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ATMOSPHERIC ELECTRICITY AS AN ENVIRONMENTAL FACTOR

BY INGVAR JØRGENSEN AND WALTER STILES

The study of the living plant and its response to environmental and genetic factors has not as yet progressed very far. Just as the struggle to acquire the necessary but preliminary knowledge of systematic botany and morphology was slow, and often hindered by the tendency to get lost in details, so the still more immense tasks which await plant physiologists and ecologists will only slowly be accomplished and in spite of similar difficulties. One of these difficulties, which is now becoming obvious, arises from the arbitrary divisions between subjects of study, and here neither ecologists nor physiologists can be regarded as having their schemes of research and fields of investigation completely mapped out. For this reason we shall here briefly deal with a recent paper by Rose Stoppel (5) where the relation between electrical phenomena and irritability has been investigated, not so much on account of the particular merits of the paper, but because it is necessary that both plant physiology and ecology should keep watchful eyes for phenomena which are likely to widen the scope of investigation in those subjects.

Livingston (3) has well said that many terms in current use in plant physiology serve principally as cloaks for ignorance. The word "irritability" must certainly be included among these.

The tendency, at any rate in this country, has been to surmount the difficulty by neglecting it, and trying to forget that irritability phenomena exist. The few investigators who have attempted to break new ground in this field cannot be said to have met with much encouragement from plant physiologists. Similarly in ecology, irritability phenomena have scarcely been recognised as having any connection with that study, and yet such universal phenomena must surely be of importance, and perhaps of vital importance, in the responses of the living plant to its environment.

As regards atmospheric electricity, in earlier years, before the time of specialisation in scientific studies, when scientists, or philosophers as they called themselves, were engaged in a preliminary survey of natural phenomena, observations on atmospheric electricity and its relation to plant growth

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occupied a very prominent position in scientific investigation. To the modern specialist it is rather astonishing to realise the power of observation of these philosophers in the absence of any but the scantiest guiding fundamental principles. Thus to give one example of many which could be taken from eighteenth century writers, we may quote from Father Giambattista Beccaria, Professor of Natural Philosophy in the University of Turin (1).

“With regard to atmospheric electricity, it appears manifest that nature makes an extensive use of it for promoting vegetation.

1st. In the spring, when plants begin to grow, temporary electric clouds begin to appear, and pour down frequent electric rains. The electricity of the clouds and of rain increases afterwards in summer, and continues to do so till that part of the autumn in which the last fruits are gathered so that it appears that the electricity which obtains in clouds and rain, when carried to a certain degree, serves to promote, with regard to vegetation, the effects of common heat.

2nd. It even seems that electricity successively supplies common heat itself with that moisture by the help of which it actuates and animates vegetation, which, if heat acted alone, would inevitably be stopped. In fact, it is the electric fire that gathers the vapours together, forms clouds with them, and afterwards dissolves them into rain. It is the same fire, therefore, that supplies the earth with the nutritive moisture which is necessary to plants, and this moisture, by melting the terrestrial saline particles it meets with, by diffusing them, along with itself, into the inmost pores of plants, causes them to grow and vegetate with such admirable and incomprehensible regularity.

3rd. The common saying of countrymen, *that no kind of watering gives the country so smiling a look as rain*, may be explained on the same principle. The rainy clouds, by extending their own electric atmospheres to plants, dispose the pores of the latter to receive with greater facility the liquid which is soon to follow; and the surrounding drops penetrate into them the better, as every one of them carries along with it a portion of the penetrating dilating element.

I know that the regular distribution of water which is made by rain also contributes to render it particularly useful. It even seems to me that to each season belong kinds of rain more or less lasting—more or less sudden—and falling in larger or lesser drops, according to the different kinds of vegetation which, in every season, are to be promoted. Now, do not all these differences chiefly proceed from the different degrees of the electricity which such rains distribute or rather accompany? I have the knowledge of many facts which are favourable to these views.

Besides, the mild electricity by excess, (positive electric action of low tension,) which, as I have observed for these many years past, constantly prevails when the weather is serene, certainly contributes to promote vegeta-

tion, in the same manner as experiments have shown us that this is likewise the effect of artificial electricity *without sparks*. And is it not likely that the former kind of electricity promotes vegetation still better than the latter can do, since nature increases it and lessens it in such circumstances and in such times as particularly require it? ”

It is interesting to note that in this country also a very large number of people devoted attention to this question in these earlier days, and many writings are to be found in the literature of the earlier half of the nineteenth century which are no less ecological in their outlook than that of Beccaria from which we have just quoted. The following passage, to take an example, is taken from an interesting paper by William Sturgeon, Lecturer at the Manchester Institute of Natural and Experimental Science, published in 1846 (6). “Clouds highly charged being endowed with a formidable repulsive force, act at a great distance, and at all times of the year. In the spring and summer months, they are often productive of lightning, and teem out heavy rains, which bring down immense quantities of electric fluid to the ground, and occasion those smiling looks and healthy changes in vegetation which no ordinary showers ever produce.”

It is unnecessary to multiply references to the numerous earlier writers who have recorded observations which bear on atmospheric electricity as an environmental factor. Before, however, dealing with the question of atmospheric electricity itself we may perhaps point out that in our own time Tubeuf, for example (7, 8), has dealt with certain effects of atmospheric electricity on forest trees, which may be of ecological significance, while Gager (2) has called attention to an allied question, namely, that of radioactivity as a factor in the environment of the plant.

The study of atmospheric electricity forms at present a branch of meteorology and pure physics undergoing rapid development. The huge amount of empirical material obtained from observations through centuries is being critically examined, theory after theory has been put forward, methods have been devised and systematic observations have been initiated, and it seems likely that out of the present apparent chaos there will arise a science with definite principles based on definite facts.

Apart from the elementary facts which present themselves in thunderstorms, where the lightning indicates that *potential differences* exist between different clouds or between clouds and the earth, it was soon discovered that such potential differences not only exist in thunderstorms but also in fine weather. The potential of the air is in the majority of cases (more than 90 per cent.) higher than that of the earth. This potential difference between the air and the earth is the greater the higher the point whose potential is being measured is above the surface of the earth. Points at the same height above the ground have the same potential, that is, the electric field of the earth above flat ground has the lines of force vertical, while the

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equipotential surfaces are horizontal planes. Further, the field is homogeneous, or in other words the potential is a linear function of the height¹.

The intensity of the electric field is generally expressed by the potential gradient, that is, by the increase in potential per metre distance measured in volts per metre. The potential gradient in *absolute units* is obtained by multiplication by $\frac{1}{3} \times 10^{-4}$. The potential gradient is of the order of magnitude of 100 volts per metre, but it undergoes considerable daily and seasonal variation, and its relation to the various astrophysical and geographical factors is still rather obscure, although records are being made at numerous meteorological stations all over the world with the object of eliminating locally explicable variations.

Potential gradients are measured by exposing at the desired height, and insulated from the ground, a 'collector,' which may take the form of a flame, a plate covered with a radio-active substance, a water jet or a photoelectric active body, etc., which rapidly assumes the potential of the surrounding air. When the collector is connected to an electrometer this will indicate the potential to be determined.

Another fundamental characteristic of the electrical properties of the atmosphere is exhibited by its conductivity, which means that a charged body insulated from the ground gradually loses its charge. Although this was experimentally proved by Coulomb in 1785, it was first realised after the researches of J. J. Thomson and his school that the air contains charged particles which are responsible for this phenomenon. These charged particles are called ions and are characterised by the ratio between their electric charge and their mass. It is generally assumed that the charge of all ions is the same and identical with that of electrolytic ions, electrons of cathode rays, β rays in radio-active substances. The following types of ions are known according to their mass: (1) electrons with a negative charge and a mass of about $\frac{1}{2000}$ of that of the hydrogen atom; (2) atom ions with a mass of the order of magnitude of that of an atom or molecule; (3) ions with a mass many times that of an atom or molecule. It is these last which are of importance in atmospheric electricity, as electrons and atom ions are only observed in rarefied gases. It is assumed that the ionisation of a gas consists in the separation of an electrically neutral gas molecule into a negative electron and a positive atom ion, and both attach themselves very quickly to uncharged molecules and thus form the ions of the atmospheric electricity. The ions are further characterised by their specific velocity (that is, the velocity with which they move in an electric field of intensity 1 volt per centimetre).

Among the chief factors which produce ions in the atmosphere are radio-

¹ At higher levels of the atmosphere this law becomes only approximately true, the potential gradient decreases with increase in the distance from the surface of the earth, approximately to the extent of 1 volt per 10 metres. To explain this one must assume both a negative charge on the earth and a positive charge in space.

active substances in the ground and in the air and ultraviolet radiation from the sun.

The *conductivity* of the air, which is dependent on the presence of the ions, undergoes similarly to the potential gradient diurnal and seasonal variations, but generally in the opposite direction. The order of magnitude of the conductivity is 10^{-4} absolute units. The potential gradient and conductivity together condition a current whose magnitude is of the order 10^{-16} amperes per sq. cm. as it is the product of potential gradient and conductivity.

The above considerations on atmospheric electricity are necessary for a proper understanding of R. Stoppel's paper on the sleep movements of *Phaseolus multiflorus*. This author's recent work is a continuation of her earlier investigations (4) in which she concluded that the periodicity was due to autonomous action as she could not correlate the movement with any external factor. In the present investigation she attempts to control as many external conditions as possible in order to see which is responsible for the rhythmic movement. To that end the seeds were germinated in a dark room and the experiments were performed with the etiolated plants in the dark at an approximately constant temperature and in an atmosphere of approximately constant humidity. The movements of the leaves were registered by means of a self-recording apparatus. Although individual curves so obtained vary among themselves to some extent they agree in exhibiting a regular twenty-four hour periodicity, the leaves occupying their lowest position in the early morning. Experiments carried out with 25 plants during 67 days gave the following result in regard to the hour of the lowest position of the leaves.

Approximate time of lowest position	Number of days
10 p.m.	2
12 midnight	3
2 a.m.	3
3 "	18
4 "	24
5 "	13
6 "	3
7 "	0
8 "	1

From this it will be observed that in the majority of cases the leaves occupied their lowest position between 3 and 5 a.m.

Experiments on the influence of temperature showed that small variations (2° C. or more) do not influence the curve of movement at all, while sudden big variations in temperature (7° C. or more) decrease the capacity for movement, produce erratic movements, or injure the plant, but she concludes that temperature changes cannot be responsible for the periodicity.

The same holds for the influence of gravity. Although the form of the normal curve was influenced, the daily periodicity could not be produced by variation in the force of gravity acting directly. The proposition that

the periodicity was fixed in the present plant, exists latent in the seed, and again appears in the leaves of the daughter plant, she rejects after experiments with plants grown from seed obtained from different parts of the world (e.g., Java, America) where the daily variations in external conditions are different. Such plants gave similar curves to plants grown from European seed.

Having thus eliminated light, temperature, humidity, barometric pressure and gravity, and also hereditary factors, our author comes to the conclusion that the only periodically acting factor which could be responsible for the leaf movements is atmospheric electricity.

Of the two variable factors, potential gradient and conductivity, only the latter could be of importance in Stoppel's experiments, which were carried out in a closed space where no appreciable potential gradient could be found, but curves of diurnal variation in electrical conductivity of the air and those representing the daily leaf-movements of *Phaseolus* showed a striking similarity, both exhibiting a maximum about 4 a.m., or actually the conductivity was at a maximum when the leaves occupied their lowest position. It is to be regretted that the author did not make any measurements of atmospheric electrical conductivity in the room where she performed her experiments, but simply relied on the compilations from meteorological stations. Her further experiments bring out however that electrical conditions do actually influence the sleep movements considerably. The normal movement curves of leaves are much disturbed simply by touching the pot and the leaves, or by insulating the pot from the earth by means of a glass plate. These disturbances are much greater if the plants are not only insulated from the earth, but surrounded by an insulated metallic network. If the plant and pot are charged by means of a galvanic cell the regularity of movement reappears. If the surrounding insulating network is charged positively the leaves perform their normal movements, but with negatively charged network there are disturbances in the regularity of the movement curves and also in the intensity of the movement.

The same experiments performed with green plants, although the normal movement curves of the leaves are somewhat different, gave identical results. Certain experiments were carried out with artificial ionisation of the atmosphere, but it is to be regretted that no quantitative measurements were made.

So the author concludes that leaves of *Phaseolus multiflorus* respond to disturbances of the electrical equilibrium of the plant by movements of the leaves. It does not matter whether this disturbance of equilibrium is caused by touching the plant, by insulating it or by removing an insulation, or by adding a static charge. She has therefore become convinced that it is processes of an electrical nature which regulate the rhythmic leaf-movement. There must therefore be a rhythmically altering electrical stimulus which

acts on plants; this she contends is the periodically changing conductivity of the atmosphere as has already been pointed out.

The author has a theoretical part to her paper in which she draws far-reaching conclusions as to the importance of various processes for the production of potential differences in the plant and between the plant and its surroundings, and she also infers from the periodicity of a number of plant processes that they are caused by variations in atmospheric electricity. However an enormous amount of experimental work is required to enable such theories to be properly discussed.

Nevertheless, in spite of the many failings of the paper, the author has successfully shown that atmospheric electricity may have a profound influence on certain vital processes of the plant. Under these circumstances it is obvious that atmospheric electricity, as the older investigators imagined, is to be included among the environmental factors affecting the life of the plant, and as such it will have to be reckoned with in ecology.

LITERATURE CITED.

- (1) **Beccaria, G.** "Della elettricità terrestre atmosferica a cielo sereno." Torino, 1775.
- (2) **Gager, C. S.** "Radioactivity a Factor in Plant Environment." *Science*, N.S., **25**, 263, 1907.
- (3) **Livingston, B. E.** "A Quarter Century of Growth in Plant Physiology." *The Plant World*, **20**, 1-15, 1917.
- (4) **Stoppel, R.** "Über die Bewegungen der Blätter von *Phaseolus* bei Konstanz der Aussenbedingungen." *Ber. d. deut. bot. Ges.*, **30**, 29, 1912.
- (5) ——— "Die Abhängigkeit der Schlafbewegungen von *Phaseolus multiflorus* von verschiedenen Aussenfaktoren." *Zeitsch. f. Bot.*, **8**, 609-684, 1916.
- (6) **Sturgeon, W.** "On the Electro-Culture of Farm-Crops." *Journ. of the Highland and Agric. Soc.*, 262-299, 1846.
- (7) **Tubeuf and Zehnder.** "Über die pathologische Wirkung künstlich erzeugter elektrischer Funkenströme auf Leben und Gesundheit der Nadelhölzer." *Naturwiss. Zeitsch. f. Land- und Forstwirtschaft*, **1**, 448-461, 1903.
- (8) **Tubeuf.** "Beobachtungen über die elektrischen Erscheinungen im Walde. IV. Absterben ganzer Baumgruppen durch den Blitz." *Naturwiss. Zeitsch. f. Land- und Forstwirtschaft*, **3**, 493, 1905.