government departments in connection with such varied matters as the acoustical treatment of rooms and buildings, apparatus for depth-sounding purposes, forest fire hazards, collection of insects and methods of plotting results of aerial surveys. In the metrology laboratory, apparatus for the precise calibration of standard gauges for industry has been designed and built. A satisfactory heater for use in refrigerator cars in winter to prevent freezing has been developed and is being taken up commercially. New apparatus has been installed in the electrical engineering laboratory to provide high-voltage current, and progress has been made in the precise regulation of voltage. Thousands of aircraft castings are being examined by x-ray methods and a 600,000-volt apparatus has been constructed to permit expansion of this work and for standardization of equipment for hospital use. Type approval of meters is being continued. The cathode-ray compass and direction finder, detection of fires through haze, estimation of forest fire hazard, vibration in aircraft, ultrasonic generators for depth sounding, problems in camera design for air photography and spectroscopic analyses are some of the other matters under study.

Recent additions to equipment include an electric surge generator capable of developing a million volts for use in the testing of transmission line and other insulating material.

Radium preparations in large numbers are measured and certified in the radium laboratory. Recently a device for rapid testing of radium tubes for leakage was constructed and a method for measuring the radium content of barium-radium bromide preparations was developed.

SPECIAL ARTICLES

EFFECT OF ULTRA-SHORT RADIO WAVES ON PLANT GROWTH

A NUMBER of papers were published during the last few years on the effect of radio waves on plant growth. The results obtained were not quite clear, but in a few cases a definite stimulation of plant growth was observed after seeds or plants were radiated with ultra-short radio waves.[1]

The present article summarizes some of the results of our investigation of the effect of radiation of young corn seedlings with radio waves 2.5 m long.

The waves used were generated by a magnetron oscillator of about 25 watts of power, with a GE type FH 11 split anode magnetron in a conventional circuit.[2] The tube was operated with a DC plate voltage of 1,500 volts in an air solenoid with a magnetic field strength of about 750 gauss. The heating of the filament was such that the plate current was equal to 50 mA. The tank circuit consisted of a single loop of two parallel thin-walled copper tubings 3 mm in diameter and 32 cm long. These tubings were placed vertically 3.5 cm apart. Their lower ends were connected to the plate terminals of the magnetron, and their upper ends were short-circuited. At a distance of 3 cm above the plate terminals a condenser was connected to the tubings. It was made of two 1/16 inch copper strips 3 by 5.5 cm bent to form a split cylindrical condenser about 3.5 cm in diameter. The wave-length was determined with a Lecher system loosely coupled with the oscillator.

The following experimental procedure was followed. Corn seeds were germinated in moist sand in a physiological darkroom at 25° C and 90 per cent. humidity. After 2½ to 3 days the seedlings were dug out for treatment in a room illuminated with white light of moderate intensity. Radiation of the seedlings was accomplished by placing the shoot (excluding the seed and roots) between the plates of the condenser on a strip (7 mm wide and 2 mm thick) of "Victron," a material which shows a very slight absorption of the waves used. The controls were treated exactly like the experimental plants, with the exception of the exposure to the short waves. After radiation the seedlings were planted in moist sand and put back in the darkroom, where they were kept for the duration of the experiment.

Various exposures were tried. Those of 60 seconds and longer usually destroyed the upper part of the mesocotyl, which became limp immediately after treatment and the seedlings died. Exposures of about 10 seconds turned out to be too short to produce any appreciable effect. Therefore the exposures of between 20 and 30 seconds were used in the experiments.

The results of these experiments did not demonstrate any stimulation of growth. To the contrary we found that the waves used produced, at least as far as corn seedlings were concerned, a markedly reduced growth of the first internode,[3] whereas the growth of the coleoptile was far less affected.

It was discovered a few years ago by one of us[4] that

[1] G. Murray McKinley, "Biological Effects of Radiation," pp. 541–558. McGraw-Hill, 1936; K. v. Oettingen, *Strahlentherapie*, 41: 251–285, 1931; S. Sasada, *Nippon Elect. Comm. Engin.*, 7: 295–297, 1937; A. Denier, *Proc. Intern. Congress for Short Waves*, Vienna, 1937: 320–322.

[2] Complete description in General Electric pamphlet GEJ–239A; see also E. D. McArthur and E. E. Spitzer, *Proc.* IRE.,19: 1971–1982, 1931.

[3] The shoot of the seedlings of grasses consists of the first internode or mesocotyl and above it the coleoptile which envelops the primary leaf.

[4] J. van Overbeek, *Rec. trav. bot. neerl.*, 33: 333–340, 1936.

the growth of the first internode of young seedlings of maize can be considerably reduced if they were kept in an electric oven at 48° C for 30 minutes. It was shown at that time that this effect of reduction of growth depends upon the decrease in auxin (growth hormone) production due to heat treatment. The auxin is produced in the coleoptile tip and controls the growth of the first internode. Thus a decrease in auxin production could account for the decreased growth of the internode. This conclusion was proven experimentally when it was shown that the application of synthetic auxin (indoleacetic acid) immediately after the heat treatment made the internode grow normally again.

The present investigation similarly disclosed that plants having a reduced growth of the first internode, due to ultra-short wave radiation, had a reduced auxin production (See Table 1). The auxin production was

TABLE 1

AMOUNT OF AUXIN, IN DEGREES OF CURVATIVE IN THE AVENA TEST, GIVEN OFF DURING HOURLY PERIODS BY 10 COLEOPTILE TIPS. THE TEST WAS MADE 20 HOURS AFTER THE SEEDLINGS HAD BEEN EXPOSED FOR 20 SECONDS (80929).

	Radiated	Controls
First Hour	6.3	11.5
Second Hour	3.5	6.9
Third Hour	1.9	6.5
Length of mesocotyl (mm)	34.6	44.8

determined by means of the diffusion method.[5]

In a number of cases additional auxin was applied to radiated plants. This was done with a paste of indoleacetic acid in lanolin applied to the tip of the seedlings immediately after the radiation. As experiments showed (see Table 2) such application of additional auxin restored the first internode to normal.[7]

TABLE 2

LENGTH (IN MM) OF THE COLEOPTILE (C) AND THE MESOCOTYL (M) OF CORN SEEDLINGS AFTER RADIATION WITH AND WITHOUT AUXIN TREATMEN . AVERAGES OF ABOUT 40 PLANTS (81007), (80924).

	Time of exposure (sec)	Auxin concentration per cent.	Time after radiation (hours) 24 C	24 M	48 C	48 M	72 C	72 M
Radiated, no auxin applied	20	..	11.2	13.0	20.3	30.8	...	...
	30	..	...	...	...	...	40.7	35.6
Not radiated, no auxin applied	..	..	13.3	17.2	26.2	39.8	45.9	53.0
Radiated, auxin applied	20	.02	12.8	25.0	20.0	50.3	...	...
	30	1.0[6]	...	...	...	...	53.3	45.6

[5] J. van Overbeek, *Plant Physiol.*, 13: 587–598, 1938.

[6] An indoleacetic acid concentration of 1 per cent. turned out to be too high, causing the internodes to swell rather than to elongate.

[7] Both control plants and experimental plants were exposed to light when brought in the radiation room. The reduction in growth caused by exposure to light is also offset by auxin application.

From these results it follows that, at least under the condition of our experiments, the effect of ultra-short radio waves on young corn seedlings can be accounted for as a heat effect.

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BIO-ELECTRIC POTENTIALS OF THE HEN'S EGG

THE possibility of detection of vital activity of the blastoderm of fertile eggs by physical means was suggested by Waller.[1] Also it was tried by Vorontzov and Serguijevski[2] to measure the electrical potential through the shell, between the top and the bottom of the egg on the equatorial plane. They observed that 3 to 4 hours incubated eggs gave an electro-potential difference of about 0.5 millivolt and 20 hours' incubation about 1.0 millivolt. But fresh eggs were almost isopotential, or electro-potentials were very small. Owing to that fact it is still a question whether there is a difference in electrical potentials in fresh fertile and infertile eggs. In an attempt to answer that question the present study of bio-electric potentials of the opened hens' eggs was undertaken.

The procedure followed was to apply a pair of physiological saline solution capillary electrodes to the opened egg. One electrode was touching the albumen several millimeters beyond the yolk, while the other electrode successively was placed on the top of the yolk in contact with points at various distances from the center of the blastoderm. To insure more intimate contact on the exposed surface of the yolk, the albuminous sac of the thick middle layer was ruptured and moved aside.

Potential differences existing between the electrodes were measured by a vacuum tube microvoltmeter similar to one described by Burr, Lane and Nims.[3] However, the circuit used by us was somewhat modified from that of Burr *et al.* A duotriode 6C8G tube was used with a pair of parallel filament resistances forming the grid biases close to floating grid potentials to partially offset A battery fluctuations. The input grid was brought accurately to floating grid potential by an additional C battery potentiometer control and the input was then applied across 10 megohms between the grid and ground.

[1] A. Waller, "Signs of Life." London, 1903.

[2] B. S. Vorontsov and M. V. Serguijevski, "L'electrophysiologie de l'oeuf de poule." Probleme der Tierzsucht No. 6, Moscow, 1933 (in Russian).

[3] H. C. Burr, C. T. Lane and L. F. Nims, *Yale Jour. Biol. and Med.*, 9: 65–76, 1936.