Growth Studies.

III. A 'Volumometer' Method of measuring the Growth of Roots.

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With one Figure in the Text.

ONE of the outstanding difficulties of studying growth in plants is the making of continuous measurements upon a single plant grown under controlled external conditions. In studies of animal growth this difficulty does not arise, since it is a relatively easy matter to weigh the animal at stated intervals. In plants, however, measurements of total weight are of doubtful value, owing to the large percentage of water present (about 90 per cent. usually), which may vary without reference to any actual change in protoplasmic mass. It is, moreover, difficult to weigh fresh plants accurately without such precautions as must destroy the plant as a growing individual, and of course dry weight determinations involve the entire destruction of the individual. In addition, even length measurements become practically impossible when dealing with branched structures such as older roots, and their value must always remain slight, on account of variations in the thickness and structure of the organs at different stages of development.

It was an attempt to overcome some, at least, of these difficulties that led the authors to devise an apparatus for measuring the volume of roots at different stages of growth. The essential idea involved in this apparatus was that roots should remain in a fixed position in some container which would allow of their being grown under suitable conditions for a comparatively lengthy period. The container had, therefore, to provide for the accurate measurement of small volumes, and yet had also to be of considerable size to permit extensive root development. In addition, it had to be provided with a means of renewing the nutrient solution.

In the following paragraphs an account is given of an apparatus devised to meet these conditions and used with satisfactory results.

The container (D C in figure) consisted of a glass vessel holding about 300 c.c. of water, with a narrow neck of about 2.5 cm. diameter. The neck was provided with a blue porcelain point, directed downwards. The

tapering base of the container terminated in a three-way tap, the bore of the passages being 2 mm.

Large seeds, such as beans, were used, and the germinated seed was wedged into the container neck, care being taken that the root was on the side of the neck opposite to the porcelain point, and the latter clearly visible. The container was filled with solution by allowing the latter to enter through the basal tap until it just touched the porcelain point. The volume of solution entering was measured, and this obviously would grow less as the

roots increased in size—the decrease in volume of solution representing the increase in the volume of the roots.

A number of containers could be used with the same refilling and measuring apparatus. Generally six were employed, each containing a plant under observation. Except during a measurement, the containers were kept in a large water bath at a constant temperature of $15^{\circ}\text{C.} (\pm 1^{\circ})$. The bath was covered over so that the roots were kept in the dark, the shoots being in the light.

The containers were filled from a series of bulbs (R S, S T, &c., see figure) fed from a four-litre reservoir of nutrient solution. As the individual containers held various amounts from 315 to 358 c.c., the bulbs were arranged so as to run in any one of the four values 297, 310, 322, and 335 c.c. with the minimum

Apparatus for measuring growth of roots in volume; for explanation see text.

number of readings. With the arrangements figured, the discharge of any one of these volumes required only two readings of meniscus levels (at T or S and at R). The diameters of the tubes on which the level marks were made was about 5 mm., so that the readings involved only a small error at most. The point R was kept at a uniformly higher level than the top of the container.

The containers could thus be nearly filled by running in a known volume from these bulbs. The final small amount of solution was added from a measuring tube, W Z, which consisted of two bulbs, and below them a long glass tube graduated in 0.01 c.c. Any volume between 0 and 6 c.c. or 16 and 27 c.c. could be run in from this tube, and in conjunction with the various filling bulbs described it was thus possible to fill and measure the volume of solution in any container between 298 and 363 c.c. The

internal diameter of the tubes Z W was less than 2 mm. A tap at N allowed for the removal of air-bubbles.

The further details of the apparatus can best be realized from a description of its use in measurement. A container holding a plant whose roots were to be measured, and filled with the nutrient solution supplied to it on the last occasion that the volume was measured, was clamped *vertically* in a stand. The connexion M, at the base of the measuring tube, was attached to the outlet A of the container. A pump connexion was then attached at Z, and the solution from the container sucked up the measuring tube as far as was necessary. The tap U was then closed and the pump disconnected. By adjusting U, the level of the fluid in the tube was then allowed to fall to Z, Y, or X as required. Tap C was then turned and the solution in the container allowed to run off through B, until the meniscus in the container was just level with the top of the tap outlet at C. Before making the final adjustment here, A was opened to allow the pressure in U M to become equal to that of the atmosphere, since otherwise it would vary with the height of the column in the measuring tube, and a volume error would be introduced. When C was adjusted the connexion on B was attached to P, no air being included. C was then opened again and the required volume of fresh nutrient solution run in from the bulbs, by adjusting tap Q. B was then closed and A opened, when, by adjusting tap U, the final small amount of fluid was run in until the surface of liquid in the container just touched the porcelain point in the neck. The reading on scale W X then gave the volume added from the measuring tube. As the roots of the plant grow, this becomes less, and the decrease in this reading indicates the volume increase in the roots. If there is any doubt as to the accuracy with which this end-point has been measured, the solution can be sucked up into the measuring tube and the final operation repeated.

The sources of error in this apparatus are obviously due chiefly to the number of readings of meniscus level. In any series of observations with the same container, however, these readings are made at the same six places in the apparatus, so that this source of error is continuous throughout the readings. Since all of these levels, except that at D, are observed in fixed and narrow tubes, they should permit of accurate determination. In the mouth of this container, however, the accuracy of the end-point in filling must depend largely on whether the container is fixed in an exactly vertical position or not. In our containers, the body was cylindrical, and its correct position was ensured by getting the edge in exact alinement with the upright of a stand behind it.

Air bubbles in the apparatus are another source of error, but they are easily seen and as easily avoided. For obvious reasons, the temperature of the apparatus should be kept approximately constant at the different readings.

As the whole apparatus is in practice filled with liquid from a large reservoir at room temperature, the error introduced by temperature changes during the course of the reading is certainly well below other sources of experimental error.

Experience shows that if the plant used is only wedged into position in the neck of the container by means of its cotyledons, it is liable to move as the cotyledons decrease in size. In future, therefore, it would be advisable to fix the plant upon a ledge in the neck of the apparatus.

The accuracy of the results obtained with this apparatus can be estimated from the first series of readings made with it. Five containers were in use at the time, each containing a growing plant. After each reading, the container was emptied and the whole reading repeated. The average divergence of the second reading from the first was 5.50 ($\times 0.01$ c.c.), the figures (unit = 0.01 c.c.) for the individual containers being as follows:

No. of container	1	2	3	4	5	
No. of observations	26	28	26	24	26	Total 130
Average divergence	5.58	5.64	5.39	5.00	5.89	Mean 5.50
Maximum divergence	12	15	19	12	19	

The largest divergence is 19 ($\times 0.01$ c.c.), and the usual character of the volume changes recorded (readings being taken every second day) can be gathered from the following summary of the distribution of the actual volume changes obtained within a few arbitrarily chosen limits:

Increase in volume 0.01 c.c. per 2 days	Over 100	100-60	60-20	20-10	below 10
No. of observations	5	9	69	26	21

This set of observations lasted considerably over a month and included not only readings when growth was practically complete, but also the temporary cessation of growth following on the development of lateral roots. During the normal development of bean roots, volume changes of the order of 0.2 to 0.6 c.c. (per two days) are to be expected, after the appearance of secondary roots. The earlier stages of root growth are probably better observed by direct measurements of length as in Leitch's experiments (1), or by the method of Neilson-Jones (2).

One further point justifies our assumption that the volume changes observed lie outside the normal range of experimental error. The main results obtained are reproducible, the growth curves of individual plants being of the same general type. We hope to present conclusions based on these results in a subsequent paper.

BIBLIOGRAPHY.

1. LEITCH, I.: The Effect of Temperature on the Rate of Growth of Roots of *Pisum sativum*. Ann. Bot., xxx. 25, 1916.
2. NEILSON-JONES, W.: A Simple Root Auxanometer. Ann. Bot., xxxiv. 555, 1920.

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