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A Microcomputer System for Evaluating the Biopotentials of Cultivated Plants

INTRODUCTION

The thorough investigation of the electric nature of the processes occurring in plants, plant cells and organs plays a very significant role in the successful management of plant growth, development and increased productivity. The biopotential is a major electric characteristic the evaluation of which allows a better study of the interrelated mechanisms of plant photosynthesis, respiration and mineral nutrition.

Thus the clarification of the molecular mechanisms of photosynthesis, for example, depends on the understanding of the nature of the biopotentials at subcellular, cellular, tissue, organ and whole plant levels. Such an understanding provides a starting point for the search of ways of governing photosynthetic productivity and revealing the molecular organization of metabolism. Metabolism, ion transfer through cell membranes and uneven ion distribution in and outside cells produce biopotentials of rest with values ranging from 60 to 100 mV [3,4].

When external irritants (light, heat, etc.) or irritating factors of electric nature come into play or when the system of mineral nutrition or water supply of the plant is changed, cells pass into an excited state and the electric charges are redistributed resulting in action biopotentials [4].

In laser-treated plants the action biopotentials dramatically increase as compared with the biopotentials of rest [2].

While the biopotentials of action and rest at subcellular and cellular levels have been extensively studied and laboratory equipment has been developed for their measurement [3,4], the biopotentials of the plant organism as a whole have not received the same degree of attention from scientists. The understanding of exactly these biopotentials, however, would facilitate the evaluation of the physico-chemical interaction between the plant and its nutrient environment as well as the mechanisms of movement of hormones and assimilates from the site of photosynthesis to the sites on which they are brought to bear. Biopotential studies at the entire plant level would make easier the understanding of the spatial, i.e. interorganic organization of metabolic processes as well as the processes underlying the physiological interaction between plants and various nutrient substrata. Also of interest as a biopotential source is the photoinduced bioelectric plant reaction because it bears a direct link to photosynthesis.

What has been said so far challenges agricultural physicists to develop modern measuring device for the evaluation of the various types of biopotentials both at the cellular level and the whole plant level. Vransky [4] and Bichishvili [1] described the design of devices for biopotential measuring. These devices may be used for individual measurements but do not allow the organization of continual long-term measurements and the recording and subsequent processing of the data obtained.

This paper proposes a design for a microcomputer system for biopotential evaluation which permits a choice and control of measuring modes with a subsequent data processing and plotting an evaluation curve of the biopotentials over a specified period of time.

SYSTEM STRUCTURE

The successful measuring of plant biopotentials requires knowledge of their variation with time, frequency range and voltage amplitude. It is known that biopotential amplitudes vary from hundreds of microvolts to tens of millivolts demanding highly sensitive sensors and measuring devices with respect to inputs. While biopotentials of rest remain considerably stable in time, action biopotentials vary rapidly with time which calls for an adequate speed of their measurement and course recording as they change with time.

Taking into account these requirements, a structure of the microcomputer system has been suggested as shown in Fig. 1. The sensors for abstracting the biopotentials represent two electrodes whose type and shape depend on the object being measured. For measuring the biopotentials of plant cells in relation to the extracellular environment, microelectrodes of platinum or of small glass microcapollary tubes filled with an appropriate electrolyte are used. The system developed for measuring biopotentials between plant leaves and plant roots uses calomel electrodes with a platinum footing. To amplify voltages, the electrode output is connected to an electromagnetic amplifier with a controllable amplification coefficient and an input resistance of the order of 10^{11} to $10^{14}\Omega$.

The amplifier used in this case is a Vaqutronic VA-SI-I-S with a KN-TZ--RT motocompensator which provide for high frequency modulation, broadband amplification and demodulation (MDM-amplification) of the biopotentials. This type of amplifier ensures effective suppression of noises and reduced the zero drift if there is high sensitivity to input signals. The analogue output signal from the amplifier is fed into an analogue-to-digital converter connected to the data input unit of a Pravetz 82 personal microcomputer. The 8-bit analogue-to-digital convertor is based on an ADC 0804 integrated circuit and operates on the principle

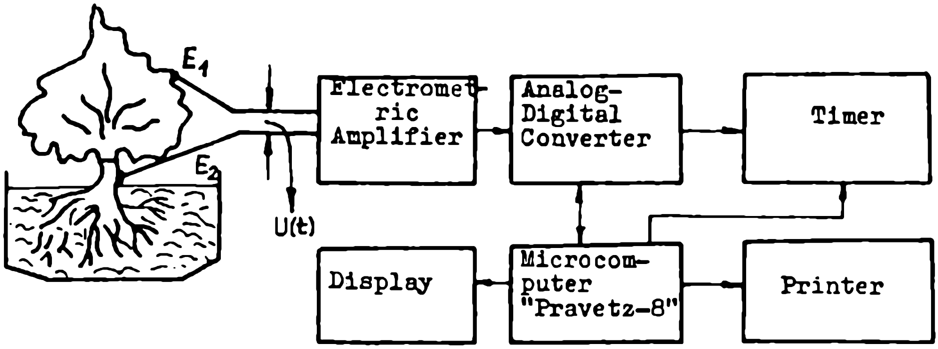

Fig. 1. Structure of the microcomputer system for measuring biopotential difference of plants

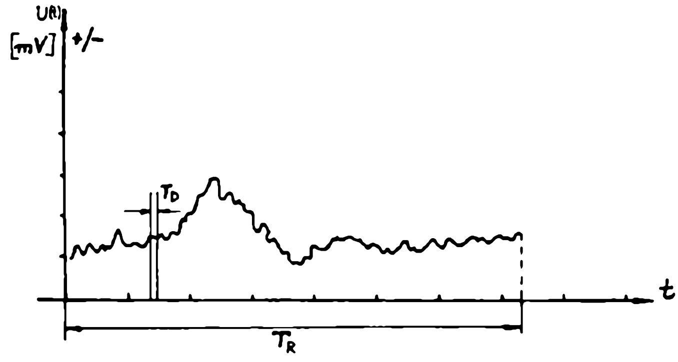

Fig. 2. Recording of the biopotential difference of a whole plant

of double integration. The unipolar analogue signal is additionally low-frequency (10 Hz) filtrated, amplified and then fed as a signal input into the analogue-to-digital converter which has a range between 0 and 3 V. A special timer is connected to the microcomputer to set time intervals T_D for the analogue-to-digital signal conversion. Using the clock cycle of the microcomputer, the timer forms impulses with a duration of 250 ms, 500 ms, 1 s, and 2 s. It can be seen in Fig. 2 that the microcomputer is assigned a time interval T_D and an integrated time interval T_R for measuring and recording the biopotentials. A shorter time interval T_D and a longer time interval T_R are chosen for action biopotentials because of their higher dynamics in time. The special timer and the analogue-to-digital converter are mounted on a separate board which is connected to the microcomputer through one of its peripheral slots.

MEASUREMENT MODES AND RESULTS

In order to organize measurements with this system, it is necessary to develop an algorithm and a program, taking into account the requirements of the researcher,

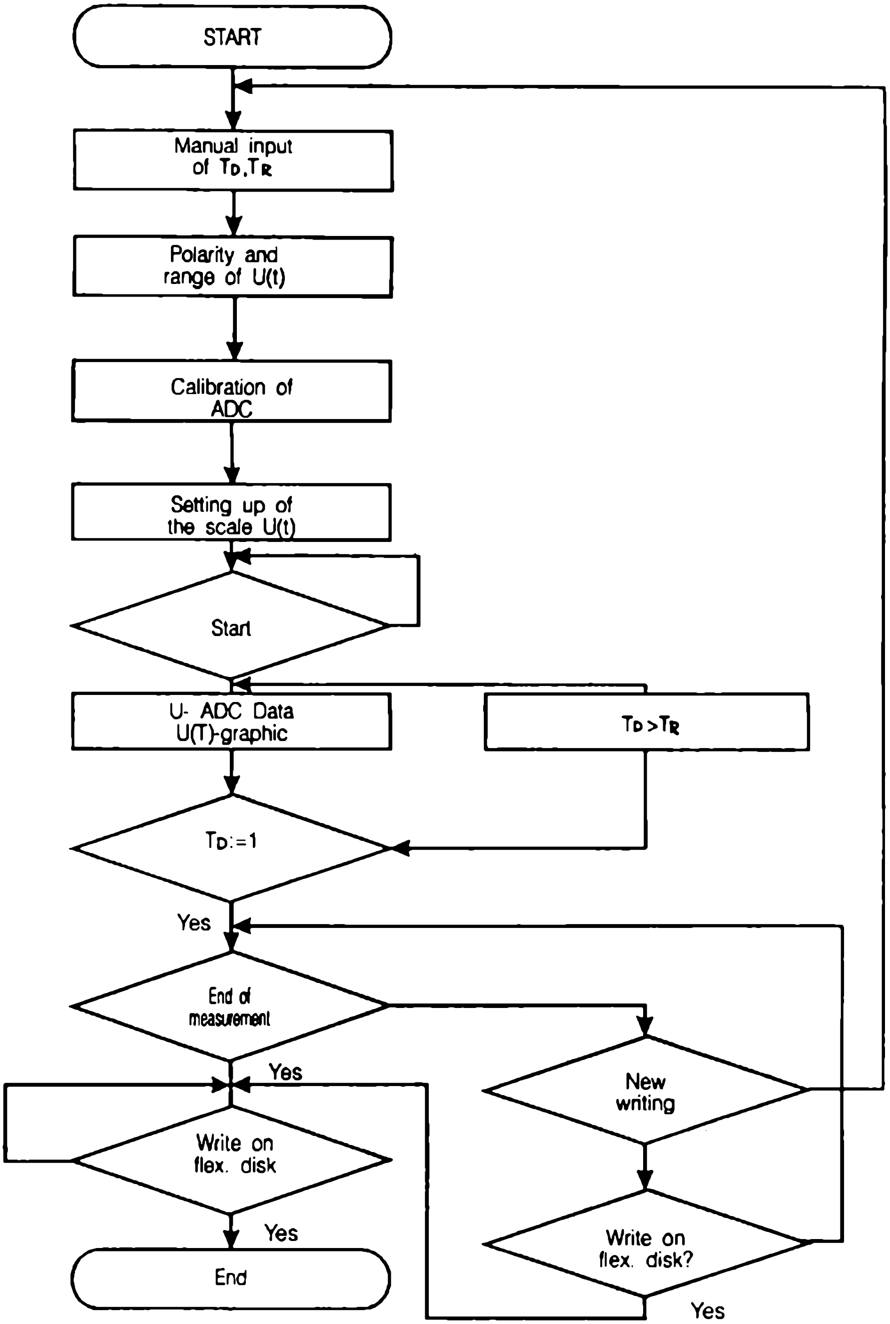

Fig. 3. Control algorithm for measuring plant biopotential

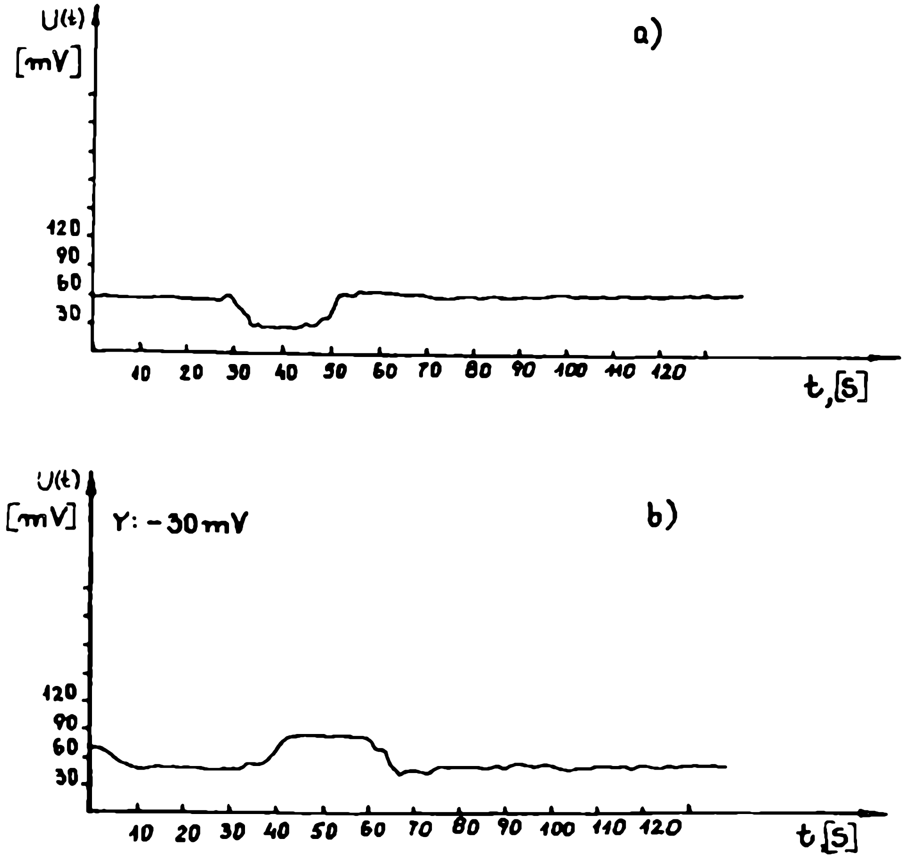

Fig. 4. Biopotential difference measuring exemplified by young soybean plants which are treated with a 60 W filament-based incandescent lamp; 4b — electrode position changed

the specific features of the object being measured and the technological capacity of the equipment used.

Fig. 3 shows the control algorithm for taking measurements which initially brings in the time values for the analogue-to-digital conversion T_D and recording T_R, the polarity and range of the biopotentials as extracted by the electrodes. The next step is the calibration of the analogue-to digital converter to check on the precision of the conversion. Then the coordinate system to which the measurement curve is to be referred is set. After these preparatory operations the actual taking of measurements, entering and storing data into the computer memory and graphic recording begin. Recording on a diskette and printing of the data are also envisaged.

The programme for the analogue-to-digital converter is written in an assembler (ADC.OBJO). The main programme for data collection and processing called ACQUISITION is written in BASIC. The operation begins with loading the computer with the ADC.OBJO programme and using a dialogue mode to assign measurement modes to the files under specified names to record data. On completing the measurements the command DATAIBIN is issued to record the data in binary code on a diskette. I is the number of the record.

A second text file DATAIDAT is created where the date, hour, and other parameters of measurement are recorded. The PRINTER programme uses a specified record number I to ensure the display of data on the screen and to print the graphics on a matrix printer. The researcher has the choice of printing the whole graphics or only interesting segments of it.

Figs. 4a and 4b shows the biopotential differences measured in young soybean plants grown in a nutrient solution and illuminated with a 60 W incandescent lamp. The lamp is switched on and off. In Fig. 4b the places of electrodes have been changed. It can be seen that the switching on and off of the lamp changes the biopotential difference which increases almost twofold when the plant is illuminated and decreases by almost the same measure when the plant is left in darkness.

The composition of the nutrient solution in which the plants have been grown also exercises significant effect on the magnitude and polarity of the biopotential difference. This could be an interesting factor to study in the context of mineral nutrition research.

Finally, the following conclusions can be made:

1. A system for measuring biopotential differences of whole plants under laboratory conditions has been developed which operates in an automatic mode.
2. This system makes it possible to analyze the biopotential difference in cultivated plants with a view to use it in mineral nutrition studies.

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