SPECIAL ARTICLES.

AN ARTIFICIAL ROOT FOR INDUCING CAPILLARY MOVEMENT OF SOIL MOISTURE.

THE rate at which a plant is able to secure water from a soil, under any given conditions, depends upon two factors: (1) The pulling force which a plant is able to exert upon the water in the soil, and (2) the capillary force with which the soil holds the water which it contains. Under a condition of equilibrium, this latter force could be expressed in terms of the curvature of the capillary surfaces. When the water in the soil begins to move, however, there is introduced, in addition to the static pull of the curved capillary surfaces, a resistance to the movement or translocation of the water over the surface of the soil particles. This resistance, which obviously depends upon the thickness of the film, must be taken into consideration in all questions relating to the rate of movement of the capillary moisture in soils.

In order to determine the rate at which a given soil with a given moisture content is able to supply moisture to the roots of a plant, one must create in the soil at some point a pulling force analogous to the action of the plant root. This may be done in several different ways:

1. The surface of the soil may be exposed to evaporation, thus producing an upward movement of the water from the lower portions of the soil. This method is open to serious objections. The surface soil soon becomes air-dry, unless the water content is kept abnormally high, so that evaporation must take place more or less from within the soil mass, which leads to indeterminate conditions. Furthermore, previous experiments have shown that the distance through which water will rise in a dry sand is only one fourth the distance through which a vertical movement will take place in moist sand.* From these facts it is evident that the capillary movement induced by a dry surface soil is not representative of the capillary movement in the soil surrounding the active roots of a plant, where the soil grains are covered with water films.

2. An osmotic cell buried in the soil may be used to produce an inward movement of the soil moisture towards the cell,* provided the osmotic pressure of the cell solution is greater than the capillary pressure of the soil moisture.† Unfortunately, the rate at which water diffuses into a cell of this kind is so slow as to preclude the possibility of taxing the soil by this method, except under conditions approximating drouth. This, combined with the changes in concentration which take place at the inner wall of the cell as water enters, and the difficulty experienced in preparing cells capable of withstanding high pressures, makes the method in general unsuitable for investigating the rate of capillary movement. When the moisture content of a soil is reduced to such an extent that the rate of movement is extremely slow, the osmotic cell furnishes a very beautiful means of producing in the soil a capillary pull of known magnitude.

3. The method which we are about to describe avoids the errors and difficulties incident to the two methods outlined above. The apparatus consists of a close-grained unglazed porcelain tube, closed at one end, and provided at the other with a tubulure, by which it can

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* Briggs and Lapham, Bull. 19, Division of Soils, U. S. Dept. of Agri., 1900.

* Cameron (Bull. 22, Bureau of Soils, Dept. of Agri., 1903) has shown experimentally that when an osmotic cell, having a calculated osmotic pressure of 36 atmospheres, is buried in a soil, there is an inward or outward movement of water depending upon the moisture content of the soil.

† The capillary pressure of the soil moisture is due to the existence of curved water-air surfaces within the soil which tend to contract and thus produce a pressure outward along the normal to the water-air surface. This surface can actually move outward only by drawing in additional water from surrounding capillary spaces. If the moisture in the soil is in equilibrium the curvature of all the water surfaces at a uniform level is the same. The pressure exerted by the capillary surfaces depends upon the curvature and the surface tension. When the moisture content of the soil is diminished, the curvature, and consequently the capillary pressure, is increased. See Bulletin 10, Div. of Soils, U. S. Dept. Agri., 1898.

be connected to an exhausted receiver. When a tube of this kind is moistened, so that the pores are filled with water, and the tube is protected from evaporation, it can be exhausted to a pressure equal to the vapor pressure of water, and, if connected to a two-liter receiver, it will maintain that difference in pressure for a day or more without sensible loss. It is evident that under these circumstances the curvature of the capillary water surfaces on the outside of the tube must exceed the curvature of the capillary surface on the inside of the tube by an amount sufficient to produce a pressure of nearly one atmosphere.

Suppose now that a tube of this kind be buried in a moist soil having a moisture content sufficiently high to reduce the pressure of the capillary water surface in the soil to less than one atmosphere. Under these conditions, a movement of moisture must take place from the capillary spaces of the soil to the capillary spaces in the porcelain tube where a greater capillary pressure exists. Now the curvature of the capillary water surface on the outside of the porcelain tube must always be sufficient to withstand the pressure of one atmosphere produced by the exhaustion of the tube, hence the water drawn into these spaces must be forced through the tube by the difference in pressure between the outside and inside of the tube, in order that the necessary curvature of the outer capillary surface may be maintained. A steady movement of water into the tube will, therefore, take place. This rate obviously depends: (1) Upon the difference in curvature of the capillary surfaces on the outside of the tube and in the soil mass, *i. e.*, upon the moisture gradient; (2) upon the resistance encountered by the water in moving over the surfaces of the grains and through the capillary spaces.

The apparatus, with which the results given below were obtained, consists of a Pasteur-Chamberland filter tube, connected by means of a short piece of lead tubing to an exhausted two-liter bottle. Air-tight connections are readily made by the use of short lengths of red rubber tubing, well coated with thick cotton-seed oil. Preparatory to placing the filter tube in the soil, a core of soil is removed by means of a tube, the external diameter of which is equal to that of the smaller end of the porcelain tube. The filter tube is slightly conical in form, so that when it is forced into this hole, a good capillary connection is established between the walls of the tube and the soil.

The apparatus was usually allowed to stand for about twenty-four hours, when the exhausted bottle was detached, and the water which had been drawn into the apparatus removed and measured. The porcelain tube was not disturbed in removing the water, which was drawn into a small flask by suction through a fine tube extending to the bottom of the porcelain tube. The apparatus was then immediately put together again and exhausted by means of an aspirator.

The water thus removed not only represents the amount of water which the soil has supplied to the tube during the preceding period of twenty-four hours, but it appears to be identical in concentration* and composition with the soil solution from which the plant obtains its food.† Therefore, the determination of the amount and composition of its soluble material gives us at once the concentration and composition of the soil solution. The apparatus thus provides a simple means of studying the changes which take place in the solution from which plants obtain their mineral food.

In the following table, the second column gives the rate in grams per hour at which moisture was supplied by the soil to the filter tube; the third, the electrical conductivity at 20° C. of the solution thus obtained, measured always in the same cell. These meas-

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* No measurable change is produced in the concentration of a soil solution by filtering it through a porcelain filter-tube which is free from organic matter, and which has been thoroughly washed. A tube clogged with chlorophyll, on the other hand, does actually appear to filter out a part of the solvent from some solutions, the unfiltered portion immediately about the filter-tube being more concentrated than the original solution. See Bull. No. 19, Bureau of Soils, U. S. Dept. of Agri., 1901.

† The arguments in support of this statement will be given in a subsequent paper.

urements consequently serve to indicate the variation in the concentration of the soil solution. The fourth column gives the moisture content of the surrounding soil taken at a distance of from twelve to fifteen inches from the tube. These determinations are rather unsatisfactory, since it was not possible to obtain the samples at a uniform distance from the tube, and the moisture determinations are, therefore, not strictly comparable.

SOIL MOISTURE REMOVED BY ARTIFICIAL ROOT.

Date.	Rate in Grams per Hour.	Electrical Conductivity at 20° C.	Moisture Content Per Cent.	Remarks.
June 7- 8	8.9			Heavy rain.
8- 9	6.5		19.2	
9–10	6.1	75.8		Heavy rain.
10–11	7.2	76.8		
11–13	5.3	78.8	18.5	
13–14	3.9	80 0	18.7	
14–15	2.8	81.6	18.1	
15–16	2.7	82.4	17.3	
16–17	2.2	84.3	18.4	
17–18	2.2	89.2	19.1	
18–20	1.8	86.5	18.1	
20–21	1.7	86.5	17.3	
21–22	2.0	89.7	20.5	Rain.
22–23	1.6	89.8	18.3	
23–24	1.1	87.9	17.5	
24–25	0.9	88.8	16.9	
June 30–July 1	13.7	89.0	22.4	Heavy rains.
1- 2	9.5	83.0	21.9	
2- 5	4.0	86.4	17.8	
5- 6	2.2	87.9	17.7	
6- 7	1.5	88.8	17.9	
7- 8	8.3	82.0	23.2	Heavy rains.
8- 9	9.3	80.8	22 3	
9–11	12.4	84.0	22.2	Showers.
11–12	5.8	86.9	21.9	Showers.
12–13	8.1		21.7	
13–14	6.2	86.4	20.2	
14–15	4.2	88.4	18.7	
15–16	3.2	90.4	17.8	
16–18	3.5	91.2	19.3	Rain.
18–19	2.7	91.1	18.6	
19–20	2.0	92 5	17.9	

The soil in which these experiments were made had been heavily fertilized the previous year. It will be noted that the conductivity, which we may assume as approximately proportional to the salt content, steadily increased from the beginning of the observations, June 7 until June 18. The rain on June 21 apparently did not change the concentration of the solution. After the rain on July 1, the conductivity dropped from 89 to 83, after which it steadily increased until the next rain on July 7. From that time, the conductivity increased from 81 to 91 on July 16. The rain on the latter date did not change the conductivity, due, perhaps, to an accumulation of soluble material at the surface as the result of evaporation on the preceding days, which was carried down by the rain. The maximum increase in the electrical conductivity of the soil solution, taking the initial value as a basis of comparison, amounted to about 21 per cent. The increase in the total solids, determined gravimetrically by evaporating a given volume of the soil solution to dryness, was about 32 per cent., the total solids varying from 1.6 gms. to 2.1 gms. per liter of solution. The maxima in the curves, representing the variation in the electrical conductivity and total solids in the soil solution, do not always correspond, which indicates a change in the composition of the solution as well as in the concentration.

The rate of translocation of the soil moisture into the tube, at the beginning of the experiment, after a heavy rain, was 8.9 grams per hour. It fell steadily during the next two weeks to about 1 gram per hour. Heavy rains in July 1 brought the rate up to an average of 13.7 grams per hour for the twenty-four hour period, after which it fell to 1.5 grams per hour on July 7, and so on.

The rates given represent, of course, the average rate for the period. At the time of a shower, the rate would temporarily be much greater. The apparatus is amply able to remove the water as fast as it can be supplied. A tube in good condition, when immersed in water and exhausted, will take up water at the rate of 50 grams per minute, while the greatest rate recorded in the table is only about one two-hundred-and-fiftieth as fast.

The apparatus thus provides:

(1) A means of determining the rate at which water can be supplied by a soil to an artificial root, by means of which a capillary pull is exerted upon the soil moisture of any desired magnitude up to one kilogram per sq. cm. This makes possible the comparison of rates of capillary movement in different soils under field conditions.

(2) A simple method of removing a portion of soil moisture with the dissolved substances which it contains, thereby enabling a study of the concentration and composition of the soil solution under different field conditions.

This apparatus has the disadvantage of being able to remove water from the soil only when the latter is comparatively moist; in other words, it fails to give us information regarding the rate of movement of soil moisture during conditions approximating a drouth. Experiments are now in progress with a view to extending the range of the apparatus.

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NOTES ON INORGANIC CHEMISTRY.

THE first fall number of the *Berichte* of the deutschen chemischen Gesellschaft, with its more than six hundred pages, brings an unusually large number of papers on inorganic chemistry. Several of these are of general interest.

IRON HYDROXID AS AN ANTIDOTE FOR ARSENIC.

THE discovery that freshly precipitated ferric hydroxid is an antidote for arsenic was made by Bunsen in 1834, and was the subject of his earliest scientific publication. He attributed the antidotal effect to the formation of a basic ferric arsenite; indeed, by working in an acetic acid solution he obtained a precipitate of such constitution. The suggestion was, however, early made that it was possible that a finely divided powder, of no physiological or chemical action, could under certain circumstances be active as an antidote in cases of poisoning, and large doses of magnesia were found by some physicians to be as efficient as the ferric hydroxid. The whole subject has now been gone over by Dr. Wilhelm Biltz, who finds as a matter of fact that no compound is formed between the arsenic and iron, but that the gelatinous precipitate acts wholly by adsorption. When the iron oxid is present in the proportion of eight parts to one of arsenious oxid, the removal of the arsenic from solution is almost complete. Dr. Biltz offers the suggestion that the action of antitoxins may be susceptible of a similar explanation.

PHOSPHORESCENT ZINC SULFID.

SOME ten years ago a description was published by Henry of the preparation of a brilliantly phosphorescing zinc blende which is known as 'Sidot Blende.' In this preparation one of the essentials was that the zinc used should be chemically pure. In this *Berichte* the subject is taken up by two observers, who independently come to the same conclusion, which is that a good preparation can not be made unless traces of impurity are present. The amount of this impurity should be very small, Grüne obtaining the best results when his blende contained one ten thousandth part of copper. This blende has a beautiful green phosphorescence. Silver, lead, bismuth, tin, uranium or cadmium can be substituted for the copper with good results. Hofmann finds that the best blende can be prepared by adding common salt and magnesium chlorid to a solution of the purest ammonium zinc sulfate, and precipitating with hydrogen sulfid. The unwashed precipitate is then heated to a white heat for half an hour. The resultant blende is composed of fine crystals and phosphoresces after exposure to the sunlight even more intensely than the best 'luminous paint.' Both observers find that when manganese is present as the impurity in the blende, the mass gives an especially beautiful golden yellow phosphorescence, which is also induced by friction, as is the case with some natural blendes. These artificial blendes are particularly valuable for use with radium, but they have no radio-activity of their own.

PLATINUM SULFATE.

SOME time since it was announced by Margules that platinum could be brought into solution in sulfuric acid by the action of the alternating current between platinum poles. At that time the compound formed could not be made to crystallize and its constitution was doubtful. More recently, by using concentrated sulfuric acid Margules has obtained the compound in deep orange-red crystals which are very hygroscopic and excessively soluble in water. These have been analyzed by Stuchlik, and found to be the sulfate of quadrivalent platinum of the composition, $Pt(SO_4)_2, 4H_2O$. When the salt has been completely freed from the adherent sul-