THE SOIL SOLUTION OBTAINED BY THE OIL PRESSURE METHOD¹

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INTRODUCTION

The study of the soil, the medium in which the plant grows, has been approached from many angles. The sum total of these efforts has thrown some light on what the soil is, what it lacks for good plant growth, and thus what it requires to make up this deficiency. The one phase which has been studied to the least extent is that of the actual medium from which the plant takes part of its nourishment, that is, the soil solution.

Soil solution is a homogeneous mixture of the water (the solvent) and the soluble ingredients of the soil (the solutes), consisting of gases, liquids and solids. These solutes may influence the solubility of other substances.

The maximum amount of the soil solution that the soil can hold depends upon the physical character of the soil—the finer a soil and also the more organic matter, humus, present, the more the soil will hold on account of the larger surface for adsorption. The capillary water present is more firmly held by the force of surface tension.

In order that the plant may take up through its roots the mineral constituents in the soil, the latter must be in solution. As the plant requires moisture for its existence, the soil water performs a double function—it furnishes the moisture to the plant, and holds in solution the mineral and the organic compounds. The solutes that are present assist by dissolving some of the constituents of the soil otherwise insoluble. The character or type of soil, *e. g.*, the size and composition of soil particles, will determine to a large extent what the soil solution contains. Treatment of the soil in regard to cultivation, drainage, fertilizer and cropping has a marked influence upon the amount and kind of solutes present.

Gedroitz (7) says that the greatest part of the soil compounds has a very low degree of solubility. The solubility of the soil compounds is not a constant quantity, but depends upon temperature and pressure and, as stated previously, upon the solutes present. Practically every soil contains all the common rock-forming minerals (4; 5, p. 9), all of which

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are more or less soluble in water, depending somewhat, as to the amount dissolved, upon such factors as temperature, pressure, etc. Not only these mineral compounds, but also the organic compounds formed from decaying plant and animal tissues are found in solution.

A very important factor was brought out by Gola (8) in regard to the colloidal character of the soil particles and its effect upon the soil solution. On account of the complexity and colloidal nature of some of the soil particles, it is claimed that the colloids adsorb some of the salts of the solution. The amount adsorbed depends upon the moisture content. Presence of a large amount of water sets up a dialysis which causes the hydrogels to give up the salts adsorbed. Reverse action takes place at first with a diminution of the moisture content, but finally the imbibition water of the hydrogels evaporates and the gel is precipitated as an amorphous mass, the bonds uniting the salts with the colloidal molecule are broken and the water set free is able to dissolve more salts than it can before the loss of the adsorbent properties of the soil.

THE REAL IMPORTANCE OF THE SOIL SOLUTION

The study of the soil solution is of great importance from various points of view. The very complexity of the soil and the constant change which the soil is undergoing introduce a countless play of factors. This complexity inherent in the subject should not discourage investigation. It must be admitted that the soil solutions from different fields or from different parts of the same field will not be exactly the same, nor even will the soil solutions present at any place remain constant. But the same could be urged against chemical analysis of the soil which likewise varies, yet which on the whole gives a general idea of the field conditions.

The soil solution, at the outset, may be considered in its relation to soil formation. Zacharov (18) maintains that the soil solution plays an essential role to the extent in which it relates to the process of leaching, dissolving and further advancement of the soil particles in the soil layer. Finding that the soil extract from different soils varied in color, reaction and amount and composition of the soluble constituents, he was able to differentiate the different soil types. The amount of humus present has a marked influence upon the color and reaction of the soil solutions. Soils of the same composition as regards type but differing in organic matter present will vary in their soil solutions as to color and reaction. Not only the humus, but also certain of the mineral constituents of the soil have a marked influence upon the color of the soil solution.

The second phase of importance from an ecological standpoint is the soil solution as the medium for plant growth—the actual medium in contact with the plant roots, and the substratum for the microbial life. The plant is susceptible to the reaction whether it is neutral, alkaline, or so-

called acid and to the amount and kind of available substances present, especially of potassium, phosphorous, calcium and nitrogen in their various forms.

Cameron and Bell (5, p. 8) say, "The soil solution is physiologically of the greatest importance, as it is the source from which plants absorb the mineral constituents which have been demonstrated to be absolutely essential to their continued existence and development. The study of the soil solution, therefore, becomes of the first importance in the investigations of the relation of the soil to plant growth."

Heretofore no available means have been devised for obtaining large amounts of the true soil solution or a fair representative of the same. From the study of synthetic solutions and of water extracts, much light has been thrown upon soil fertility. With a true soil solution, much more valuable information ought to be obtained. For example, we have used the soil solution obtained by the method herein described to study the effect of the microorganisms in fertilized soils and also to show the effect of soil reaction upon the number and kind of microorganisms present. This phase of the work will be taken up in a later publication.

PREVIOUS METHODS

Various investigators have tried to find some means of obtaining a soil solution as it exists in the soil in order that they may become better acquainted with the medium in contact with the plant roots and the medium in which microbial activities must take place. Among the first tried may be mentioned the drainage waters (9, p. 22-25; 11).

1. *Drainage Waters*

Some pertinent objections may be brought against this method. The gravitational or drainage water as it moves downward through the soil carries with it only a small part of the film water, but if the flow is continued long enough this film will be entirely replaced by a new one which for the time being is not concentrated to the same degree as the one before it. Schloesing (14, p. 99) claims that drainage water collected after it has passed through a meter of earth does not faithfully represent the solution which the arable layers imbibe. In all drainage water, according to Hilgard (9, p. 271) the chief nutritive ingredients of plants except nitrogen are present in traces only. The drainage waters, therefore, contain too much of some ingredients and too little of others to give any definite information as to the soil requirements.

2. *Soil Extracts*

Soil extracts have, no doubt, been used more than any other method for the study of the soil. It depends upon whether a total analysis of the soil is desired, or whether just the ingredients that may become easily

available to the plant are desired, as to the nature and strength of solvent used. Some investigators use mineral acids, others organic acids and still others use water.

In all such extractions, none deals with a solution which contains the exact amount of substances available to the plant. It is seriously questioned if they give data on actual soil conditions. Consequently water, the least objectionable, has been used as a solvent for determining the available plant nutrients in the soil. While Briggs' method of separating the turbid supernatant liquid by forcing it through a Pasteur-Chamberland filter or the other common method of separation by filtering through filter paper, is obviously more applicable for yielding data than extractions with acids and the like, yet it yields only dilute washings of the soils which cannot be concentrated to reproduce the original solution.

3. *Artificial Root*

In their study of capillary movement of the soil moisture, Briggs and McCall (2) tried to imitate the plant root in its adsorption of moisture by using a close-grained porcelain filter connected to an exhausted receiver and placed in the soil. It is claimed that the solution thus obtained is identical in concentration and composition with the soil solution from which plants get their food. The disadvantage is that it is applicable only to those soils of comparatively high moisture content and that it furnishes only a small amount of solution. The adsorption by the clay filter itself is known to be important enough to alter seriously the solution obtained.

4. *Centrifuge*

Briggs and McLane (15) tried to obtain the soil solution by means of whirling the moist soil at a very high speed. Thus they were able to reduce the soil moisture to approximately the optimum condition for plant growth and this method therefore is limited to soils containing more than the optimum. Nevertheless by this method it has been possible to gain some valuable information concerning the actual concentration of the free soil moisture. For any extensive study the amount of solution obtained is comparatively so small as to be practically prohibitive.

5. *Displacement Methods*

Among the first attempts to obtain the soil solution in an unaltered condition was that of Th. Schloesing (13; 14, p. 98) in the '60's. In this method pure water was carefully added so as to force out the water already in the soil. To make the line of demarcation between the added water and that already in the soil he colored the water with carmine. The objection raised to this method by Itscherekov (10, p. 147) was that it did not work well with soils containing less than 20 per cent of moist-

ure and the time required was too long. Itscherekov conceived the idea that the attractive forces of the soil particles would be more easily overcome and also that the capillarity would not be destroyed, but somewhat modified, by using a liquid lighter than water that would wet the soil and penetrate the smallest pores. Otherwise, the soil solution would rise above the displacing liquid and lessen the mechanical mixing of the two substances. For this purpose he (10) selected alcohol, either methyl or ethyl. It is claimed that soils with a moisture content of 10 to 2 per cent were extracted with success. The chief objection is that alcohol mixes to some extent with the soil solution, and also, that the alcohol is an active agent dissolving and precipitating out certain of soil ingredients.

Gola (9, p. 22-25; 16) tried an imitation rain and pressure method. After allowing an excess of water to drain off, he subjected the soil to the pressure of a screw press. The chief objection that Stiles and Jorgensen (16) raise to this method is that it is not applicable to all kinds of soils, but it may be used for all soils having a high water capacity. Hesselhink van Suchtelen (17) impressed by the feasibility of the Itscherekov's method modified the plan and after some preliminary work selected a thin paraffin oil, later a thicker and heavier one as a displacing liquid for obtaining the soil solution in its natural condition. The oil was drawn through the soil placed on a large Büchner funnel by means of suction. The pressure thus obtained was too low for satisfactory results.

PRESENT METHOD

Paraffin Oil Displacement—Pressure Method

Later, instead of using suction as described above, a pressure method was undertaken by van Suchtelen and Itano with the idea that if a greater force could be applied than could be obtained with the suction pump, better results would be attained. Therefore, another apparatus was necessary. In this apparatus the displacing liquid was forced through the soil instead of being pulled through by suction. It is with this apparatus and with the solution obtained that the author has been experimenting for over two years.

Apparatus

This consists of a cylinder connected at the top with a high-pressure pump and open at the bottom with a small-bored spout from which the soil solution flows. The details of the construction may be seen in Plate I. After trial with a cast-iron cylinder 5 inches in diameter and 22 inches long, others were made later of larger dimensions, 6 by 24 inches. The cylinder is screwed into a flange and reducer. The union is soldered in order to make a more perfect joint. The reducer is connect-

ed to the pedestal, the upper part of which is hollow, while the part below the spout is plugged (to prevent loss of solution). This entire lower part can be easily removed from the cylinder for cleaning. The cap is fastened on with bolts. A gasket of copper and asbestos is used to make a tighter joint. In the bottom of the cylinder is placed a perforated plate and above this two fine wire gauzes to hold back the soil. These gauzes are larger than the plate to prevent the soil from passing under its edge. A series of cylinders can be arranged in a battery, so that all can be worked at the same time, or any one or two cut out. In our experiment, three were so connected. For this purpose any kind of hand pump can be used that will force the liquid through under pressure. The gauge is an ordinary 500-pound steam pressure gauge and is placed on the main line so that the pressure can be read on any cylinder of the battery, by putting in or cutting out the cylinders from the pressure pump.

The small cylinder (5 by 22 inches) is capable of holding 18 to 30 pounds of soil, depending upon the nature of the soil, while the larger ones (6 by 24 inches) hold 35 to 50 pounds.

Before using the cylinders the inside is coated with hot paraffin; in order to keep the soil and the solution away from the iron. The lower pipe and spout, as well as the plate and gauze in the bottom, are treated in a like manner.

The cylinder is weighed before and after filling in order to get the weight of the soil used. The soil used is thoroughly mixed by rolling it back and forth on a large piece of oil cloth. The soil is added in small quantities (about a double handful) at a time, a small portion being saved each time for a composite moisture sample. The soil in the cylinder is thoroughly packed down by means of a stick with an iron disk on the end. A great deal depends upon the packing. If loosely packed, or unevenly packed, there will be left an easy channel for the displacing liquid to pass without much pressure being exerted and also without obtaining the total amount of solution possible. The pressure exerted will depend upon the moisture content of the soil. It is raised gradually as long as moisture continues to come until finally 500 pounds pressure is reached if the oil has not come through before the pressure reaches this maximum. One reason why the pressure is raised gradually is to give the soil an opportunity to adjust itself and thus to prevent the oil from passing through too soon as a result of the formation of channels. Some soils with a very high moisture content, even on packing, will give off some of the solution that they contain.

When the oil comes through in any of the cylinders, the valves on the others are closed to hold the pressure attained, while the pressure is being released on the first by opening the release valve on the pump. After

this, the action is reversed and the pumping is continued as before. When all the cylinders are used for extraction of the same soil, all extractions, if mixed, will give an abundance of material to work with. In the sandy soils oil will make its appearance generally from 3 to 9 hours, while with the finer-grained soils the oil may not come through for several days. Solutions for analysis are hardly ever used after a protracted (48-hour) extraction. Solutions are gathered from time to time and placed in a refrigerator to retard the bacterial action. Care is taken to prevent chemical changes in the solution by using resistance glass.

When cleaning out the cylinders, the oil that is superimposed on the soil is saved and can be used again provided one strains it to get rid of the dirt that it might contain. It is found that in order to clean out the cylinders easily, it is best to bore into the soil either with an ordinary soil auger or with an ordinary 3-inch bit (with the former several holes will be necessary), then with a bar the soil may be pried from the sides and taken out quite readily. With heavy soils like clay, chunks of soil may be pulled out with the soil auger which acts as a cork-screw. To remove the soil in the bottom of the cylinder unscrew the cylinder from its pedestal and invert it, then, through the opening in the bottom, one can force the soil out by driving on the perforated plate with a piece of pipe and hammer. The soil in the bottom will be found to be packed harder and drier than that at the top.

The inertness of paraffin oil gives it an advantage over alcohol; it does not act upon the soil nor does it mix with the soil solution. Whatever oil comes through with the solution can easily be separated by cooling the flask so that the oil will adhere to the sides, and then pouring off the water or by using a separatory funnel.

The method can be used with all kinds of soils, but it is better adapted to the coarser and more porous soils like the sands and sandy loams than to the finer-grained and less porous soils, such as the clays and clay loams. In nearly all of the extractions thus made, a thick, viscous filtered oil of cylinder stock was used. If the oil at times became so thick as to prevent its entering the pump, it was thinned with a thin paraffin oil.

Moisture Content of Soils and Solution Obtained

This method will not give the entire moisture content, nor will any method yet devised give the entire moisture content as it exists in the soil. The moisture content that is necessary for an extraction depends upon the nature of the soil used. The greater the amount of moisture present up to its total water capacity, the larger is the amount of solution that can be procured. It is assumed that, everything else being equal, all the solution above a certain point can be obtained. If we consider the work of Briggs and McLane (3) we note the force with which the water

film is held to the soil particles. In the whirling of moist soils, they found that this film was not removed by a force of 3,000 times the force of gravitation. In the paraffin oil pressure method, the highest pressure used was only 550 to 600 pounds, or about 40 atmospheres. The thicker the film around the soil particles, the smaller is the amount of force required to remove the moisture from the outer edge of the film. Lord Rayleigh (12), as a result of some experiments, calculated that the thin film was held with a force as high as 25,000 atmospheres. With part of the moisture held by that great force, it would be impossible to get it all with 40 atmospheres.

Since the oil penetrates some soils only in part and other soils entirely, the amount of moisture that remains is calculated by the difference between the total moisture content of the soil and that obtained by extraction.

Properties of Soil Solution

The study of certain of the physical, chemical and biological properties of the soil solution ought to give some information in respect to the soil problems.

TABLE I
MOISTURE CONTENT OF THE SOIL AND AMOUNT EXTRACTED

Soil	Per cent of Moisture in Soil before Extraction ¹	Number of Soils	Number of Determinations	Per cent of the Total Moisture in Soil Extracted ²
1. Fine sand (surface)	42.02—46.73	5	10	11.10—29.14
2. Fine sandy (surface))	7.66	1	2	35.17
3. Fine sandy (surface)	29.74	1	2	30.48
4. Fine sandy (subsoil)	17.35—23.18	4	8	42.88—74.08
5. Medium sandy loam (surface)	27.24—29.36	2	6	11.19—17.92
6. Medium sandy loam (surface)	45.38	1	2	27.25
7. Clyde F. S. loam (surface)...	40.57—43.82	3	4	1.50—8.50
8. Miami silt loam (surface)....	35.12—37.81	3	6	4.60—22.80
9. Clyde clay loam (subsoil)....	40.86	1	2	5.18
10. Miami clay (surface)	24.52	1	1	5.80
11. Peat (surface)	132.90—251.95	2	2	14.60—23.40
12. Muck (surface)	98.22—164.00	3	5	2.00—12.68

¹ Based on oven-dried soil.

² Based on total moisture in soil.

One of the important factors in the study of the soil solution is its concentration because of the bearing it has upon the development of the living cell. This form of concentration concerns not only the amount of total solids present, but still more the effect it has on the depression of the freezing point. The latter determines the force or pressure that the solutes exert when placed under varying conditions. The specific gravity, surface tension and viscosity are very important, also, in that they have much to do with the capillary movement of the soil water. The greater the surface tension, the thicker will be the capillary film and the

harder it will be to remove this film. The more viscous the liquid is, the less will be the movement due to capillary action. The reaction is worthy of consideration both in case of the microorganism and of the plants, for upon this depends the development and growth of the lower and the higher forms of life.

The results in Table I are based on duplicate determinations except No. 10, two determinations of No. 8, and one of No. 12. Where more than one soil is used the range of the moisture content of those soils and the range of percentage of total moisture extracted are given. In all other cases the results are based on average determinations.

TABLE II
TOTAL SOLIDS OF SOIL SOLUTIONS FROM SOILS EXTRACTED

Soils	M.C.						
1. Fine sandy (surface)	7.66	29.74	40.77	42.02	43.98	46.02	46.73
	T.S. 400	700	1960	1809	1675	1380	1820
2. Fine sandy (subsoil)	17.35	17.71	21.08	23.18			
	T.S. 1345	1075	977	590			
3. Medium sandy	24.80						
	T.S. 35,880						
4. Clyde F. S. loam	*40.56	*43.82	41.91				
	T.S. 1320	1120	650				
5. Peat	132.90	251.95					
	T.S. 1320	840					
6. Muck	155.93	164.00					
	T.S. 1080	980					
7. Miami clay	24.52						
	T.S. 260						

* Same soil. The moisture content of one was raised and allowed to stand for one week to come to an equilibrium. In No. 1 the last four are similar soils, while the other two are dissimilar but belong to the same type. Their total solids should not be compared with that of the others.

T. S., Total solids, parts per million of soil solution. M. C., Moisture content.

From Table I, it will be noted that the amount of moisture extracted depends upon the kind of soil and also the amount of organic matter present in the soil. The fine sandy soils with very little organic matter gave the best results, as seen in No. 4, where on the average over 60 per cent of the moisture present was extracted. In two or three instances over 70 per cent was extracted. The results obtained with No. 2 are excellent, considering the amount of moisture in the soil. The others varied considerably. In some cases this was due to improper packing, permitting the oil to come through before the extraction was completed. The data for peat and muck demonstrate how tenaciously the organic matter retains the water.

In the same types of soil, the increase in moisture content causes a decrease in total solids, measured in parts per million. In one or two cases it was noted that the total solids were inversely proportional to their moisture content. In most cases illustrating the above, the ratios

were not as would be desired, possibly because of the fact that the soils were not portions of the same sample and were taken at different times. The majority of soils extracted had from 700 to 1300 parts per million of solids. Several had nearly 2,000 and one as low as 260. One was exceptionally high, but it was a poor uproductive soil. It had 35,880 parts per million and the freezing point was depressed 1.69°. Its other properties varied accordingly. Some of the reactions were neutral and others alkaline, as tested by means of the electric conductivity method.

The mineral constituents studied were those that were of some use to the plant, potassium, phosphoric acid, calcium (magnesium in later determinations), and nitrogen in the forms of ammonia, nitrite and nitrates. The nitrogen varied, but this is to be expected since it is a more changeable factor. The solutions from the same soil extracted at the same time, one from a small cylinder and the other from the larger one, in most cases, agreed fairly well in total nitrogen (sum of the different kinds), whereas they varied in the ammoniacal, nitrate, or nitrate nitrogen.

The phosphorus, especially in the various sandy soils, remained practically constant. The other types varied more or less. Table III gives an average of phosphorus, in parts per million, of the soil solutions, with the lowest and highest included in the average.

TABLE III
PHOSPHORUS IN SOLUTIONS FROM VARIOUS SOILS

Type of Soil	No. of Soils in Average	Phosphorus Average p.p.m.	Lowest p.p.m.	Highest p.p.m.
Sandy soils (including loams) ..	21	4.3	3.0	5.20
Clay	1	9.2	...	
Clay loam	2	15.7	6.8	25.00
Peat	4	8.8	1.6	15.40
Muck	2	2.6	2.5	2.70

The potash varied considerably in all the soils with the exception of peat and muck. It had a total range of 18 to 71 parts per million. In peat it varied from 71 to 125 parts per million, and in muck 20 to 38. The calcium and magnesium variation was quite marked. All the determinations were made by the colorimetric method, except for calcium and magnesium in the later work, which were made gravimetrically. A difference noted in the amount of nitrite present at the beginning and at the end of an extraction led to the examination physically and chemically of two similar soils, one a subsoil and the other a surface soil. Sandy soil was used because it gave a larger amount of solution for studying the various portions.

In the above two soils, successive portions of the solutions were examined as noted in Table IV. It will be noted that the successive por-

tions do not vary much in specific gravity or specific conductivity, but there is a slight decrease in total solids in Soil 34, while those in Soil 35 remain about the same. The difference here is more in the organic matter (loss on ignition) than in the inorganic matter. This would indicate that part of the total solids was adsorbed. The first portions came from the lower part of the cylinder and the last portion from the upper layers.

TABLE IV
PHYSICAL ANALYSES OF DIFFERENT PORTIONS OF SOLUTIONS FROM THE
SAME SOIL

FINE SANDY SOIL (SUBSOIL)

Lab. No.	Total Moisture in Soil c.c.	Amount Extracted c.c.	Sp. Gravity	Sp. Conductivity	Parts per Million of Solution		
					Total Solids	Inorganic Matter	Organic Matter
34 I	2710	538	1.000607	0.000863	1260	440	820
		450	1.000528	0.000889	1090	450	640
		445	1.000509	0.000901	790	340	450
		167	1.000528	0.000928	960	600	360
Total and average..		1600	1.000560	0.000887	933	432	501
II	3828	545	1.000607	0.000916	1100	660	440
		545	1.000490	0.000916	1280	420	860
		530	1.000528	0.000920	900	390	510
		540	1.000560	0.000904	880	540	340
		250	1.000512	0.000901	780	490	290
		225	1.000450	0.000904	790	550	240
		150	1.000560	0.000924	740	450	290
Total and average..		2785	1.000540	0.000913	981	507	474

FINE SANDY SOIL (SURFACE)

35	903	212	1.0010	0.000238	380	280	100
I		103	1.0022	0.000255	440	300	140
Total and average..		<hr/> 315	<hr/> 1.0017	<hr/> 0.000254	<hr/> 399	<hr/> 286	<hr/> 113
II	1452	200	1.00018	0.000257	440	300	140
		220	1.00010	0.000246	350	240	110
		95	1.00020	0.000274	430	330	100
Total and average..		<hr/> 515	<hr/> 1.00015	<hr/> 0.000257	<hr/> 400	<hr/> 280	<hr/> 120

I Small cylinder. II Large cylinder.

NOTE.—The averages are calculated according to the amount of moisture in the portions rather than by the number of determinations.

In Table V it will be noted in Soil 34 that the nitrogen as ammonia remains the same with one or two exceptions, but in Soil 35 there is a decrease. In all cases the nitrogen as nitrite increased while the nitrate decreased, with the exception of No. 35 II where it increased. The change in this case was between ammoniacal nitrogen and nitrate nitro-

gen. In nearly all cases there was a very slight decrease in the total nitrogen (sum of the different forms of nitrogen) in the successive portions of soil solution.

Only a very small percentage of the bacteria are removed from the soil since the soil in the cylinder acts as a filter in holding back most of the suspended substances. The soil acts on the same principle as a filter bed in a water-purification plant. If the cylinders are allowed to stand too long a very marked anaerobic decomposition takes place which is quite marked in clay soils or in those with considerable organic matter, as is evidenced by the disagreeable odor given off at the times of cleaning out the cylinders. In Table IV there will be noted a slight denitrification—less nitrates and more nitrites. This is especially true in Nos. 34 I and II, and 35 I.

TABLE V
NITROGEN DETERMINATION OF DIFFERENT PORTIONS OF THE SAME SOILS
(Amount of N in Various Portions of Extraction of a Sandy Soil)

Lab. No.	Portion	Parts per Million of Soil Solution Nitrogen as			
		NH ₃	NO ₂	NO ₃	Total N
34 I	1	1.5529	Trace	1.6875	3.2403
	2	1.5528	0.0108	1.5000	3.0636
	3	1.2930	0.1000	1.2300	2.8828
II	1	1.5528	Mere trace	1.7120	3.2640
	2	1.5528	Slight trace	1.5140	3.0660
	3	1.5528	Slight trace	1.4060	2.9580
	4	1.5528	0.0150	1.3340	2.9010
	5	1.5528	0.0550	1.1250	2.7320
	6	1.0352	0.1000	1.0440	2.1790
	7	1.3860	0.2390	0.8680	2.4930
35 I	1	0.5127	0.0111	0.3438	0.8676
	2	0.2717	0.0291	0.3375	0.6383
II	1	0.5435	0.0062	0.3438	0.8935
	2	0.2939	0.0107	0.3938	0.6984
	3	0.2717	0.0112	0.4183	0.7012

I Small cylinder.

II Large cylinder.

This soil solution is now being used in connection with the study of the microbial decomposition of nitrogenous compounds in the soil. Favorable progress has been made. Mr. O. M. Gruzit, in this laboratory, has used the soil solution to study the effect of some acids, alkalis and inorganic salts upon soil bacteria and has found some interesting results. A report on the results of these investigations is now being prepared for publication.

SUMMARY

The paraffin oil pressure method furnishes in most cases plenty of solution for the necessary analytical work. In sandy soils as high as 74 per cent of the moisture present in the soils was obtained.

A large amount of solution may be obtained without its coming in contact with the oil. If it does it can be easily separated by cooling and by the separatory funnel.

The concentration of the soil solution from different samples of the same type of soil varies according to the moisture content of the samples from which it is derived.

Successive portions of the same extraction vary only slightly in their physical properties, but to a considerable extent in the various forms of nitrogen.

The forms of nitrogen vary in the different solutions, since they are changeable factors. Calcium and magnesium also vary according to the treatment and reaction of the soil. The phosphoric acid (PO_4) is fairly constant. Potash (K) varies somewhat.

A small percentage of the bacteria are removed from the soil, since the soil acts as a filter.

Anærobic changes take place in the cylinder if it is allowed to stand for a long time.

The paraffin oil displacement-pressure method furnishes, as far as we are able to judge with our present facilities, a fair representative of the solution as it exists in the soil. The method permits the use of a large amount of soil, thus a better representative sample. Work now in progress indicates that it furnishes a valuable index of the microbial changes in the soil.

POSSIBILITIES AND LIMITATIONS

The soil solution is important from the plant physiologist's point of view for the studying of plant nutrients and balanced solutions. It opens another field for the soil chemist and physicist for the study of some of the soil conditions, *e. g.* composition and concentration of the liquid phases of the soil. To the soil bacteriologist it is important for the study of the microbial changes that takes place in the soil, of filterable microorganisms in the soil and of the pathogenic microorganisms that will live in the soil.

The method has its limitations in that the oil does not entirely penetrate all soils and therefore, does not give all the soil solutions that might be otherwise obtained.

The obtaining of any solution is limited to the moisture content of the soil and depends upon the type of soil. The greater the moisture

content, the greater is the amount of solution that can be obtained from the various samples of similar soils. From samples of dissimilar soils having equal moisture contents, the proportion of the total moisture varies with the soil types, the largest percentage being obtainable from sandy soils and the smallest amount from clay soils.

The method is still open for improvement. Certain phases of it need further study, as the type of cylinder, displacing liquid, and the method of packing the soil in the cylinder.

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PLATE I

Fig. 1.—Battery of cylinders showing how connected and means of collecting soil solutions.

Fig. 2.—Cylinder and its parts.

A, cylinder; B, wire gauze; C, cylinder; D, perforated iron plate; E, pedestal with spout; F, copper and asbestos gasket.

Fig. 1.

Fig. 2.