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XXI

GENERAL HISTORY SURVEY OF MINNESOTA
CONWAY MACMILLAN, *State Botanist*

Minnesota Botanical Studies

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XVI. ON A NEW REGISTERING BALANCE.

ALEX. P. ANDERSON.

In the course of certain experiments on transpiration lately conducted in the laboratories for plant physiology of the University of Minnesota it became apparent that to ascertain the rate of transpiration for some length of time some self registering mechanism that could be used to record the increase in the weight of the absorber was necessary. With such an appliance the periodicity (if any) in transpiration could be determined, and a true transpiration curve plotted. After repeated trials and alterations, such a registering balance has been designed consisting essentially of a balance, one arm of the beam of which is lowered by the increase in weight of the calcium chloride absorber.

As this arm is lowered a circuit is closed and an electromagnetic mechanism releases a weight which falls on the other arm of the scale beam, or rather into its scale pan. Thus the scale is balanced automatically, after an increase equal to the weight used has taken place. At the same instant that the weight is released it is recorded on the registering cylinder of the recorder, which can be at any distance from the balance itself. The scale and balancing mechanism are enclosed in a case which entirely protects the whole from falling moisture.

The following detailed description will serve to illustrate the action: The weighing apparatus consists of a platform scale made especially for the purpose, and to fit the registering mechanism. This scale is sensitive to one-fifteenth of a gram, with a capacity of five kilograms. It has a beam eleven inches long, the supports of which are screwed to an iron plate in the bottom of the case, thus making the scale and case practically one and both can be leveled and adjusted together. The brass scale pans are seven inches in diameter and are carried by brass supports, attached to the arms of the scale beam. The scale bearings are of diamond steel.

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The electro-magnetic balancing mechanism consists of a weight holder and an electro-magnet, together with the contact point on the scale beam, mercury cup, wiring, batteries and the necessary fittings.

The weight holder is a coiled brass tube that holds about one hundred and twenty-five weights. At the lower end of this brass coil is a lever that can turn back and forth on pivot. One end of this lever is connected by a link to the armature of the magnet, and the other end, which is held in place by a spring, when the circuit is open, has a weight pocket that takes one weight from the weight tube each time the circuit is closed and carries it laterally about five-sixteenths of an inch and lets it drop, through a hole in the brass plate, on to the scale pan. As soon as the circuit is opened again by the readjustment of the scale beam the lever returns to its position and receives another weight from the tube, and is again ready to drop it into the scale pan as soon as the necessary increase in weight to close the circuit at the other end of the beam has taken place.

The weight holder has a calibre one-sixteenth of an inch larger than the diameter of the weights used. It is screwed to the frame of the electro-magnet and extends upward and to the outside of the case for the reception of the new weights at its exterior end. It is made air and water tight from the exterior by means of a rubber stopper that fits into the case. The weight holder can therefore be taken out and replaced by one of greater or less calibre, depending upon the size of the weights used, thus if two tubes, five-sixteenths and one-fourth inch respectively, are used, two sets of weights can be put in, viz.: one-fourth inch weighing about one gram, and three-sixteenth inch weighing about one half a gram. Larger or smaller sizes could be used, but for growth or transpiration the above sizes are sufficiently delicate to give a good curve.

The weights used are steel balls, the same make and size as are used in bicycle bearings. These are perfectly accurate, not varying in diameter more than one two thousandths of an inch, and in weight on an average not more than one thousandth of a gram. Sets of these balls can of course be weighed and verified by the experimenter himself.

The electro-magnet has a single coil, and one end of the core is joined with the frame of the magnet which forms the return magnetic circuit. The other end of the core is contracted in the form of a paraboloid.

The armature having a recess to correspond with this paraboloid, is placed between the two sides of the frame, being pivoted at one end; the other end has a lever communicating with the weight dropping mechanism by a connecting link. This construction of the magnet gives a double magnetic circuit of low resistance, and also a maximum pull and greater range of movement of the armature. The current from a single good carbon-zinc cell is sufficient to operate the weight dropping mechanism. The current from the battery passes through the magnet to a mercury cup, thence through a platinum contact point on the scale beam to the binding post on the case and back to the battery.

The case is twelve by eighteen inches and is made of enamelled sheet iron riveted to a frame work of wrought iron. The edges of the sheet iron are turned in^o so as to make with the frame work a groove on each side for two sliding glass doors. Thus the whole inside of the registering balance can be seen and watched from without, and either side of the case opened as desired. The case is leveled by means of four milled headed brass screws. A circular spirit level is placed on the iron plate immediately in front of the scale beam supports and thus the entire apparatus can be leveled in a few moments. The whole case is made so that it can be used in a green-house or in the open air without interference from moisture or rain.

The registering balance can be used for registering any continuous increase in weight. For transpiration a combined calcium chloride and sulphuric acid absorber is placed on one scale pan, and the previously dried air that takes up the transpired moisture from the plant chamber (bell glass) is forced through the absorber by means of an aspirator. Two light pieces of rubber tubing connect the absorber with the plant chamber and aspirator, by means of pieces of glass tubing in rubber stoppers fitted into the case. The rubber tubes are thus inside of the case and can not be disturbed by any outward influence. They buoy up and down with the scale pan and absorber. In balancing the scale for the beginning of an experiment these pieces of rubber tubing are partly weighed and continue to be a part of the weight on the absorber pan, but as their weight is approximately constant no error results.

An attachment is made to the balance when used for weighing large fruits, which necessarily must be grown outside of the case. This is made by elongating the scale pan support to

the exterior by means of a light brass tube. One scale pan will then be on the outside of the case and can be used for the growing fruit.

In the preliminary experiments on transpiration this apparatus has been found to eliminate a large proportion of the errors usually attending this work, while it is of equal value in work on growth increase of weight.

See Plate VII.

XVII. ON A NEW ELECTRIC AUXANOMETER AND CONTINUOUS RECORDER.

W. D. FROST.

THE ELECTRIC AUXANOMETER.

In undertaking recently some work on growth in thickness it was found that there was no available auxanometer suitable for the exact needs of the line of experiments designed. Pfeffer's auxanometer was the best instrument within reach of the writer, and while this is adapted for work with moderately large plants it is too cumbersome for delicate ones, as the counter-weight required to overcome the friction of the pulleys is sufficient to produce abnormal conditions. In the measurement of growth in thickness of stems, fruits, etc., it seemed absolutely necessary that the whole instrument used should be attached to, and suspended from the plant, to avoid any error caused by movements, such as twisting or bending, due to heliotropism or geotropism.

To meet these conditions the only contrivance which seemed possible was one in which a very small increment of growth should momentarily close an electric circuit by means of some easily adjustable mechanism. The increment of growth necessary to close the circuit being constant, successive closures of the circuit could, of course, easily be registered.

A working model was constructed upon this principle, and it proved so successful that it has been put in permanent shape by the instrument maker of the laboratory. It has furthermore seemed advisable to print here a description of it in advance of the results from its use in investigations now in progress in the laboratories for plant physiology of the University of Minnesota.

While it was originally intended for measuring growth in thickness, yet it is equally efficient in measuring growth in length. Its extreme lightness and delicacy make it especially useful in measuring the growth of small plants, and since it is

constructed of aluminum, it can be used on plants while they are under normal conditions of moisture, without injury to the instrument. The auxanometer proper can be separated an indefinite distance from the registering apparatus. Registrations have already been made in the laboratory of the growth of plants under natural conditions, 400 yards distant and in another building.

The auxanometer consists of a ratchet-wheel on a steel axis which also bears a series of small grooved wheels 1, $3\frac{1}{2}$ and 6 mm. in diameter, and a somewhat larger wheel upon which is wound a thread bearing a counter-weight. The diameter of the larger wheel, is about 5 cm. and the circumference contains 144 notches. A ratchet which fits in the notches of this wheel, is mounted on an axis similar to that of the others, and has a long horizontal arm. This arm has a platinum tip. As the large wheel turns, the ratchet drops into the notches in its circumference and the platinum tip is lowered so that it touches a drop of mercury which is held in a small cup on the arm of the frame. This arm is insulated from the rest of the instrument and is connected by means of a small wire, to one pole of an electric battery. The other part of the instrument is connected with the other pole of the battery. The screw underneath enables the height of the mercury to be regulated, and consequently the length of time which the current remains closed or open.

The frame work of the instrument is made of aluminum, and entire weighs 15 gms. It may be attached to the arm of a tripod support, and in this position can be used for measuring growth in length, (as shown in *Plate x*). For measuring growth in thickness the instrument can be fastened to the support and held against the stem, or fruit, which is to be measured, or it can be removed from the support and attached to the plant. When attached directly it is held in place by a clamp. This can be entirely removed and placed around the plant. It is roughly adjusted in place by means of a catch, which fits into the notches on the clamp. The fine adjustment is accomplished by a screw. When the apparatus is in place a silk thread is fastened to the hook on the frame, passed around the plant in the direction opposite the hands of a clock, so that the thread may be in contact with the entire circumference of the plant. The thread is then passed through a hole in the axis of the auxanometer where it is securely fastened and the

counter-weight on the wheel is made sufficient to keep taut the thread which passes around the plant.

As the plant increases in thickness the thread is unwound from the pulley upon which it was previously wound; and as this turns, and the teeth of the large wheel pass the ratchet, the electric current is alternately opened and closed.

In measuring growth in length the instrument is supported above the plant and the thread passed from the growing part to the small wheels. If the smallest wheel is used, during the growth of a millimeter, 46 registrations are made, that is to say one-forty-sixth of a mm. in length causes the circuit to be closed, while the largest wheel registers a growth of one-seventh of a millimeter.

See Plate VIII.

THE CONTINUOUS RECORDER.

This part of the apparatus consists essentially of two rollers, one of which is attached to a clock train, and as it revolves winds upon itself a ribbon of paper on the other roller, and an electro-magnet, to the armature of which is attached a pen that presses against the paper on the second roller. While the circuit remains open a continuous line is traced near one edge of the paper ribbon. When the circuit is closed the pen is drawn to the other side of the paper and the length of the line traced there denotes directly the length of time that the circuit is closed.

The clock train is an eight day lever movement with strong double springs. The case which is seven inches in diameter is finished in brass, and is so attached to the base that it can be easily removed. Projecting through the front of the case is the pinion by which the rollers are turned. This pinion revolves once in twelve hours, carrying with it the roller made of brass carefully turned and balanced. It is slightly less than four inches in diameter; thus the paper moves at a rate of one inch per hour. It has quarter inch flanges, and an arrangement by which the end of the paper is held in place. On the outer surface of this roller is a dial plate with the lettering opposite to that on an ordinary clock. Upon the support is a pointer. By means of this arrangement the time indicated by the clock can be read within a few minutes.

The second roller, with the exception of the dial, is exactly similar to the first. Both are mounted on steel shafts, turned

to fit the bearings. The supports are made of brass and screwed to a black walnut base, which is built of narrow strips to prevent warping.

The paper ribbon on which the record is obtained is two-thirds of an inch in width and made in two lengths, one sufficiently long to run four and the other eight days. Across the upper surface of the paper ribbon is printed a series of lines that divide the ribbon into hour spaces, which are numbered consecutively. These hour spaces are so ruled that the time of registration can be read to one minute directly from the ribbon.

A source of error arising from the fact that the paper as it is wound on the first roller increases the circumference of the roller, and causes the paper to move at an increased rate as the paper continues to be wound up, is avoided by having each successive hour-space longer than the preceding one. The correction, however, is very slight on account of the thinness of the paper used, and would amount to only six minutes at the end of the eighth day.

The time marker consists of a pen made of brass, and large enough to hold an amount of aniline ink sufficient for two weeks registration. This pen is attached by means of a rolled brass strip to the armature of an electro-magnet, which is hung on a hinge close to the base. Thus, as the armature moves in response to the attraction of the magnet, or the pull of a tension spring, the pen is drawn through a short horizontal distance. The rod simply serves as a support to the pen. The pen presses against the paper on the roller, and by means of the milled nut it can be kept at any required pressure, or can be withdrawn from the paper entirely when the latter is to be removed or replaced.

When the circuit is open the armature is held back by the tension spring, and the length of the brass strip is so arranged that the pen then traces a line near the right hand side of the ribbon, as it is shown in the plate. When the circuit is closed the armature is attracted and the pen is pushed to the other side of the paper ribbon, thus making a short line at right angles to the length of the paper. If the circuit is immediately opened the time of registration is marked simply by a single cross mark. If, however, the circuit remains closed for some time a line is traced on the left side of the paper.

In reading the record in this case the length of time elapsing between two successive closures of the circuit, is indicated

by the distance between the two successive forward movements of the pen, or, what is the same thing, the length of the line traced while the circuit is closed, plus the length of the line made while the circuit is open, as any one notch passes the ratchet.

The auxanometer is connected with the registering apparatus and an electric battery. The battery is of a type suited for a closed circuit. The two instruments may be placed upon the same table, or they may be separated any distance, as is most convenient for the operator.

This recorder may also be used with many other kinds of apparatus wherever a continuous record is desired.

See Plate IX.

XVIII. TITLES OF LITERATURE CONCERNING THE FIXATION OF FREE NITROGEN BY PLANTS.

D. T. MAC DOUGAL.

The relations sustained by plants to the nitrogen compounds of the soil and water, and to the free nitrogen of the air form a subject of great biological import, and since aside from its purely scientific aspect certain phases of the main question are of vast practical interest they have attracted the attention of the agriculturist and chemist as well as of the botanist.

The results of the investigations, from these various points of view, which have been in progress for a century, form a mass of literature which is scattered through the journals and proceedings of the various branches of natural science in such manner as to be very difficult of access to the student with ordinary facilities.

Among this rich and withal unwieldy mass of literature the part of especial interest to the botanist is that which concerns the fixation of free nitrogen by the leguminous plants and the organism found in the tubercles which characterize this group, and the fixation of free nitrogen by green plants which do not sustain mutualistic relations to the lower organisms.

The large number of controversies resulting from the attainment of radically different conclusions from similar experiments along certain lines of the work, in the hands of various investigators, leads to the belief that safe generalizations can be made from the restricted groups of facts thus obtained only when confirmed by extended and parallel researches. To meet this idea the references given below concern the points of central interest to the botanist, beside a number of titles to "nitrification," and to cases of mutualism and symbiosis which may offer a comparison however distant with the relations existing between the leguminous plant and the tubercle organism.

The list is composed of titles which have been incidentally collected by Professor MacMillan and the writer, and are comprised in the card catalogue of the botanical department of the University of Minnesota. Their presentation in this form is for the purpose of making them still more readily available to students and investigators in connection with this department, and wherever this line of work is carried forward. It is purposed to bring out a second installment of titles which the writer in the limited time at his disposal was not able to prepare for this number.

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DESCRIPTION OF PLATES.

PLATE VII.

The Anderson registering balance set up to weigh transpired water.

PLATE VIII.

The Frost electric auxanometer in use to determine growth in length.

PLATE IX.

The Frost time-recorder.

PLATE X.

The Frost auxanometer connected with recorder.

From photographs by Professor Wm. R. Appleby.

PLATE VII.

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PLATE VIII.

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