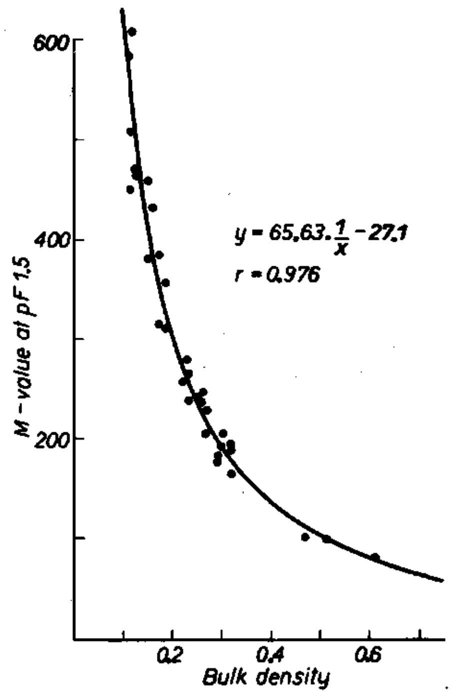

Fig. 2. The relationship between bulk density and M-value at pF 1.5 for the growth media of fig.1 (M-value - moisture content in grammes per 100 g dry matter)

His data in respect of the relationship between the organic--matter content and the moisture content at pF 1.5 are given in Fig.1.

Sonneveld investigated also the relationship between the moisture content at pF 1.5 and the bulk density. His data in respect of this relationship are presented in Fig.2. From this figure, it is apparent that adjustment of analytical results by means of the bulk density is not reliable for growth media which have a bulk density below 0.2.

As far as I know, the only way to get to a correct adjustment of analytical results of 1 : 25 extracts is determination of the moisture content at a suited pF value. For purposes of routine analysis, however, such a determination is too laborious. For these reasons, the Research Station

at Naaldwijk tries to find an useful water-extraction method with which adjustment of analytical results is not needed. The saturation- and 2 + 1 extracts do not offer possibilities for the routine analysis of growth media. For the 2 + 1 extract, the reason of that its preparation is impossible for growth media which contain peat with a low bulk density. As to the saturation extract, its preparation is not only very laborious but in addition many growth media do not have a clear condition of water saturation.
At present, the possibilities of a volume extract are studied. The results obtained till now are very promising.

S u m m a r y

In greenhouse cultures, it is of importance to know the chemical composition of the soil solution. In an investigation at the Research Station at Naaldwijk, the chemical composition of the soil solution was compared with the chemical composition of both the saturation extract and the 1 : 5 weight extract. Both extracts gave satisfactory estimates of the electrical conductivity and the chloride-, nitrate-, potassium-, and magnesium contents of the soil solution.
A correct comparison could not be established for phosphate. For this element, the method which was applied to obtain the soil solution did not meet the requirements. Therefore, the following statements do not apply to phosphate.
There was a simple relationship between the chemical compositions of the soil solution and the saturation extract. However, the preparation of this extract is too laborious for routine soiltesting purposes. In order to obtain satisfactory estimates by means of the 1 : 5 weight extract, it was necessary to determine the sulphate content of this extract. The moisture content of the soil at field capacity had to be know as well. This moisture content was calculated from the organic-matter content of the soil.
In another investigation, a comparison was made between the saturation extract and an extract which was termed 2 + 1 extract.

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Я. ван ден Енде

Анализ тепличных и горшечных почв и питательных сред

Р е з ю м е

В возделывании овощей закрытого грунта наиболее важным является знакомство химического состава почвевного раствора. В опитной станции Наальдвийк химический состав почвенного

раствора сравнивали с раствором насыщенным и таким, в котором экстрагировали почву в весовом соотношении 1:5. Определения хлоридов, нитратов, калия, магния и электропроводимости в обоих растворах по сравнению с почвенным раствором дало хорошие результаты, однако не удалось получить положительной корреляции для фосфатов. Между почвенным и насыщенным раствором установлена прямая корреляция, однако изготовление такого раствора в случае массовых анализов является сравнительно трудоёмким. Для получения при вильных определений при экстрагировании почвы в соотношении 1:5 необходимо анализировать экстракт на содержание сульфатов и определять полевую влагоёмкость почвы.

В другого рода исследованиях сравновали насыщенный экстракт с экстрактом полученным специальным способом при объемном соотношении между почвой и экстракционным раствором 1:2. Результаты анализа этих двух видов экстрактов были очень сходными.

Более значительные трудности и связанные с ними проблемы возникали в исследованиях касающихя анализа питательных сред.