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PLANT BIOELECTRIC POTENTIAL VARIATION IN CROTON (EUPHORBIACEOUS GENUS CODIAEUM) UNDER NATURAL LIGHT CONDITIONS

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Plant bioelectric potential (BEP) variation was observed in actively photosynthesizing leaves of croton plant under natural light conditions. It was found to vary with the intensity of light. BEP reached a 'saturation' value in 4 to 4½ hours time on upper surface of leaf, whereas 'saturation' occurred in 2½ hours for the lower surface of the leaf. The BEP of leaf exposed to sunlight was considerably higher than that of leaf covered. The BEP slowly declined after the 'saturation' value during midday and reached a minimum at midnight and early hours of the day. It is suggested here that BEP arises due to light dependent processes namely photosynthesis in plants.

Key words: Plant BEP, effect of photosynthesis

INTRODUCTION

The electrical responses of biological meterials can arise from many photoreceptors, thermoreceptors, electroreceptors, chemoreceptors and mechanoreceptors [1]. The conductivity of protein systems is based on electron transfer between redox centres which involves jumping of electrons from one organic group to another, also known as hop mechanism [2]. Also a large number of metal complexes present in plant materials are centres for such electron transfer apart from pigments like chlorophylls, flavins, quinones,carotenoids, polysaccharides and thiols. The electric potential generated in plants is the result of ion exchange properties and the existence of numerous fixed negative charges in the polysaccharides of the cell wall [3] giving rise to a Donnan potential.

Use of microelectrodes [4-7] in electrophysiological investigations has established that illumination of green plant cells is associated with changes in the difference of electrical potentials between contents of cell and the external medium, and those changes were found arising due to photosynthesis. The rate of electron transfer from photosystem 2 (PS2) to photosystem 1 (PS1) in photosynthesis is known to be controlled by the redox state of a pool, probably of plastoquinone reacting in between the two photochemical systems [8]. However, no extensive studies have been made to conclusively determine variation of bioelectric potential of intact plant leaf with the intensity of light, *in vivo*. Bioelectric potential (BEP) measurements of germinating seeds of various plants and that of Hydrilla verticillate under varying conditions of respiration and photosynthesis have been reported [9] with a conclusion that the BEP in plants is the result of respiration. The present study of the variation of BEP on the surface of intact leaf of croton plant *in vivo* under natural light conditions further confirms the view that the photosynthesis also contributes to the plant BEP.

EXPERIMENTAL

The plant BEP was measured on the surface of an actively photosynthesizing leaf of croton plant *(euphorbiaceous genus codiaeum)* grown in an earthen pot and regularly irrigated. The working electrode was a platinum foil of size 2 x 2 x 0.05 cm, soldered to a silver wire lead. The potential on the leaf surface was measured with high impedance electrometer in conjunction with a saturated calomel reference electrode placed in the soil of the pot through an agar agar bridge as shown in Fig.1.

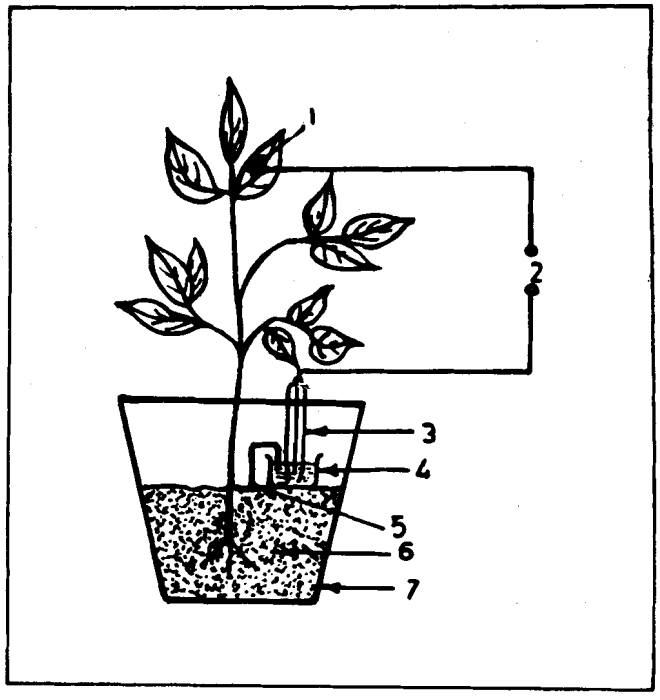

Fig. 1: Experimental set up for measurement of bioelectrical potential (BEP) in the croton plant
1. Metal probe (Pt foil) 2. Electrometer,
3. Saturated calomel electrode 4. Saturated KCl
5. Agar agar bridge 6. Soil 7. Pot

All the recordings were made under natural physiological conditions of the plant. The test leaf chosen for the experiment was always from the upper most branch of the plant. Measurement of BEP was done by fixing the platinum foil probe to the surface of test leaf with the help of a cellophane tape. Before the start of the experiment the plant was thoroughly irrigated with water.

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RESULTS AND DISCUSSION

The plant BEP was recorded during the course of the day. BEP on the upper surface of the leaf was higher than the lower surface of the leaf and increased from -9 mV to + 173 mV in former case and from -40 mV to + 140 mV in the latter case. In both the cases there was an increase in BEP during the course of the day as shown in Fig. 2.

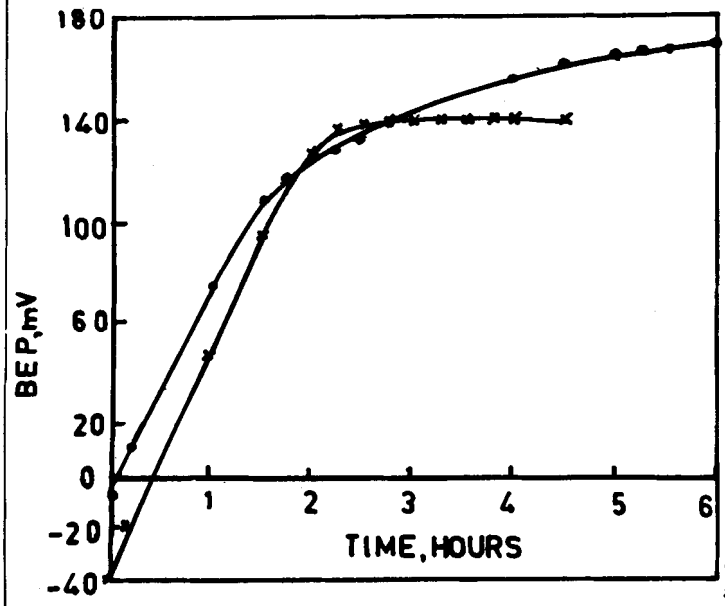

Fig. 2: Variation of BEP during the course of the day —.—.— Upper leaf surface; —x—x— Lower leaf surface

The value reached a 'saturation' in about 4½ hours time in case of the upper leaf surface, whereas it reached a 'saturation' value in the lower leaf surface in about 2½ hours time. The intensity of light during this period progressed from 60 mW/cm^2 to a 'saturating' value of 86 mW/cm^2 and temperature varied from 310K to a maximum value of 317K. As can be seen from the Fig.(2), 'saturation' sets in at higher intensities of light whereas at low illumination amplitude of potential changes is proportional to the intensity of light. The results were reproducible when repeated under similar physiological and environmental conditions.

BEP monitoring was also done on the surface of leaf covered with a thick black paper. There was a significant difference in the maximum value for potential (+ 120 mV to + 140 mV) between leaf exposed to sunlight and leaf covered. The value of BEP of leaf unexposed to light was markedly less than the BEP of leaf exposed to light, although the pattern of increase in BEP with increasing time was maintained in both the cases (Fig. 3).

A 24-hour monitoring of BEP on the surface of leaf recorded by printing voltameter revealed a gradual decline in potential with the passage of time and reached a minimum after midnight (Fig. 4). It is interesting to note that BEP falls gradually from 6.20 P.M. and is very low during midnight and early hours of the day.

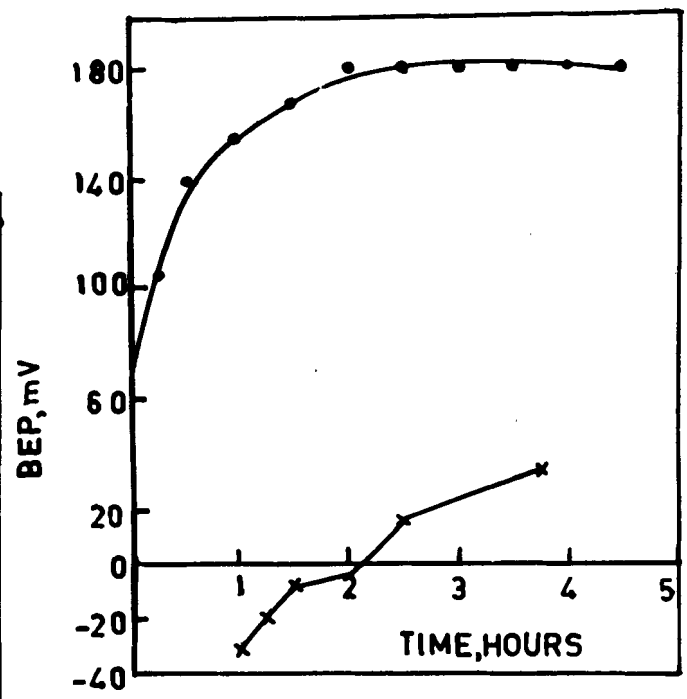

Fig.3: Light dependence of BEP; —.—.— BEP of leaf exposed to sunlight; —x—x— BEP of leaf covered with black paper

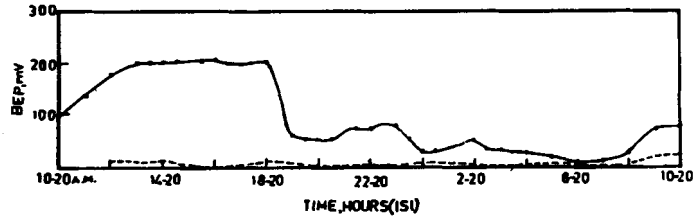

Fig.4: A 24-hour record of BEP for leaf exposed to sunlight (—.—.—) and for leaf covered with black paper (.....)

These results clearly show a dependence of the plant BEP on intensity of sunlight. Although the results were reproducible when done on clear days, the readings remained constant or fluctuated, on cloudy, partially cloudy or windy days. This again indicated that a light dependent phenomenon may cause a change in BEP and is confirmed by our experiments (Figs. 2-4). It has been reported [10] that change in potential difference between the cytoplasm and the external medium of higher plants was dependent upon the intensity of the exciting light and temperature of the medium. However, photoinduced BEP observed in our experiments was found to be independent of temperature when experiments were carried out in presence of heat cut off water filter (data not shown). The difference in the value of BEP found on

upper surface and lower leaf surface (Fig. 2) can be attributed to difference in illumination of the two surfaces. Our results also showed that BEP may differ in value and polarity due to variation in leaf size, plant growth conditions and other environmental factors although it was independent of location of the sensing probe on the surface of test leaf.

Since BEP observed on the surface of leaf was light induced, it is suggested that it possibly arises due to charge transfer components involved in the process of photosynthesis. It is likely that slow variation of BEP observed with time (Figs. 2 and 3) is due to the fact that potential sensing probe is on the surface of leaf, rather in contact with internal cellular compartments of photosynthesis. The initial rapid rise in potential may arise due to separation of charges on the surface. A fall in BEP with a fall in intensity of photosynthesis was observed [11] and related it to photophosphorylation. Saturation behaviour of light induced electron spin resonance (ESR) signal I in light mostly absorbed by photosystem-II in intact algal cells, isolated chloroplasts and intact leaf segments was reported [12]. ESR signal-I could not be observed in leaf segments even at high light intensities and it was suggested that a rate limiting step may occur on the acceptor side of PSI leading to a build up of electrons at the primary acceptor and hence preventing the formation of signal-I. It was suggested [13] that such an abundance of reductant may occur under certain physiological conditions. Our results though may not give a direct evidence for the correlation of the plant BEP to the process of photosynthetic electron transport occurring at cellular level yet can be correlated indirectly to the process of photosynthesis through its dependence on light.

CONCLUSION

The plant BEP is considerably affected by intensity of sunlight. It attains a maximum steady value around midday after which it slowly declines to a minimum value during midnight and early hours of the day. In the earlier study [9], the light dependence nature of the plant BEP could not be observed clearly. Perhaps, it might be due to difference in location of the platinum sensing probe. The present observations clearly indicate that in addition to other factors photosynthesis also contributes to plant BEP.

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