Electrical response of *Mimosa pudica* to an external stimulus

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ABSTRACT

Mimosa pudica's surname is sensitive because this plant closes its leaves when it is exposed to a shock (wind, vibration or touch). First, the plant has the perception of the stimuli, then transmits the electrical signal and finishes by the leaves movement. We studied the second stage: the voltage response of the petiole (a part of the stem), induced by mechanical stimulus in the primary pulvinus (a junction bewteen stems), and an electrical stimulation of the petiole. For that, we used an alligator clip for the mechanical stimulus and applied a low electrical shock of 1,37 V. We observed that there is a voltage response of the plant to external stimuli and that the responses were different for each type of stimulus. We observed that the amplitude for the electrical stimulus was highter than the amplitude for the mechanical stimulus.

Key- words: *Mimosa pudica, Sensitive, voltage response, mechanical & electrical stimuli*

INTRODUCTION

Mimosa pudica (Fig1.c) is an angiosperm plant (flowering plant) and belongs to *Fabaceae*. It is a seismonastic (or thigmonastic) plant, it reacts to external tactile stimuli. Indeed, movements can be observed in response to touch or electrical stimulus, the leaves close and the petioles hang down[1,2] (Fig1.c). This feature is a response against predators[3], thereby decreasing visibility to herbivores. This particular movement is interesting in the domain of electrophysiology. The folding movements are regulated by electrical signals that propagate from the site of stimulation[3]

We wondered if an electrical shock and a mechanic stimulus involved the same electrical responses. Does the plant recognize the origin of the stimulus? Does the plant react differently according to the nature of the stimulus?

That's why in this study we wanted to compare experimentally the variation of the voltage of *Mimosa pudica* when it is stimulated electrically and mechanically in a petiole. We expected to observe a similar response to electrical and mechanical shock. Indeed, we thought that the electrical transmission in plant was the same, whatever the type of the stimulus was, because they didn't have specialized cells to differently treat the two kind of stress.

We made a greenhouse (Fig1.a), this had two benefits: it was easier to control our parameters (like custom size), and it was cheaper than a purchased greenhouse.

In order to reproduce the same growth conditions we also mastered our parameters by hand-made groves (Fig1.b), thanks to arduino[4], a small computer and an open-source electronic platform used like an interface between sensors and computer. All our installation and a voltmeter allowed us to observe and understand electrical phenomena in *M.pudica*.

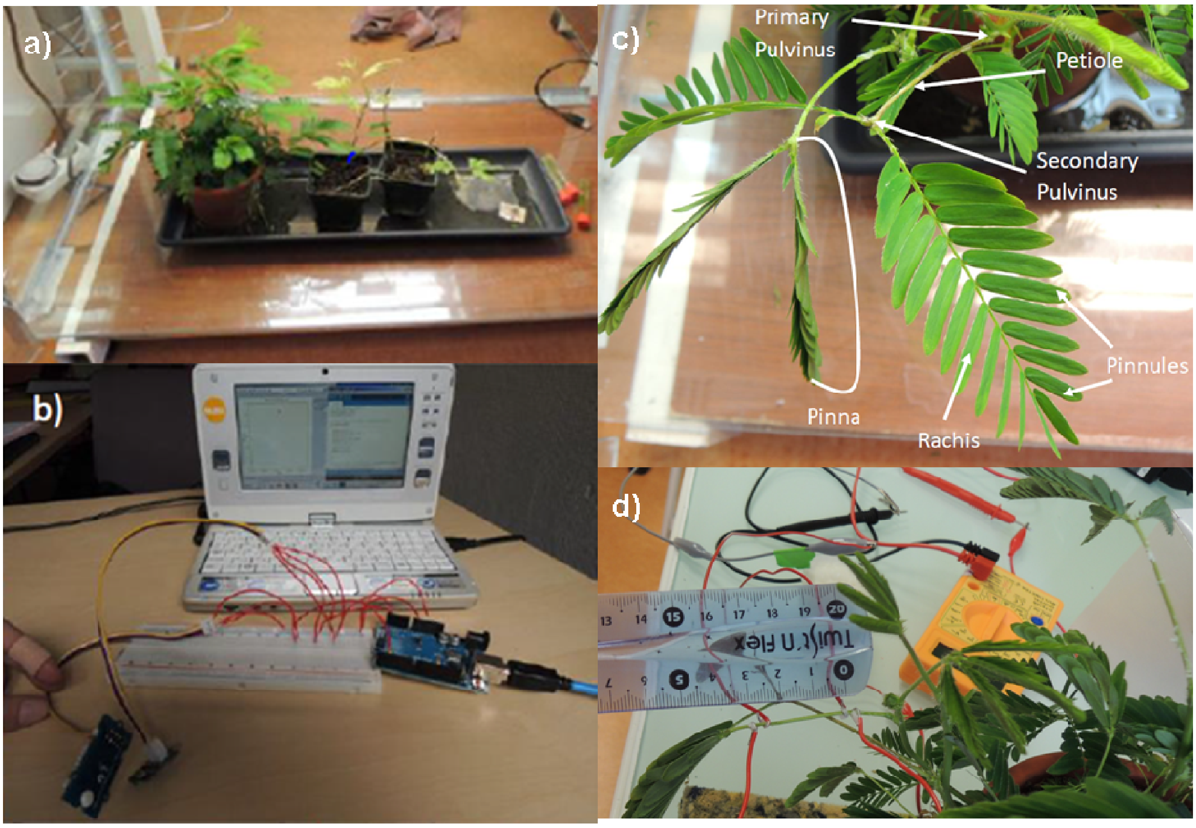


Figure 1: *M.pudica* and Experimental setup:
a) *Mimosa pudica* in our hand-made green-house. b) arduino groves in the bottom-left: temperature & humidity on left, light intensity on right. c) Photo of *M.pudica*. d) *M.pudica* with electrodes connected to the voltmeter.

MATERIALS AND METHODS

We grew two plants of *M.pudica* in the greenhouse for one month. They grew at 25℃ at 40% of humidity and under an intensity of 65µE. One plant served for the mechanical stimulus and the other one for the electrical stimulus. We realized the experiments in triplicate. The aim was to get the voltage of the plant during the all experiment time. We decided to do the measurement during five minutes. We put the electrodes on the petiole, spaced by three centimeters because we supposed it was better to increase the probability to observe the voltage variation compare to far away electrodes. We recorded the values at minimum 30min after insertion of the electrodes and between experiments.

In order to have reference voltages, we realized two kinds of control. For the first one we applied the external stimulus (electrical and mechanical) on a foam during one minute and we took the voltage during five minutes. For the other one, we measured the voltage in the plant and the foam during five minutes without applying the external stimulus. We also did a recording on another plant (Ficus) without any stress.

The greenhouse was hand-made with Plexiglas and assembled with silicone and corner iron pieces. In order to control the optimal conditions of growth for the *M.pudica* to make our experiment reproducible, we used groves that were connected to a microcontroller: “arduino” (Fig1.b). This board was linked to a computer and worked with a software “arduino” which executed the informatics code[6,è] to record the groves data.

Then, we used a voltmeter to record the voltage data. To obtain the maximum of voltage data, we filmed the screen of the voltmeter during all the experiments. After the experiment, we picked up the voltage values (with 0,1% of error due to the device) every second during the first two minutes and every five seconds during five minutes.

For the mechanical stimulus, we put two electrodes[8] (Fig.1.d), which were connected to the voltmeter. The electrodes were made with a copper wire and the contact with the petiole with electrocardiogram gel. We applied the mechanical stress during one minute with an alligator clip on the closest pulvinus. Then we took off the alligator clip and continued the recording during 4 min.

For the electrical stimulus on the second plant, we put the same electrodes linked to the voltmeter, on the petiole at the same distance. We put, at the inner side between these, two electrodes (3mm away from the voltmeter electrodes) connected to the battery (1,37V). We applied the stimulus during one minute with the battery, then we took off the battery and continued the data recording until the end of the time.

RESULTS

First we tested the mechanical stimulus because in the natural environment of *M.pudica*, these stimuli are the most frequent, due to the wind for example. Then we tested the electrical stimulus because we could compare the voltage response.

Without stress

First, we observed, the difference of the resting potential for each plant. The electrical plant experiment had a resting potential around -70mV and the mechanical plant experiment had a resting potential around +34mV. For the plant test *Ficus* it was -27mV. Without a stress there was no voltage variation in the petiole during the 5 min experiment. As expected, we detected no voltage values in the foam.

Data analyze

Thank to the graphs, we determined several values: the amplitude, the return time and the resting voltage.

The amplitude (Fig.3) was the difference between the resting voltage value and the value just after applying the stress.

The return time (Fig.3) was the time the signal took to go back to the resting voltage (Fig.3).

Impact of stress on voltage

First, we measured the electrical response under an electrical stress. The purpose was to show if there was any change in the voltage variation.

Under an electrical stimulus the voltage decreased brutally: for the first experiment, the voltage decreased from -12mV to -488mV in 1 second. (Fig.2.b), then the voltage tended to stabilize. When we put off the battery, we observed that the voltage increased quickly: the voltage increased from -372mV to 7mV, then decreased in order to stabilize to the resting voltage value. The two other experiments of electrical stimulus were similar. The mechanical stimulus made the plant react differently: (Fig.2.a) For the first experiment, the voltage was constant during several seconds, then it decreased from 14.6 mV to -4.2 mV in 1 second. Then, we put off the alligator clip and the voltage increased from 4.2mV to 14.2 mV in 28 seconds, although we noted some oscillation. However, it tends to stabilize at a resting voltage.

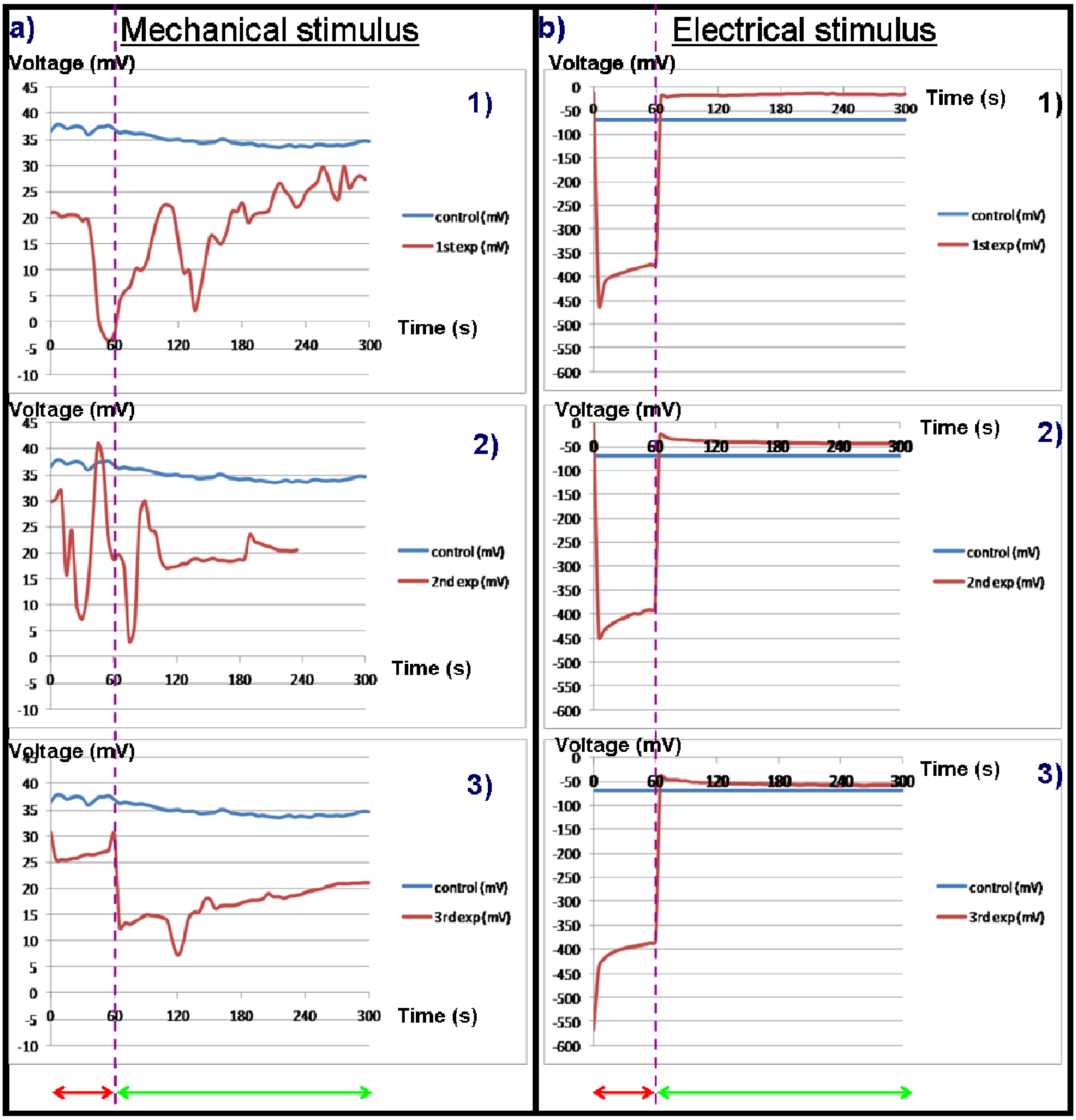


Figure 2: graphs of the plant responses:

a) voltage response to mechanical stimulus: 1) in the first experiment; 2) in the second experiment; 3) in the third experiment.

b) voltage response to electrical stimulus: 1) in the first experiment; 2) in the second experiment; 3) in the third experiment.

: with stimulus

: stimulus removed

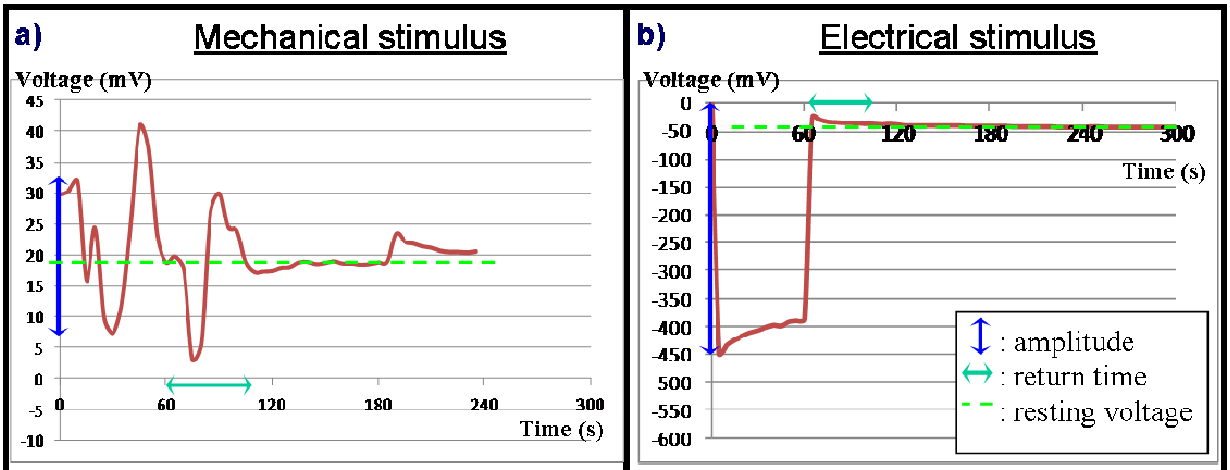
: stimulus removing

Differences between electrical and mechanical stimuli

Under the electrical shock, we observed a threshold value negative, (for instance the first electrical experiment the resting voltage was -14mV (Fig.3.b)), and we observed that the voltage decreased more quickly than under the mechanical stimulus.

The amplitude for the electrical stress was significant comparing to the mechanical stress. Indeed in average, the amplitude was 450mV higher for an electrical stress than a mechanical one. For instance the amplitude for the first electrical stress was 477mV while for the first mechanical stress the amplitude was 14,6mV (Fig.3).

And the return time to the resting voltage is longer under a mechanical stress conditions than electrical, although the return time increased from 14s to 32s, between the first and the last electrical experiment (Fig.3.b).



	Amplitude (mV)	Return time (s)	Resting voltage (mV)
1st experiment	17,6	Not visible	27
2nd experiment	34,2	45	20
3rd experiment	4,9	92	28

	Amplitude (mV)	Return time (s)	Resting voltage (mV)
1st experiment	477	14	-14
2nd experiment	497	20	-38
3rd experiment	551	32	-52

Figure 3: Values exctrated from a plant graph:

a) Example of a graph (here, the 2nd mechanical experiment) with the representation of the value extracted. Table with the value extracted from the three experiments.

b) Example of a graph (here, the 2nd electrical experiment) with the representation of the value extracted. Table with the value extracted from the three experiments.

DISCUSSION

As shown in Figure 2, according to the stimulus, the plant *Mimosa pudica* didn't react with the same electrical response. But the two *M.pudica* and the *Ficus* didn't have the same resting potential. That means even in the same growth conditions each plant has its own behavior. Our data for mechanical stress experiment are not comparable with a cold wound[8] because we have a smaller amplitude or a return time to resting voltage much longer.

Moreover, there were too many voltage variations for the mechanical stress experiment, maybe due to our movements during the experiment (passing by the plant for example), which may have shocked even more the plant and disturbed its response to the original stress, by the alligator clip. It can be due, as well, to the copper wires which were quit rigid and acted physically on the plant behavior. Moreover, our electrodes fixation method, with the electrocardiogram gel, was not optimal.

But these experiences permitted us to understand some aspects of electrical signals transmission in plants and show the fact that each stimulus has its own mechanism to induce a response. Our amplitude value is comparable with an observation of action potential.

In order to have more data, we should have repeated the experiment on several plants. Indeed this would have allowed us to have more tests and better results. We also could have done a statistic study. Here, we had too less data (three data for each experiment), and our data were too different, indeed the variation was important.

Moreover, it would have been interesting to repeat the same experiment of external stress on different species of plants and to study their voltage response. This way, we could have seen if there was a difference in the electrical response between a sensitive and a non-sensitive plant.

We wanted to make “Do It Yourself” devices to reduce the cost of the project, and to control the growth conditions parameters. We succeeded in building the greenhouse and the groves and in making use of them to realize our project in the way we wanted.

Ethical reflection

Ethically, our project raised questions because we did experiments on living organisms. Plants don’t possess a nervous system like animals[10] and there are often considered as without “feeling”. But we were carefully because the plants react physically and physiologically to a stress so we didn’t know if they could “feel” hurt sensation.

CONCLUSION

To conclude, the voltage decreased under an external stimulus, and it increased when we stopped this stimulus. Thus, the stress caused the decrease of the voltage.

In this way, *M.pudica* reacted when we applied an electrical or a mechanical stimulus.

We showed that there were differences between the two stimuli. When we applied an electrical stimulus, the amplitude was more important for the electrical shock than the mechanical stress. Furthermore the voltage response for the return of the threshold value after the mechanical stress was stochastic. That means there still are a lot of unknown parameters which can explain these variations.

The nature of the stress influenced the response. This would have an important consequence for the study of the plant behavior in response to an external stimulus and sets good bases to approach the research fields of vegetal biology. But more interdisciplinary studies are necessary to have a better understanding of the seismonatic movements of *M. pudica*. As the ability of the plant to memorize the stimulus or the observation of action potentials[11,12,13], if we look at the cell scale, are required to continue the clarification of these movements.

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