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To Investigate the Effect of Pressure on the DC Resistance of the Aloe-vera (Aloe Barbadensis Miller) Leaves

Sanjeev Kumar Sharma, Randhir Singh, Parveen Lehana

Abstract— In nature, plants interact with many environmental factors such as winds, monsoon rains, touch, and herbivore attacks, in addition to many other ruthless mechanical perturbations that can menace plant survival. As a result, over many years of evolution, plants have developed very sensitive mechanisms through which they can identify and respond to even slight stimuli such as touch. Some plants respond behaviorally to the touch stimulus within seconds, while others show morphogenetic alterations over long periods of time, ranging from days to weeks. Aloe-vera plant has been known and used for centuries for its health, beauty, medicinal, and skin care properties. The name Aloe Vera derives from the Arabic word "Alloeh" meaning " shining bitter substance," while "vera" in Latin means "true". In this paper, investigations were carried out to study the effect of DC resistance of the Aloe-vera leaves. The resistance of the leaf measured shows a comparative change with the change in the apply pressure on the leaf. The resistance of the leaf tissue decreases with the corresponding increased in applies pressure between the electrodes due to increase in current path. A mechano-stimulus received at the cell wall may cause alterations in the intracellular pressure. This pressure stimulus may lead to the translocation of sub-cellular organelles, thus transducing the stimulus to a cellular alteration with the potential for downstream effects.

Index Terms— Aloe-vera, aloe barbadensis, force sensitive resistance, DC resistance.

I. INTRODUCTION

Every living organism either plant or animal has a property that they respond to internal as well as external stimuli. Plants can be considered as complex multicellular organisms and are as sensitive as human beings for initial assessment of effects and testing of new therapies [1]. Because of their immobility, plants are affected by environmental stresses. One of the important research fields focused by biologists and physicists is the relationship between environment stress and plants could respond to the environmental factors such as wind, touch, electric field and ultraviolet radiations by modifying their physiological properties. Xiujuan et.al. [2] in 2002 found that the relationship between environment variables and growth of plant was highly correlated. Plants growth can be considered as the sum of cell proliferation in the meristem and the subsequent elongation of cells. Gurovich and Hermosilla [3] studied the electrical signaling in fruit trees in response to water applications and light-darkness conditions. Resulting from abiotic and biotic changes in environmental conditions, all living organisms generates and conduct electrochemical impulses throughout their different tissues and organs. Plieth et.al [4] in 1999 have demonstrated experimentally the properties of temperature sensing in plants. The plants also show response to the stimulating electrical signals. These signals may set off different physiological reactions [5]. For example, the signals can cause swift leaf movements in certain plants and some other changes in plant physiology [6]. Desrosiers and Bandurski [7] in 1987 investigated the effect of longitudinally applied voltage on the growth of Zea mays seedlings. Four days old Zea mays was taken and voltages ranging from 5 to 40 volts were applied along the mesocotyl region for the time period of 3 or 4 hours. It was found that a 5 Volt Potential inhabited the growth strongly, when the seedling's shoot was electrically positive as compared to base of the seedlings. On the other hand, no effect was seen reversing the direction of polarity. Ksenzhek et. al. [8] in 2004 investigated the electrical properties of leaves of monocot plant Zea mays indurata. The DC resistance of plant tissues was calculated in different directions with respect to midrib due to macroscopic structural anisotropy of the leaves.

In physical terms stress is defined as mechanical force per unit area applied to an object. In response to the applied stress, an object undergoes a change in the dimension, which is also known as strain. As plants are sessile, it is tough to measure the exact force exerted by stresses and therefore in biological terms it is difficult to define stress. A biological condition, which may be stress for one plant may be optimum for another plant. The most practical definition of a biological stress is an adverse force or a condition, which inhibits the normal functioning and well being of a biological system such as plants [9]. A cell is separated from its surrounding environment by a physical barrier, which is the plasma membrane. This membrane is permeable to only some small lipid molecules such as steroid hormones, which can diffuse through the membrane into the cytoplasm and is impermeable to the water-soluble material including ions, proteins, and other macromolecules. The cellular responses are initiated primarily by interaction of the extracellular material with a plasma membrane protein. This extracellular molecule is called a ligand (or an elicitor) and the plasma membrane protein, which binds and interacts with this molecule, is called a receptor. Various stress signals both a biotic as well as biotic serve as elicitors for the plant cell.

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* Correspondence Author (s)
Sanjeev Kumar Sharma*, M-tech, Electronic & Communication Department, Sri Sai College of Engineering & Technology, Pathankot, Punjab. India.
Randhir Singh, Assistant Prof. and HOD, Electronic & Communication Department, Sri Sai College of Engineering & Technology, Pathankot, Punjab, India.
Parveen Lehana, Associate Prof., Physic and Electronics Department, Jammu University, J&K, India.

Each plant has its unique set of temperature requirements, which are optimum for its proper growth and development. A set of temperature conditions, which are optimum for one plant may be stressful for another plant. Many plants, especially those, which are native to warm habitat, exhibits symptoms of injury when exposed to low non-freezing temperatures. These plants including maize (Zea mays), soyabean (Glycine max), cotton (Gossypiumhirsutum), tomato (Lycopersicon esculentum), and banana (Musa sp.) are particularly sensitive to temperatures below 10–15 °C and exhibits signs of injury. The symptoms of stress induced injury in these plants appear from 48 to 72 hours. However, this duration varies from plant to plant and it also depends upon the sensitivity of a plant to cold stress.

Mechanical perturbations are among the many environmental stimuli to which plants respond. Plants sense forces ranging from very severe and to more subtle and moderate ones as well. Many studies have focused on plant responses to wounding, a tissue-damaging mechanical perturbation often used to simulate insect and microbe attacks. Plants sense and respond to mechanical stimuli instantly, as well as over time, by synthesizing an array of phytohormones and other chemicals in addition to expressing defense related genes that decrease herbivore ability to colonize, feed, and reproduce. Similar responses occur in plants stimulated by more subtle mechanical cues including touch [10]. Systemic induced immunity in plants to viruses, bacteria, and fungi has been well documented over the past 4 decades, and numerous reports of induced insect resistances that are systemically mediated have appeared within the past 5 years. Only a few of these systemic resistance responses toward microorganisms and insects have been studied at the biochemical or molecular levels.

The most important physical signal in any organism is electrical signal. As compared to chemical signals (e.g. hormones) electrical signal is capable of transmitting signals more quickly over long distances. Recently, biologists have discovered that electrical signals are very important to many physiological activities [11]. In fact, one of the basic modes of information transmission is the intracellular electrical signals in plant cells. Electrical signals have been shown to be involved in many processes in plant life, including respiration, water uptake, leaf movement, and biotic stress response [12].

Our hypothesis is that the health of each plant may be predicted by recording the electrical signatures of the plants in response to external stimuli such as sound, touch or vibrations. Moreover, intracellular pressure may play a role in perceiving mechano-stimulation. A mechano-stimulus received at the cell wall may cause alterations in the intracellular pressure. This pressure stimulus may lead to the translocation of sub-cellular organelles, thus transducing the stimulus to a cellular alteration with the potential for downstream effects. A limited work has been reported on recording and relating the electrical signatures of the plants with their health. The objective of this paper is to investigate the effect on the DC resistance by applying pressure on the leaves of Aloe-vera. Aloe-vera has been chosen because of its numerous applications in dermatology.

Fig. 1. Aloe-vera.

II. ALOE VERA

The Greek scientists regarded Aloe-vera as the universal panacea. The Egyptians called Aloe “the plant of immortality.” Today, the Aloe-vera plant has been used for various purposes in dermatology. New plants mature in 4-6years and can survive for nearly 50 years in favorable conditions. They have thick, green leaf like structures that grow from a central point. Aloe does not have a typical stem like other plants do, it is a stemless plant. The plant can survive in hot temperatures ranging from 104 degrees Fahrenheit down to freezing temperatures as long as the root of the plant is not damaged [13]. There are more than 9200 compounds found in Aloe-vera, about 75 of which are biological active [14]. The prominent components are anthraquinones [15], aloin, aloe emodine polysaccharides [16], and enzymes reducing sugars, organic acids, and metallic cations [17]. The aloe gel or fillet, which is stored in the inner portion of the leave, contains 99.5% water and 0.5% solid matter. The solid ingredients in its gel are divided into large molecules (0.1 %) and small molecules (0.4 %). Large molecules are polysaccharides and the minor constituents include a mixture of proteins (glycoproteins), and compounds of lower molecular weights, such as sterols, terpenes, and other molecules.

In Arabian medicine, the gel is used on the forehead as a headache remedy or rubbed on the body to cool it in case of fever, as well as being used for wound-healing, conjunctivitis, and as a disinfectant and laxative [18]. The aloe gel has been extensively used in gastrointestinal disorders, including peptic ulcer, and its clinical efficacy has been well documented [19], [20].

The original commercial use of the plant was to grow for the production of a latex substance called aloin, which is yellow in color possessing bitter and lingering taste. The latex of aloe contains the laxative anthraquinones that have been shown to possess substantial antimicrobial activity against a wide variety of microorganism [21]. The other main ingredient of aloe is called gel, which covers inner portion of the leaves. It is clear, colourless, and tasteless. Aloe-vera gel, like most natural juices in both fruits and vegetables, is unstable and subject to discoloration and spoilage from contamination by microorganisms. It is, therefore, most important to stabilize and concentrate the gel in powder form, for commercial use in nutritional foods and cosmetics.

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Today the aloe industry in USA and Mexico has established high ethical standards for businesses and aloe products. Through the International Aloe Science Council of America (IASC), the aloe Industry in America and Mexico solidified its dedication to providing the world with highest quality aloe and aloe products. The wide acceptance of aloe by society in so many consumer-products suggests that the IASC is moving in the right direction. The IASC has committed professionals to the further growth of aloe products by quality-research and marketing.

III. METHODOLOGY

The investigations were carried out on the leaves of Aloe-vera plant to investigate the effect of electrical signals on the health of the leaves. The effect due to external pressure on the DC resistance of the leaves of Aloe-vera was studied by recording the variation dc current and voltage across the leaf. The plant was grown in a pot containing fertile soil under natural environmental conditions. Plant was watered every day and the care was taken for its proper growth and development.

Fig. 2. Experimental setup for DC analysis.

The experimental setup is shown in Fig. 2 and is used to measure the resistance with respect to the pressure applied between two different electrodes along the length of Aloe-vera leaf. The triangular shaped electrodes of zinc (Zn) and copper (Cu) measuring in area as 0.04 cm^2 with resistance of approx. 0.7 Ω to 1.2 Ω were used for establishing contact with the leaf tissues. Extra care was taken to ensure that the plant tissues are not damaged while connecting the electrodes to the leaf. The experimental setup comprised of an external DC source *(V_1)*, potentiometer *(R_1)*, micro-ammeter (μA) for measuring current (*i*), milli-voltmeter (mV) for measuring voltage (V_2), and force sensitive register (FSR) connected along the length of Aloe-vera leaf between two electrodes that sense pressure and converted into V_{fsr}. The FSR model is 402 and it is shown in in Fig 3.

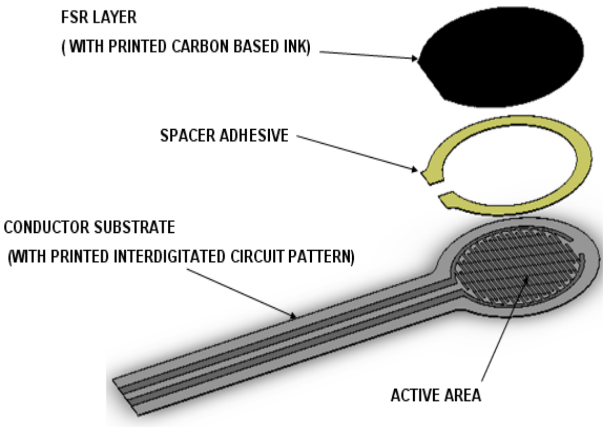

Fig. 3.A 402 Model of Force sensitive register**.**

The schematic for the dc circuitry is shown in Fig. 5. The DC source used was kept fixed at 2.5 volts and the value of series resistor was taken as 10 kΩ. The pressure was applied using an adjustable clip and fixing it on the leaf. The FSR was fixed in the claws of the clip. Measurements were started after 30 seconds to give proper relaxation time to the plant leaf. This interval was found to be sufficient for measurement because all induced processes are settled down in this time.

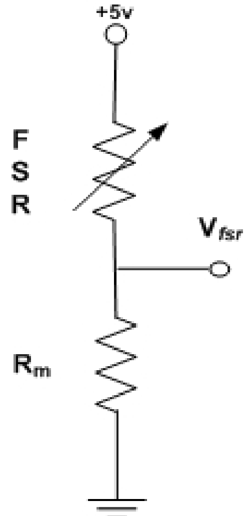

Fig. 4. Circuit diagram converting external pressure to voltage (V_{fsr})

For a simple pressure-to-voltage conversion, the FSR device was tied to a measuring resistor in a voltage divider configuration. The output is described by the equation

$$V_{fsr} = (V+) / [1 + R_{fsr}/R_M].$$

In the above configuration, the output voltage increases with increase in external pressure applied to the FSR. Due to applied pressure resistance (R_{fsr}) of FSR was varied and thus the output voltage V_{fsr}. Thus pressure (kpa) and V_{fsr} *are* proportional to each other. The measuring resistor, R_M was fixed at 10 KΩ and was chosen to maximize the desired pressure sensitivity range and to limit current. The current through the FSR should be limited to less than 1 mA/square cm of applied pressure.

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IV. RESULT AND DISCUSSION

Table 1 shows the DC resistance estimated from the ratio of voltage and current recorded at different pressures on the leaf. The recorded current and voltages are plotted in Fig. 6 and Fig. 7, respectively. The current increases almost linearly with external pressure. The variation of voltage across the leaf with the external pressure is observed somewhat nonlinear. This may be due to the use of different type of electrodes used for the measurement. Different types of electrodes cause some contact potential and disturbs the relation between the voltage and external pressure. The ratio of voltage and current is plotted in Fig. 8. It is clear from the plot that DC resistance increases with the increase in external pressure between the electrodes. The deviation from the exact straight line relationship may be due to the variation in shape and offset voltages developed at the contact junctions. The investigations with different leaves having varied type of damages showed that the relationship differs. It means the estimate of the damage and the internal health of the plant leaves may be assessed by observing the DC resistance of the leaves. The setup may be automated for the entre garden by using separate micro-chip for each plant to monitor the growth of the aloe-vera for improving the quality and quantity of the Aloe-vera products.

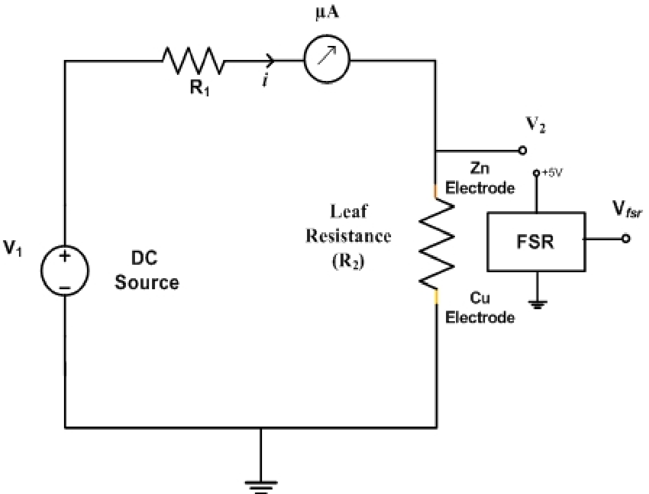

Fig. 5. Schematic for the DC circuitry with FSR.

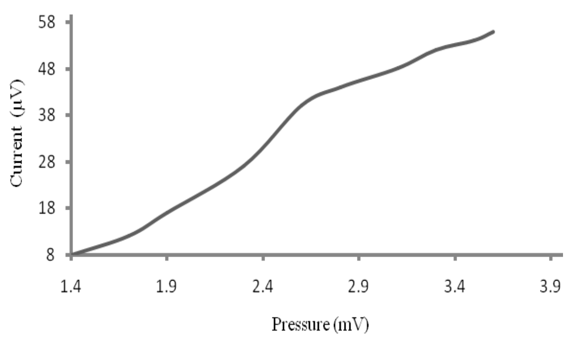

Fig. 6. Variation of current with respect to pressure.

Table I. Recorded values of voltage and current.

Pressure or V_{fsr} (mV)	Current i (µA)	Voltage V_2(mV)	Resistance R_2 (KΩ)
1.4	8.0	2.1	262.50
1.7	12	2.1	175.00
1.9	17	2.0	117.65
2.3	27	1.9	70.37
2.6	40	1.6	47.50
2.8	44	1.6	36.36
3.1	48	1.6	33.33
3.3	52	1.6	30.77
3.5	54	1.6	29.63
3.6	56	1.6	28.57

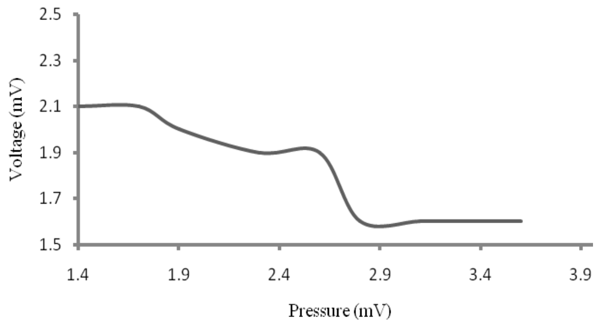

Fig. 7. Variation of voltage with respect to pressure.

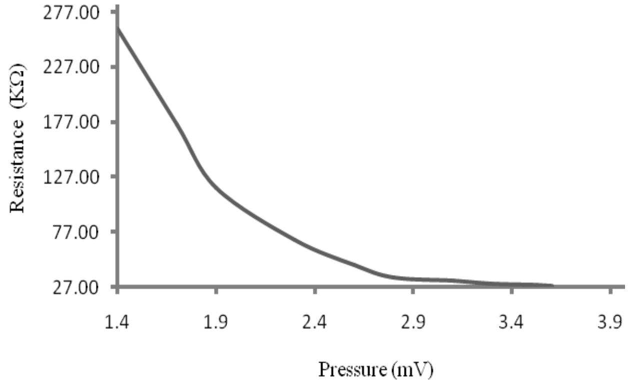

Fig. 8. Variation of DC resistance estimated from the ratio of voltages and corresponding currents with respect to pressure applied between electrodes.

V. CONCLUSIONS AND FUTURE SCOPE

Investigations were carried out to study the electrical behavior of Aloe-vera leaves for DC signals. DC analysis provides information about physiological changes in outer or inner cells, and on the membrane. Significant effect of external pressure was observed on the DC resistance of the leaves. The investigations may be very important for the assessment of the health of the Aloe-vera and its leaves. Automation of the setup may be used for controlling the quality of the Aloe-vera products. The information generated through these studies should be utilized in making transgenic plants that would be able to tolerate stress condition without showing any growth and yield penalty. Moreover conception of electrical processes in plants may lead to elaboration of new approaches and mean of objective diagnostics of physiological state of the plants.

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Sanjeev Sharma received his B.Tech. Degree in Electronics and Communication Engineering from Government College of Engineering. and Technology, canal road Jammu (J&K) affiliated to Jammu University, Jammu(J&K). He is presently doing M-Tech in Electronics and Communication Engineering from Sri Sai College of Engineering and Technology, Pathankot (Punjab).

Er. Randhir Singh received his M.Tech. in Electronics and Communication Engineering from Beant College of Engineering and Technology, Gurdaspur (Punjab) affiliated to Punjab Technical University, Jalandhar (Punjab). He is presently working as (H.O.D, Electronics and Communication Engineering Department, Sri Sai College of Engineering and Technology, Pathankot (Punjab) and pursuing PhD in signal processing. His research interests include speech signal processing, digital signal processing, image processing, analog and digital communication, electronics and control systems, etc. He has more than dozen of research papers to his credit. He is guiding several M.Tech students in electronics.

Prof. Parveen Lehana received his Master's degree in Electronics from Kurushetra University in 1992. He worked as lecturer in Guru Nanak Khalsa College, Yamuna Nagar, Haryana for next two years. He qualified NET-JRF in Physical Science in 1994 and got selected as permanent lecturer in A. B. College, Pathankot, where he worked for one year. He also qualified NET-JRF in Electronic Science and presently working as Associate Professor in Physics and Electronics Department, University of Jammu, and did his research from IIT Bombay in the area of signal processing. He has been a resource person in many national and international conferences. Several institutes are utilizing his talent in signal processing, MATLAB, speech recognition, speaker transformation, nano technology based sensors, robotics, image processing, and microwaves. He has good experience of guiding M.Tech, M.Phil, and Ph.D. students. He has more than 100 research papers to his credits.

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