Lethal Effect of Electrolysis on Nematodes (*Meloidogyne incognita*)

S. K. GHOSH, P. K. DAS and N. C. SUKUL

Department of Physics and Department of Zoology, Visva Bharati University, Santiniketan 731 235 (West Bengal, India), 14 October 1975.

Summary. Electrolysis of salt solutions produces mortality of a plant-parasitic nematode *Meloidogyne incognita*. The mortality depends on the nature and amount of the products of electrochemical reactions and is enhanced in presence of Cu-electrodes. Application of magnetic fields on electric fields alters nematode mortality in ferro-magnetic electrolytes.

Exposure of organisms to electric fields in water produces 2 major effects: 1. orientation reaction and 2. mortality. While much attention has been paid to the first effect[1–7], the second effect has not been studied in detail. The present paper deals with the mortality of a plant-parasitic nematode *Meloidogyne incognita* resulting from electrolysis of different salt solutions made with copper and platinum electrodes.

Materials and methods. M. incognita larvae were released, in batches of 500, into electrolyte solutions between a pair of Cu- or Pt-electrodes, 1 cm^2, 0.3 cm thick and 3 cm apart, in petri plates of 4 cm diameter. The potential difference across the electrodes and the current, obtained from a 6-V battery, were 3 to 3.6 V and 0.06 mA respectively. There were 4 sets of experiments: 1. KNO_3 solution at 10^{-1} g lit^{-1} was electrolyzed with Cu-electrodes for 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 h separately and nematode mortality was determined for each duration. 2. KNO_3 solution at 5×10^{-3}, 2×10^{-2}, 4×10^{-2}, 6×10^{-2}, 8×10^{-2} and 10^{-1} g lit^{-1} was electrolyzed for 2 h and nematode mortality was determined for each concentration. 3. Solutions of 9 salts at 5×10^{-3} g lit^{-1} of the ferro- ($FeCl_3$, $CoCl_2$, $NiCl_2$), *para-* ($MnCl_2$, $CrCl_3$) and dia-magnetic groups ($ZnCl_2$, $BaCl_2$, NaCl and KCl) were electrolyzed for 2 h with Cu- and Pt-electrodes, and the mortality was determined in each case. 4. A uniform magnetic field of 750 *g* superimposed on the electric field in all the 9 salt solutions as in 3. The magnetic field was produced by bar magnets with pole faces 5 cm × 2 cm and 4.4 cm apart and was applied at right angles to the electric field ($E \perp H$), parallel to the latter with north pole and anode on the same side ($E \parallel H.N^+$) and parallel with north pole at cathode ($E \parallel N.H^-$). The control was without any electric field in 1, 2 and 3 and with only magnetic field in 4. All the experiments were done at room temperature (33 ± 2 °C) and were repeated 5 times each.

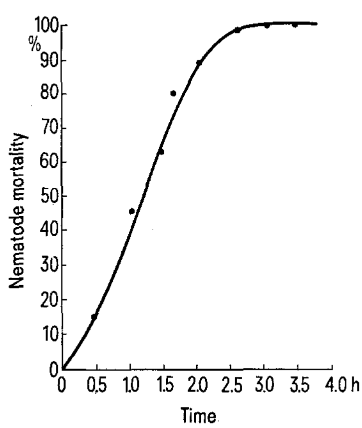

Fig. 1. Relationship between nematode mortality and duration of electrolysis of KNO_3 solution at 10^{-1} *g* lit^{-1} concentration using Cu-electrodes. Curve visually adapted. No mortality in the control without any electric field in 4 h.

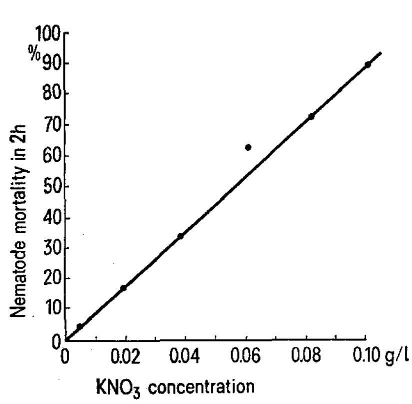

Fig. 2. Relationship between nematode mortality and varying concentration of KNO_3 solution electrolyzed for 2 h with Cu-electrodes. Curves visually adapted. No mortality in the control without any electric field in 2 h.

Results and discussion. Nematode mortality rose very sharply with the increase in time (Figure 1) and concentration of KNO_3 solution (Figure 2). Nematodes also died in 2.5 h in pre-electrolyzed KNO_3 solution at 10^{-1} *g* lit^{-1}. After 2 h of electrolysis of that solution, the pH was 6.5 at anode and 9.0 at cathode. No nematodes died in the control. The results suggest that the mortality was due to the toxic products of electrochemical reactions and was directly proportional to their amount. The mortality follows Faraday's 1st law of electrolysis. In the abscissa of Figure 1 the time could be replaced by the quantity of electricity. Nematode mortality was significantly higher (at 0.01 level) with Cu- than with Pt-electrodes in electrolytes of the 3rd set, excepting $ZnCl_2$ and KCl solutions (Figure 3). The difference in mortality was tested by Mann-Whitney test. The higher mortality with copper may be due to $CuCl_2$ as copper tends to dissolve in electric current[8]. Further, $CuCl_2$ solution at 5×10^{-3} and 2×10^{-3} *g* lit^{-1} killed 79.34% and 39.28% nematodes respectively in 2 h.

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The mortality with platinum, an inert metal, was low and might be due to the toxicity of the salt ($BaCl_2$) or to HCl and HOCl formed as a result of reaction between chlorine and water molecules. The highest mortality with

$$2\,Cl^- \rightarrow Cl_2 + 2e$$
$$Cl_2 + H_2O = HCl + HOCl$$

$BaCl_2$ (Figure 3) might be due to the toxicity of barium because the control with $BaCl_2$ alone showed 18% mortality.

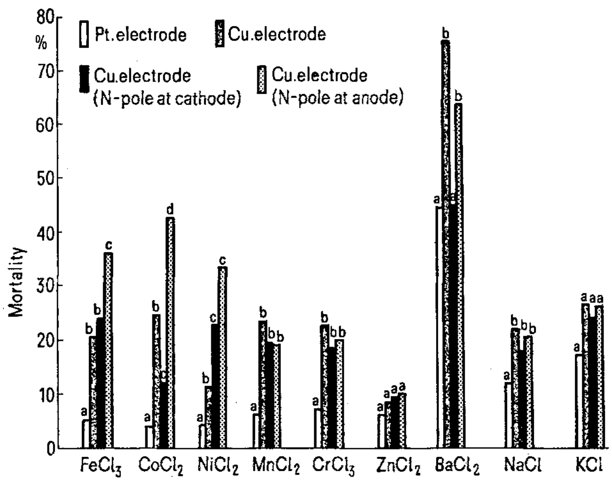

Fig. 3. Nematode mortality resulting from electrolysis of 9 salt solutions at 5×10^{-3} *g* lit^{-1} concentration for 2 h using Cu- and Pt-electrodes with and without magnetic field. Controls for each electrolyte excepting $BaCl_2$: 1. without electric and magnetic field – no mortality in 2 h; 2. with magnetic field alone – no mortality in 2 h. 18% mortality in $BaCl_2$ in both 1 and 2.
a, b, c, d, different letters indicate significant difference in mortality at 0.01 level within the graph for an electrolyte.

The average percentage mortality under crossed fields (E H) was the same as under E H.N+ and would therefore stand for both the situations in Figure 3. In solutions of ferro-magnetic salts there was a significant increase (at 0.05 level) in nematode mortality in both electric and magnetic fields (E H, E H.N+). In $CoCl_2$ there was a significant decrease (at 0.05 level) in mortality under E H.N–. No nematodes died in the control of 4.

The rate of chemical reaction is altered under the influence of magnetic fields[9–12]. BHATNAGAR and MATHUR[9] suggested that the altered rates in a number of chemical reactions were caused by a stirring effect of the magnetic field on the solution as well as an alignment of paramagnetic moments of the molecules involved. In the present experiment biomagnetic effects were observed only in case of ferro-magnetic salts and, as such, could be ascribed to the alignment of *para*-magnetic moments of the molecules which might have increased the velocity of electrochemical reactions.

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Degradation of Phenylalanine in the Presence of Hydrogen Peroxide

A. S. ANSARI, S. TAHIB and RASHID ALI[1]

Department of Biochemistry, Faculty of Medicine, Aligarh Muslim University, Aligarh 202 001 (India), 18 November 1975.

Summary. UV-irradiation of phenylalanine by 253.7 nm light in the presence of hydrogen peroxide formed 5 ninhydrin reactive products and ammonia. Four of them were identified as aspartic acid, serine, alanine and lysine.

Stable and unstable substances which produce chemical effects have been shown to be formed by ultraviolet (UV) light. One such substance is hydrogen peroxide formed during UV-irradiation of nicotine in the presence of methylene blue[2]. FERRARI and PASSERA[3] have shown the formation of serine by UV-irradiation of aspartic acid. They suggested that the hydroxyl radical for its formation comes from hydrogen peroxide, produced by UV action on oxygen present in solutions.

We noticed different behaviour of hydrogen peroxide on UV-irradiation. Exposure to 253.7 nm light results in its disappearance and the same trend was noticed when irradiated in the presence of citrulline and arginine. However, in the presence of lysine, tyrosine and phenylalanine, the amount remained unchanged with varying radiation doses. In view of these observations, an investigation of the effect of 253.7 nm light on aqueous solutions of phenylalanine in the presence of hydrogen peroxide was undertaken. Special emphasis has been laid on the separation and identification of amino acids thus formed.

A short wavelength UV-lamp Spectroline (manufactured by Black Light Eastern, Inc. USA, model R-51) having maximum emission at 253.7 nm and intensity 155 $\mu w/cm^2$ at a distance of 18″ was employed as radiation source. Aqueous solution of 2 m*M* phenylalanine were exposed to UV as previously reported[4]. To study the effects of hydrogen peroxide, equal amounts (v/v) were

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