BIOELECTRIC POTENTIALS OF TUMOR-INFECTED PLANTS

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Bioelectric potentials are considered by Burr (2) to be a vital part of life processes, and any change affecting life processes is bound to exert an effect on these potentials. There is little doubt that radiation injury exerts a profound effect on the potentials of the avian embryo, as shown by Romanoff and Bless (7) and on seeds as found by Bless (1) and Jones et al. (6). The effect of tumor on the potentials is not so unambiguous. Burr and coworkers (3) found changes in the potential, measured across the chest of mice with induced tumors, the character of the changes being dependent on the age and the strain of the animals. The work of Burrows et al. (4) seems to contradict these findings. The object of these experiments is to study the effects of tumor on the potential of plants. Two sets of experiments separated by a considerable time interval have been performed with results that are essentially similar.

The circuit for measuring potentials was essentially a bridge network using an FP54 electrometer tube (5) in vacuo with an input resistance of $1.16 \times 10^{11}$ ohms. With the voltages of the plants used the current was below $10^{-12}$ amperes. Contact with the plants was made by means of felt brushes moistened with a KCl solution flowing from test tubes into which were immersed Ag—AgCl electrodes. The sensitivity of the apparatus was about 0.1 mv./div.

Tomato plants were chosen for this study because of their relative homogeneity. Two groups of 30 plants each were cultivated; one group in six-inch standard flower pots, the other in four-inch pots. Fifteen of the plants in the six-inch together with 10 of the plants in the four-inch pots were maintained as control. All plants were inoculated; those in the experimental groups with a strain of Phytoponas tumefaciens which produces a hairy tumor, and those in the control groups with distilled water. The latter action was taken so that effects due to external injury would be the same for all plants. The injections were made with a hypodermic needle at a depth of about 1 mm. below the surface. Precautions were taken to be able to locate the exact spot of the inoculation. The plants were protected with bandages at the point of insertion of the needle to prevent further infection. The plants were approximately 50 cm. in height at the time of inoculation, and about 1 cm. in diameter.

The potential of each plant at the point of inoculation relative to a point directly across the stem was measured at the same time of day on alternate days. Resistance measurements were at first taken across the same portion
of the plant for which potential readings were taken, but these were discontinued when it was found that there was no apparent difference between the resistance of tumorous and normal tissues. The potential measurements for each of the four sub-groups were begun before inoculation and extended over a period of about five weeks.

The average potential of each of the four groups is plotted in figure 1. The potential reading of each plant was taken several times so that each point on the graph represents the average of as many as 80 readings.

As is usual with work on bioelectric potentials the readings varied within wide limits. The somewhat arbitrary elimination of 10% of the readings from each end did not change appreciably the average values but reduced considerably the deviations from the mean. The uncorrected average deviation was about 0.5 mv, while the standard deviation from the mean was about 10 times as large.

It is evident from the figure that the potentials of the infected plants in the larger pots were essentially the same as those of controls during the first 16 days after inoculation. After that the potentials of the infected plants were considerably lower than those of controls. Differences in the average of the two groups became evident about seven days before the tumors became visible. In the second series of experiments, readings of the
potential were taken daily and the point of inoculation was observed by means of a pocket microscope. The tumor became discernible in 30% of the plants at about the same time as significant differences of potential appeared in the two groups. The plants in both groups were all vigorous and well nourished, since they were cultivated in pots large enough to produce fruit.

The potentials of plants grown in smaller pots followed exactly the same pattern. At first the potentials in the two groups were similar. Later the infected group showed a lower average potential than the control, which became definitely noticeable about seven days before the appearance of the visible signs of the tumor. However, the tumor as well as the significantly lower potentials appeared four days earlier than in the larger pots.

The plants in the smaller pots were definitely undernourished, being cultivated in containers too small to allow fruiting without the addition of special nutrients. They were considerably smaller than those in the larger

![Diurnal variation of potential of plants.](image)

Fig. 2. Diurnal variation of potential of plants.

pots. The fact that the tumor in the plants grown in the smaller pots appeared earlier than in the larger pots indicates that the resistance of the plants to the tumor was lower in the undernourished group. This group also showed larger variation of potential than those in the larger pots.

The deviation of the mean from zero in the initial period of the experiment and of the mean of the uninfected plants throughout the experiment was attributed to injury produced by inoculation. Obviously readings taken directly across the stem of the uninfected and uninjured plants would probably tend to average zero, providing the readings are not taken near a node.

During the seven-day period before the appearance of the tumor, a few plants still showed a higher potential for the inoculated side. This exceptional and disappointing behavior proved to be due to the fact that for some reason the tumor appeared on the side of the stem opposite to that of inoculation. The side on which the tumor appeared was consistently negative with respect to the opposite point of the stem although the magnitude of the negativity varied.
The potentials of individual plants varied greatly at first in magnitude and sign, and later in magnitude only. It seemed interesting to find out whether the variation has a diurnal periodicity. The potentials of 10 plants from each of the infected and uninfected groups were measured at six-hour intervals for 72 hours. The measurements were started at a time when about 30% of the plants showed the presence of tumor when observed with a microscope. The variation of the average potential for each of the groups is shown in figure 2. As is evident from the figure there seems to be a periodicity irregular in time in the case of the uninfected plants, while those infected seem to show a different periodicity.

Potential gradients were plotted for six plants cultivated in six-inch pots, three healthy and three infected, subsequent to inoculation but prior to the appearance of tumor. One contact was kept fixed at a point about 1 cm. above the level of the soil and the other was moved upward along the opposite side of the stem in 1 cm. intervals. The resulting curve is shown in figure 3. It was expected that the gradient would be affected by the presence of the tumor in the infected plants, but no such behavior was found. Two interesting facts were revealed, however; the trend of the gradients seemed to be from the higher to lower potential upward along the stem, and the presence of leaf sprouts caused in most cases a sharp rise in the curve.

These experiments indicate that the bioelectric potentials are affected by the presence of a tumor in plants even before the tumor becomes visible to the unaided eye. While the potential of a plant fluctuates greatly during its growth, the point at which a tumor develops shows an unmistakable trend to become electronegative with respect to a neutral point.

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LITERATURE CITED


