A MEASUREMENT OF GROWTH

F. M. ANDREWS, Indiana University

Of the many methods used in measuring growth some are very simple—but some of these are apt to lack the necessary accuracy required in certain studies. It is easy to see that certain plants or parts of them elongate when observed at considerable intervals of time even with the naked eye. Great differences have been observed in this respect, for the staminal filaments of Triticum may lengthen "from 4-7 mm. in two minutes." This is seen to be especially rapid for growth when compared with many lichens which may grow "not more than 2 to 5 mm. in the course of a year even under favorable conditions." Even here special means of observation are advisable. The growth of individual cells may be directly observed with a properly equipped microscope, or the growth of filaments from spores. In this case the conditions of growth that are most favorable can be easily controlled. Disturbances that are often present with the mechanism used in growth registration of higher plants can be avoided in these experiments. In such experiments the rapid growth of certain pollen tubes can be easily observed. For example, the pollen tube of *Torenia Asiatica* grows so rapidly, under these conditions, that the tube can be seen to move across the field of the microscope with comparatively low magnification. A cell generally attains its full size in length, breadth, and width before its walls begin to thicken. The reasons for this are obvious. But instances are known in which the same cell increases in size and thickens its walls at the same time. This frequently results in a retardation of communication between the cells concerned, although such functions may then be on the wane and a different function commence with new cells often appearing to assume the office of the original thin walled cells.

The horizontal microscope has long been used for the study of growth and other phenomena. The usual method of procedure is a study of elongation. The plant used here was *Rhizopus nigricans* grown on bread. Using an instrument with a scale whose spacing equalled .05 mm. between the lines it was observed that not only rapid elongation occurred, as is well known to this plant, but also that the diameter often increased from two to four times the usual amount as rapidly as elongation occurred. An improvement over the usual method of using the horizontal microscope for observation of the growth of seedlings is obtained by making the spacing marks very distinct and thin on one side or sometimes for special observation of young roots entirely around by means of a suitable revolving apparatus. The glass apparatus containing the marked seedling for observation should then be maintained at an absolutely constant temperaturs in order to avoid condensation. With a scale spacing of .05 mm. the readings taken can be made very

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exactly. The absence of strings or other attachments as is often the case in stem measurements is an advantage as even slight disturbances are apt to result in considerable growth alterations. By the proper adjustments the diminution in diameter may also be observed as well as occasionally a contraction in length which latter still awaits explanation in various respects. While a slight disturbance will affect the growth of the roots involving great care in their treatment, yet on the other hand it is interesting to note that the severe conditions, such as pressure, displacement of contents, and other changes from the normal which may surround them, may not be fatal nor even cause a cessation of growth. Before the elongation of roots and stems as well as any increase or decrease in diameter, as in the fungi and other small plants, can be accurately measured by means of the horizontal microscope.

For the measurement of stems the arc-indicator as first used by Sachs is unnecessarily complicated. The one later used by Pfeffer is better. I have devised a form in which the usual lever which magnifies the growth ten times is a rigid truss. The usual lever is transformed into a truss from the axis to the end over the arc. It is composed of steel and brass and, although very light, is very strong, and permits no sagging at the arc end, and is balanced by a weight where the plant is attached. The ordinary forms are very apt to show some drop at the arc end and this error is made more serious on account of the magnification of growth that is involved. The accuracy of this truss arc is indicated by actual measurements of the same plant where used and auxanometer readings. Great care is necessary in attaching the string or thread to the plant, for no matter how carefully this is done the rate of growth is unavoidably influenced to a degree by this treatment. It is advisable in this case as with the auxanometer to give special attention to the preparation of the thread, to use Nathansohn's method of attachment and to use as short a thread as is consistent with the working of the apparatus. The temperature and light conditions may be controlled as was used by Sachs, by means of halved cylinder carrying a thermometer. When in strong illumination an opening should be provided for the passage of air to control the inner temperature. By suitable arrangement the specimen and flower pot may be inclosed in a thermostat and thus the effect of temperature very closely studied. The diametrical growth may also be studied, under proper conditions, by using a square rectangular clear glass box around the plant. The disadvantage of the arc form of auxanometer is that only those periods of time which are observed show the growth which has occurred.

This difficulty is removed in the automatic auxanometers which have been constructed. A good many forms of such instruments have been made by different investigators, but the best one thus far made is the self-registering auxanometer as devised and constructed by Pfeffer. Different increments of time may be employed as desired or in accordance with the rapidity of growth of the plant used. When properly used this instrument is capable of very desirable accuracy, but this requires great precaution. Specially prepared and treated silk threads should be used and when these are adjusted to the plant and the machine, the first few hourly records of growth should be discarded, until the necessary adjustments of the parts concerned have been established. The value of the machine would be considerably enhanced if it were provided with light cone pulleys in place of the usual ones employed, although this is, in many cases, cared for by the provision for setting the clock for different intervals of time. I have supplied the apparatus with what has proved to be a useful feature. This consists of a rectangular box large enough to enclose the plant and connecting threads with all or part of the sides and top of glass. This arrangement allows direct observation at all times since illumination is provided for, and at the same time this box prevents the disturbing effects of currents or air. The box is so arranged that opaque sides may be used when it is desired to darken the plant. A darkened electric light bulb of suitable size is also contained in the box so that the plant is independent of the temperature outside. By thus raising or lowering the inside temperature by this means an exact method of the effect of temperature is possible. A slow stream of air of sufficient rapidity to effect a desirable change is possible by adjusting the glass lid to the box. Some hours before arranging the experiment the plant should be well watered, allowed to stand till the earth has ceased to settle and the pot then placed in a glass vessel of proper depth and its top covered with paraffined paper to prevent further loss of water except through the plant. Unless this latter precaution is followed, and the growth of the plant becomes slow, a reverse graph will be produced due to the fact that the slight settling of the soil in the pot due to drying may exceed the slight amount of growth as indicated by the graph. The common *Phaseolus multiflorus* is a suitable plant for experimentation as its stem tip affords a good surface for attachment, but plants with leafy stem tips when young should not be used. The method of thread attachment as employed by Nathansohn should be used. A magnification of growth of ten times may be obtained, which is sometimes too great for one hour periods so that the use of shorter time intervals are often necessary in the case of very rapidly growing plants. A study of 60 hourly growth records of *Phaseolus multiflorus* of 50 different specimens of this plant gave uniform results. Their growth averaged 1.6 mm. for the first accepted five hour records which was in daylight and 2.8 for the next ten hours which was during the night. The second day's growth of twelve hours when the plant was illuminated averaged .3 mm. for each hour and .5 mm. per hour during darkness. This bears out what plants usually do under conditions of illumination and darkness but in these experiments the temperature was accurately controlled which enabled a safe comparison, which might otherwise be annulled by the difference in temperature being too high during the day or too low for good growth at night. The records obtained by means of the autonomic auxanometer also agreed very closely with the hourly growth records which it was possible to observe and obtain by means of the arc-indicator, as I have constructed it. The unsupported arm lever type is not reliable for accurate measurements. Growth in thickness of the elongating region began early as indicated by the horizontal microscope before it was detectable otherwise and was far advanced by the end of the first 24 hours.

The magnetic crescograph of Bose is very sensitive and is capable of magnifying growth 10,000 times. The use of a thread attachment with this instrument also has its objections. Certain projection apparatus eliminates the use of any attachments to the plant and is capable under favorable conditions of magnifying growth thousands of times. Its use is, however, limited and photographic registration is necessary for undisturbed records of growth in plants.

Cinematography has been employed successfully for many growth measurements, and Cine-photomicrography is also useful in cell growth.

PRESERVATION OF DRY PLANT MATERIAL

F. M. ANDREWS, Indiana University.

Material for plant study, as is often preserved in alcohol or other preservatives, to use for subsequent investigation, at times dries up entirely and is frequently then considered of no further value and is therefore generally thrown away. This is important since valuable and oftentimes irreplaceable material is lost. It is also at times a serious loss of time and much care and effort which may have been expended in fixing and preserving the material up to the point of dehydration of the alcohol used. It has been the writer's custom to bring the specimens gradually into 95 per cent alcohol and allow them to remain there until needed. It is inadvisable to allow bulky specimens to remain in alcohol of even 70 per cent, especially if there is a considerable quantity of them. The specimens should be separated from one another so that they will be completely surrounded by a large volume of alcohol, and this changed frequently as the process of dehydration slowly progresses. In the higher per cents of alcohol the specimens should always be left a longer time than in the lower per cents. Several days, at times and according to the nature of the material, is not too long to allow the specimens to remain in 70 per cent, and stronger per cents of alcohol even if the specimens are to be used at once, since it insures more gradual and more completely dehydration without damage to the material. Much of such material of plants which has dried out and generally supposed to be a total loss may be restored to a good condition if proper care is used as regards its structural features. In order to recover some plant material, that was of sufficient value, the writer has subjected the dried out parts of certain plants to a special treatment which has again rendered them available for certain studies from a structural standpoint. The plants used for this treatment were the stems of *Zea mays*, and *Cucurbita Pepo* and the leaves of *Iris versicolor*, *Iris cristata*, and *Sambucus canadensis* and the petioles of *Caladium bicolor*. All of these plants are of sufficient delicacy to allow of great shrinkage and distortion by complete desiccation. In addition to the above mentioned plants, branches from three to six millimeters in diameter of *Tilia americana* were also dried after having been in 95