Effect of external electrical field on mobile water fraction and physiological processes in wheat (*Triticum aestivum*) leaves

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Experiments were conducted to study the effect of external electric field on physiological processes, moisture content and mobile water fraction in wheat leaves. Application of electric field increased the stomatal resistance immediately and it continued to increase up to 10 min. Photosynthesis and respiration of leaves decreased with the application of external electric field. Leaf moisture content and mobile fraction of water measured as relaxation times were marginally increased with electric field. Closure of stomata, in spite of maintaining higher leaf moisture content of the leaf with external electric field, suggested that electric field might have regulated stomatal movement through hormones or ion flux across the cells.

Plant growth and regeneration processes are regulated by spatial patterns of an electrical potential and an electric current. Maintenance of morphological and physiological polarity in higher plants and rhizoid formation in brown algae *Fucus* have been found to be associated with the gradients in bioelectrical potential. It is also known that, in plants, bioelectrical potential is involved in coordinating various physiological processes. Stomatal closure was observed within 20–200 sec after the propagation of an action potential (AP) in KCl treated pumpkin plants, 2–5 sec after propagation of ABA induced AP in *Wile salix* and within 25 sec after polyethylene glycol (PEG) induced AP in sunflower. Propagation of wound induced variation potential decreased the photosynthesis rate of tomato and increased the respiratory rate of liverwort *Coneophyllum conicum*. Changing the bioelectrical potential gradients by an external electric field affected plant growth, development and physiological processes.

Electric shock applied to the leaves closed stomata in *Mimosa*, *Phaseolus* and *Nicotiana*. In maize the application of external weekly current accelerated growth of axial plant organs and altered the mode of basipetal transport of auxin.

In this study, the effect of external electric field on stomatal resistance, photosynthesis rate and respiration rate of wheat plants were measured. Regulation of these physiological processes was found to be related with the leaf mobile water fraction. Mobile water fraction is related with the molecular mobility of hydrogen nuclei present in the sample, which is measured as spin lattice relaxation time in pulsed NMR. Higher the relaxation time lesser is the degree of binding of liquid phase. Hence, in order to understand the effect of electric field on mobile fraction of water the relaxation time of wheat leaves was measured after the application of external electric field.

Wheat (*Triticum aestivum* var. C-306) seeds were obtained from Division of Genetics, Indian Agricultural Research Institute, New Delhi. Seeds were planted in earthen pots (25 cm diameter; 30 cm height) of 8 kg capacity. Recommended dose of fertilizer and FYM were applied at the time of sowing. Plants were irrigated daily and placed in a nethouse with 1250 to 1500 uEinstein m⁻² s⁻¹ solar radiation and maximum temperature ranged between 30° to 35° C. Experiments were conducted in 30 day old seedlings.

Smooth, non-damaging crocodile clips were connected on the plant surface to make electrical contact. The positive polarity (anode) was connected at the shoot tip and the negative polarity (cathode) was connected at stem base. External electric field of 3 and 12V DC was supplied to the plant using chargeable nickel-cadmium battery cells. Control plants had electrode connection without electricity supply. Electric potential was measured at regular intervals at the point of connection using a digital multimeter to ensure proper flow of electricity through the plant. All the treatments had minimum of 4 replications until unless mentioned.

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The following observations viz. diffusive resistance, photosynthesis rate, respiration rate, spin-lattice relaxation time and moisture content were recorded in the flag leaf of electric field applied plants.

Diffusive resistance of the top most fully opened leaf was measured using steady state porometer (LI-1600 with Vaisala HUMICAP sensor). Diffusive resistance was measured in control (no electric current) and treated (3 and 12V DC voltage) plants at different time intervals (sec.cm⁻¹).

Photosynthesis rate of the top most fully opened leaf was measured using a portable photosynthetic system (LI-6200, Lincoln/Nebraska, USA). It was measured before making electricity connection and at the end of 30 min of electricity application. Similarly, respiration rate of topmost fully opened leaf was measured at initial stage and at the end of 30 min electricity application using Oxygraph (Gilson Oxygraph)¹⁸.

Relaxation time of control and electricity applied leaf was measured at 20 MHz and ambient temperature using a Bruker Minispec PC 20 pulsed Nuclear Magnetic Resonance (NMR)¹⁹. Immediately after excising the sample leaves from the plant, it was folded without damaging any part and inserted into an 18 cm³ NMR tube. Care was taken to see that no air space is left in the tube. Each measurement took 2 min.

Leaves moisture content was determined and expressed on fresh wt basis. Per cent moisture content = [(FW-DW) / FW]×100. Where FW is the fresh wt of the leaf blades and DW is dry wt of the leaf after dehydration for 24 hr in an oven at 80°C.

Stomatal resistance of wheat increased with the application of an external electrical field. Control plants had a stomatal resistance ranging from 1.46 to 1.52 sec cm⁻¹ (Table 1). Application of 3 and 12 V electricity raised stomatal resistance to 1.598 and 2.164 sec cm⁻¹ respectively at 2 min. It further increased to 1.92 and 3.06 sec cm⁻¹ with 3 and 12 V respectively at 10 min. At 30 min stomatal resistance was stabilized at 1.93 and 3.24 sec cm⁻¹ with 3 and 12 V respectively.

Application of external electric field reduced both photosynthesis and respiration in wheat (Table 2). Electricity passed through the stem for 30 min reduced the photosynthesis rate by 19 and 23 %, and respiration rate by 6 and 25 % with 3 V and 12 V electricity respectively.

Electric field brought about a marginal increase in leaf moisture content and relaxation time (Table 3). Moisture content increased by 0.48 and 0.93% while relaxation time showed an increase of 3.3 and 10.5% with 3 and 12 V DC respectively. A positive correlation was observed between moisture content and relaxation time (r=0.656).

External electric field applied to wheat plant increased the moisture content and relaxation time, i.e. mobile fraction of water in leaves. Increase in moisture content and relaxation time was more with 12 V as compared to 3 V DC current. Positive correlation was observed between moisture content and relaxation time (r = 0.656). Similar kind of relationship between moisture content and relaxation time was recorded in control and drought stressed pearl millet.

Stomatal resistance increased with the application of external electric field in spite of higher leaf water content as maintained in these plants. This suggested that electric field might have regulated stomatal...
movement either through hormones or ion flux in wheat. In *Wilo salix*, it has been observed that application of external ABA generated an action potential (AP) which closed the stomata. Similarly, association between electrical potential and ion movement has been characterized in animals and lower organisms like Chara and Nitella, where K⁺, Na⁺, Ca²⁺, and Cl⁻ has been shown in generation and propagation of, AP. Further, sunflower plants deficient in K in rooting medium did not elicit propagation of AP, when they were given an electric shock of 3V.

Stomatal closure with application of external electric field had led to less availability of CO₂ inside the leaf, hence, the photosynthesis rate was reduced. This led to decreased availability of substrates for respiration and thus respiration rate was decreased.

In conclusion it can be stated that electrical potential in plants might be coordinating with various physiological processes through regulation of ions movement into and across the cells or by altering the hormone levels.

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