11 Effects of Electrical and Electromagnetic Fields on Plants and Related Topics

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Anyone reading this book cannot fail to realize the importance of self-generated electric fields and currents in the energetics and control of metabolism in plants. We should therefore not be too surprised to find that externally applied fields also have effects. In this chapter, I will describe a few of the more significant findings from over a century of research and try to explain and sometimes reinterpret them in the light of more modern knowledge. The work is divided into three sections. Section 1 is on the non-polar effects of DC fields, where the effects are not related to the direction of the field. It ranges from responses to massive electric fields, such as those found in thunderstorms, to the effects of much weaker ones on the growth and differentiation of tissue cultures. Section 2 is on the polar effects of DC fields, where the direction of the response is related to the direction of the field and includes effects on polar growth and tropisms. Section 3 is on the effects of time-varying and alternating electromagnetic fields, where I will present evidence that a simple change in membrane stability can account for virtually all of the hitherto mysterious biological effects of weak electromagnetic radiation.

11.1 Non-polar effects of DC electric fields

11.1.1 High voltage natural fields and the rise and fall of electroculture

11.1.1.1 Phenomenology

Work on the effects of electrical fields on plants goes back several centuries, but the first person to carry out large scale experiments was Karl Lemström, who was a Professor of Physics at Helsinki. He had paid several visits to the Arctic, and was surprised how green and healthy the vegetation looked, despite the low light and temperature. He wondered whether this might be due to the weak electric currents carried through the atmosphere by air ions from the aurora borealis. His suspicions were confirmed when he looked at

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the annual growth rings of fir trees in the region, which showed a periodicity, with best growth during the peaks of sunspot cycles when the aurora would have been most active. To test his theory, he exposed a range of different crops in several European countries to high voltage gradients from wires suspended above them. The voltages were produced by an electrostatic generator and, from the length of the sparks it could produce, we can estimate that the gradients applied to the plants were approximately 10 kV/m. He found that the treated plants were greener, sturdier and often showed dramatic increases in yield, compared with the controls. Although the technique didn't always work, on average there was a yield stimulation of around 45% (Lemström 1904). This led to a flurry of activity by agricultural scientists hoping to exploit this effect, which had now been given the name *electroculture*. Amongst these were Blackman and his co-workers of Imperial College London, who used higher voltage gradients (20–40 kV/m) in both field and pot experiments. They found that it did not matter whether the overhead wires were positive or negative, but the amount of current flowing was important. A current of 10^{-11}–10^{-8} amps per plant normally stimulated growth but higher values were injurious (Blackman 1924; Blackman and Legg 1924). But the stimulations did not occur all the time. Out of 18 field trials with wheat, barley and oats performed by Blackman (1924), only 14 gave significant increases in dry weight, Murr (1963) only found a greening effect, and Briggs et al. (1926) found no significant response in a whole series of experiments in the USA. There were many claims and counter-claims about the beneficial effects of electroculture and the matter was highly controversial. However, most of the agriculturally oriented work was discontinued in the 1930s, largely because the cost, electrical hazards, and the uncertainty of getting positive results, made it uneconomic.

11.1.1.2 Ecological significance of natural electric fields

The conflicting results of these early workers now make sense. Plants seem to be using the very strong electrostatic fields associated with thunderstorms as a signal to let them make the best use of the rain (Goldsworthy 1996). If a plant in otherwise dry conditions is to use the rain to best advantage, it must respond quickly before the water drains away. But the synthesis of new proteins, chlorophyll etc. takes several hours, so it will be of selective advantage to start before the water trickles through the soil and can be sensed by the roots. The electric fields from thunderclouds are an excellent signal for this. Schonland (1928) measured voltage gradients of up to 16 kV/m under thunderclouds, which is the sort of gradient that was effective in the electroculture experiments. The first clue that plants may actually be *using* natural electric fields to stimulate growth came from Lemström (1904), who reported that electroculture was often *inhibitory* in dry weather, presumably because the anticipated rain never came and the plants' resources were being wasted. The